Studien und Berichte 52

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Aging, Professional Expertise, and Cognitive Plasticity

The Sample Case of Imagery-Based Memory Functioning in Expert Graphic Designers

Max-Planck-Institut für Bildungsforschung

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Studien und Berichte
In dieser Reihe veröffentlicht das Max-Planck-Institut für Bildungsforschung abgeschlossene Forschungsberichte, die vorwiegend eine spezielle Thematik behandeln.

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Abstract

Investigated whether professional expertise in graphic design attenuates age differences in the plasticity of imagery-based memory performance. A group of old expert graphic designers ($N = 6$; mean age: 69.9), old normal subjects ($N = 6$; mean age: 70.5), and young adults ($N = 6$; mean age: 22.9) participated in a 21-session training program with the *Method of Loci* (MOL), a mnemonic device facilitating the serial recall of word lists. During the Test Phase of the program, systematic variations in presentation rate, imageability, within-list similarity, and list length were included to identify group differences in the range and limits of mnemonic skill. The professional expertise of old graphic designers was validated with a visual creativity test. Old normal subjects and old expert graphic designers did not differ on standard measures of intelligence and short-term memory.

Professional expertise in graphic design was expected to transfer to memory functioning with the MOL because both activities centrally involve the generation of visual images. It was predicted that professional expertise in graphic design would attenuate, rather than eliminate, age differences in the upper limits of mnemonic skill. In addition, group differences in mnemonic skill were examined at the processual level of analysis, and the predictability of mnemonic skill through spatial visualization ability and chronological age was investigated.

Results were generally consistent with the predictions. During the Test Phase, young adults reached higher levels of cued serial recall than old graphic designers, and old graphic designers reached higher levels than old normal adults ($p < .01$ for both contrasts). Spatial visualization ability at pretest predicted interindividual differences in mnemonic skill. Throughout the experiment, the amount of variance uniquely related to chronological age (i.e., not explained by psychometric ability markers) was significant. The results of additional analyses strengthened the link between professional expertise and the visual image generation component of the MOL. However, the prediction that old graphic designers would form more discriminable visual images than old normal adults was not supported by the data. Alternative interpretations of the present findings, especially in terms of group differences in "latent" (i.e., not expertise-related) ability, are discussed.

Zusammenfassung

Die vorliegende Arbeit untersucht die Auswirkungen beruflicher Expertise auf die Plastizität kognitiver Funktionen im Alter. Der Begriff der kognitiven Plastizität bezieht sich allgemein auf die intraindividuelle Variabilität kognitiver Leistungen; im besonderen bezeichnet er das Lern- und Leistungspotential von Personen unter optimalen Bedingungen (Baltes, 1987). Unter Bezugnahme auf Forschungsergebnisse aus der Biologie des Alterns (Fries & Crapo, 1981) wird von Entwicklungspsychologen der Lebensspanne eine Abnahme des Ausmaßes an kognitiver Plastizität im Laufe des Erwachsenenalters postuliert. Dieses Postulat bezieht sich auf das Bündel fluider Fähigkeiten (Cattell, 1971), das heißt auf jene kognitive Leistungen, die überwiegend oder ausschließlich von der Qualität (Schnelligkeit, Genauigkeit) elementarer kognitiver Prozesse bestimmt werden. Für diese Leistungen, die auch unter dem Begriff der „Mechanik" der Intelligenz zusammengefaßt werden (Baltes, Dittmann-Kohli, & Dixon, 1984), wird eine altersbedingte Reduktion in den Obergrenzen der Leistungsfähigkeit vorhergesagt.

Die Erfassung von Altersunterschieden in der Plastizität kognitiver Leistungen wurde in der vorliegenden Arbeit mit einer als „cognitive engineering of skill" bezeichneten Untersuchungsmethode verfolgt (vgl. Kliegl & Baltes, 1987). Bei dieser Methode werden die Probanden in einer kognitiven Fertigkeit instruiert und trainiert mit dem Ziel, die oberen Grenzen ihrer Lern- und Leistungsfähigkeit zu bestimmen. Im vorliegenden Fall handelte es sich bei der zu trainierenden Fertigkeit um die sogenannte *Methode der Orte* (Bower, 1970a). Diese Mnemotechnik dient dem Einprägen und Erinnern von Wortlisten, wobei geographische Orte als Hinweisreize fungieren. Die Auswertung der Literatur führte zu dem Schluß, daß die mit der *Methode der Orte* gemeinhin zu beobachtende Steigerung der Behaltensleistung auf dem Bereitstellen einer Gedächtnisstruktur beruht, die das sequenzielle Erzeugen und Abrufen bildhafter Vorstellungen erleichtert. Das Erzeugen bildhafter Vorstellungen ließ sich aufgrund der bestehenden Kenntnisse als eine wichtige Komponente der Gedächtnistätigkeit mit der *Methode der Orte* identifizieren.

In früheren altersvergleichenden Trainingsstudien mit der *Methode der Orte* wurden stark ausgeprägte Altersunterschiede sowie eine Vergrößerung dieser Unterschiede im Laufe des Trainings beobachtet (Kliegl, Baltes, & Smith, 1989a; Yesavage & Rose, 1984). Die Leistung junger Erwachsener lag deutlich über der Leistung älterer Erwachsener, und im Vergleich zu anderen fluiden Maßen der intellektuellen Leistungsfähigkeit wurde eine Entzerrung der Verteilungen alter und junger Probanden beobachtet. Diese Ergebnisse stimmten mit der anfangs dargestellten Hypothese einer Reduktion der kognitiven Plastizität überein und deuteten darauf hin, daß Trainings-

programme mit der *Methode der Orte* Altersunterschiede in der Mechanik der Intelligenz zum Ausdruck bringen.

Die Reihe dieser Studien wurde in der vorliegenden empirischen Untersuchung fortgeführt. Die wichtigste Erweiterung gegenüber vorhergehenden Arbeiten bestand darin, daß außer dem chronologischen Alter eine weitere personenbezogene Variable berücksichtigt wurde, nämlich das Ausmaß an präexperimenteller Übung im Erzeugen bildhafter Vorstellungen. Zusätzlich zu einer Gruppe junger Studenten ($N = 6$; Altersdurchschnitt: 22,9 Jahre) und einer Gruppe älterer Probanden ($N = 6$; $x = 70{,}5$) nahm auch eine Gruppe von älteren Graphikdesignexperten ($N = 6$; $x = 69{,}9$) an der Untersuchung teil. Es wurde angenommen, daß ältere Graphikdesigner aufgrund ihrer Berufserfahrung über ein hohes Maß an Übung und Wissen im Erzeugen bildhafter Vorstellungen verfügen. In Anlehnung an Thorndikes Konzept des Transfers gleicher Elemente (Thorndike, 1906; vgl. Anderson, 1987) wurde ein positiver Transfer beruflicher Expertise auf Behaltensleistungen mit der *Methode der Orte* erwartet. Das Hauptanliegen der vorliegenden empirischen Untersuchung bestand also darin, am Beispiel der vorstellungsgestützten Gedächtnistätigkeit zu erforschen, in welchem Ausmaß kognitive Prozesse wie erworbenes Wissen und Übung, die im weiteren Sinne der „kristallinen Intelligenz“ (Cattell, 1971; Horn, 1982) beziehungsweise der „Pragmatik der Intelligenz“ (Baltes, Dittmann-Kohli, & Dixon, 1984) zugerechnet werden können, den altersbedingten Abbau in der Mechanik auszugleichen vermögen.

Die berufliche Expertise der Graphikdesigner wurde mit einem Test zum kreativen visuellen Vorstellen validiert (Torrance, 1966a, 1966b). Ferner wurde darauf geachtet, daß sich die Gruppe der älteren Graphikdesigner und die Gruppe der normalen älteren Teilnehmer nicht in Markertests des fluiden Fähigkeitsbündels (Zahlensymboltest), der kristallinen Intelligenz (Wortschatz) und des Kurzzeitgedächtnisses (Zahlennachsprechen) unterschieden. Damit sollte der Interpretation begegnet werden, daß eine eventuelle Überlegenheit der älteren Graphikdesigner in der Gedächtnistätigkeit mit der *Methode der Orte* lediglich eine Folge ihrer höheren allgemeinen intellektuellen Leistungsfähigkeit sei. In diesem Zusammenhang ist vor allem der Umstand bedeutsam, daß die Mittelwerte der beiden Gruppen älterer Teilnehmer im Zahlensymboltest nahezu identisch waren, weil sich dieser Test in vorhergehenden Untersuchungen als ein guter Prädiktor der maximalen Behaltensleistung älterer Personen mit der *Methode der Orte* erwiesen hatte (Kliegl, Smith, & Baltes, 1989b). Die Gruppe der jungen Teilnehmer schnitt im Zahlensymboltest deutlich besser ab als die älteren Teilnehmer; ihre Leistungen in den beiden anderen Tests unterschieden sich nicht signifikant von der Leistung der älteren Teilnehmer.

Das im Anschluß an die psychometrische Testung durchgeführte Trainingsprogramm mit der *Methode der Orte* bestand aus insgesamt 21 Sitzungen. Auf eine 7 Sitzungen währende Trainingsphase folgte eine 14 Sitzungen dauernde Testphase. In jeder Sitzung wurden 5 Wortlisten verabreicht. Die Entscheidung, auf eine relativ kurze Trainingsphase eine relativ ausgedehnte Testphase folgen zu lassen, basierte auf der in vorherigen Untersuchungen gewonnenen Erfahrung, daß der Großteil des Anstiegs in den Behaltensleistungen unmittelbar nach der Instruktion sowie in den ersten Trainingssitzungen zu beobachten ist.

In der Testphase wurde die durchschnittliche Aufgabenschwierigkeit im Vergleich zur Trainingsphase gesteigert. Dies wurde durch Variationen in den Dimensionen Darbietungszeit, Bildhaftigkeit, Ähnlichkeit und Listenlänge erreicht. Außerdem wurde eine Liste mit zweistelligen Zahlen verabreicht (s.a. Vorhersage 8).

Bei einigen Versuchen wurden die Probanden gebeten, die „Vorstellungsbilder oder Gedanken", mit denen sie versucht hatten, sich die Wörter einzuprägen, unmittelbar im Anschluß an die Erinnerungsphase zu verbalisieren. Ein Teil der so entstandenen verbalen Protokolle wurde nach Abschluß des Experiments den Probanden vorgespielt. Dabei wurden sie gebeten, sich einige Verbalisierungen, die auf bildhafte Vorstellungen verwiesen, auszuwählen und ein Bild dieser Vorstellungen zu zeichnen. In der vorliegenden Abhandlung wurden weder die verbalen Protokolle noch die Zeichnungen einer systematischen Analyse unterzogen.

Die empirische Untersuchung wurde von elf Vorhersagen geleitet, die sich in drei inhaltlich definierte Kategorien einteilen ließen: (1) Behaltensleistungen mit der *Methode der Orte;* (2) nachgeordnete, prozeßorientierte Analysen der Behaltensleistungen; (3) Prädiktoren der Behaltensleistung. Die zur ersten Kategorie gehörenden vier Vorhersagen lassen sich im einzelnen wie folgt beschreiben. Erstens wurde für alle drei Gruppen ein Anstieg der Behaltensleistungen während der Trainingsphase erwartet. Diese Vorhersage leitete sich aus der in vorherigen Untersuchungen bereits bestätigten theoretischen Überlegung ab, daß die Plastizität kognitiver Leistungen bei gesunden älteren Personen erhalten bleibt und sich der altersbedingte Abbau vor allem auf die Obergrenzen des Lern- und Leistungspotentials bezieht (Baltes & Lindenberger, 1988). Zweitens wurde erwartet, daß die älteren Graphikdesigner in der Testphase höhere Behaltensleistungen aufweisen würden als die Mitglieder der älteren Kontrollgruppe. Diese Vorhersage wurde mit dem Transfer beruflicher Expertise begründet und beruhte auf der Annahme, daß der Erzeugung bildhafter Vorstellungen sowohl im Berufsfeld Graphikdesign als auch in der Gedächtnistätigkeit mit der *Methode der Orte* eine zentrale Bedeutung zukommt. Drittens wurde vohergesagt, daß die jungen Probanden in der Testphase höhere Behaltensleistungen erreichen würden als die Gruppe der älteren Graphikdesigner. Diese Vorhersage beruhte auf dem theoretischen Postulat, daß erfahrungsbezogene Faktoren wie zum Beispiel berufliche Expertise die altersbedingte Reduktion in den Grenzen der kognitiven Plastizität nicht vollkommen auszugleichen vermögen, wenn die betreffende Aufgabe hohe Ansprüche an die Mechanik der Intelligenz, das heißt an die Qualität kognitiver Basisprozesse stellt. Die Vorhersagen 2 und 3 besaßen einen transitiven Charakter ($A > B$, $B > C$) und brachten die Haupterwartung der Untersuchung zum Ausdruck, daß berufliche Expertise die altersbedingte Reduktion der Plastizität kognitiver Leistungen vermindern, jedoch nicht beseitigen kann. Viertens wurde vorhergesagt, daß die Teilnehmer in allen Gruppen zu Beginn der Testphase ein relativ stabiles (asymptotisches) Leistungsniveau erreicht haben würden. Eine empirische Bestätigung dieser Vorhersage würde die Aussagekraft der Daten hinsichtlich der Frage altersbedingter Unterschiede in den Obergrenzen der Leistungsfähigkeit erhöhen.

Bei der Analyse der Ergebnisse ergab sich eine deutliche Bestätigung der Vorhersagen 2 und 3. Die Behaltensleistung älterer Graphikdesigner lag über der Leistung der normalen älteren und unter der Leistung der jungen Probanden.[1] In der zentralen

Analyse, die die durchschnittliche Behaltensleistung mit 48 Wortlisten während der Testphase betraf, waren die entsprechenden Kontraste hoch signifikant ($p < .01$). Eine Inspektion der Daten zeigte, daß nur ein Mitglied aus der Gruppe der normalen älteren Teilnehmer den Mittelwert der älteren Graphikdesigner erreichte, und daß nur ein einziger älterer Graphikdesigner über dem Niveau des jungen Probanden mit der niedrigsten Leistung lag.

Ferner bestätigte sich die Erwartung, daß Probanden in allen drei Gruppen ihre Behaltensleistung während der Trainingsphase steigern würden (Vorhersage 1). Nicht bestätigen ließ sich hingegen die Erwartung, daß die Probanden zu Beginn der Testphase ein relativ stabiles (asymptotisches) Leistungsniveau erreicht haben würden (Vorhersage 4). Dies schwächte die Bedeutung der vorliegenden Ergebnisse für die Frage der Altersunterschiede in den Obergrenzen des Leistungsvermögens ab, weil eine den Hypothesen zuwiderlaufende Veränderung der Gruppenunterschiede im Falle einer denkbaren Fortsetzung des Trainingsprogramms nicht mit Sicherheit ausgeschlossen werden kann. Vor allem mußte offen bleiben, ob es den älteren Graphikdesignern möglich gewesen wäre, die jungen Teilnehmer zu einem späteren Zeitpunkt einzuholen. Eine solche Entwicklung erscheint allerdings nicht wahrscheinlich, weil der Leistungsunterschied zwischen den beiden Gruppen sehr groß war und weil die Gruppe der älteren Graphikdesigner keine signifikant größeren Leistungszugewinne aufwies als die Gruppe der jungen Probanden.

Die Ergebnisse der prozeßorientierten Analysen lassen sich wie folgt zusammenfassen. In Übereinstimmung mit Vorhersage 5 variierte die Größe der Gruppenunterschiede in der Behaltensleistung mit der Aufgabenschwierigkeit. Der Leistungsunterschied zwischen älteren Graphikdesignern und normalen älteren Probanden wurde in einem niedrigeren Schwierigkeitsbereich maximiert als der Leistungsunterschied zwischen älteren Graphikdesignern und jungen Teilnehmern. Außerdem ergab die Analyse der Positionskurven, daß niedrigere Behaltensleistungen generell mit einem Anstieg von Primacyeffekten verbunden waren (Vorhersage 6). Dieser Anstieg deutet darauf hin, daß niedrigere Behaltensleistungen mit einer weniger konsistenten Verwendung der *Methode der Orte* einhergingen, da die Gedächtnistätigkeit mit der *Methode der Orte* durch eine weitgehende Abwesenheit von Positionseffekten gekennzeichnet ist (vgl. Roediger, 1980). Die Ergebnisse bestätigten die Erwartung, daß die Unterschiede zwischen älteren Graphikdesignern und normalen älteren Teilnehmern einerseits sowie zwischen älteren Graphikdesignern und jungen Teilnehmern andererseits immer dann maximiert wurden, wenn die überwiegende Zahl der Mitglieder der leistungsstärkeren Gruppe noch in der Lage war, bildhafte Vorstellungen entsprechend der *Methode der Orte* zu erzeugen, während die überwiegende Zahl der Mitglieder in der leistungsschwächeren Gruppe zu weniger aufwendigen, aber auch weniger effektiven Enkodierstrategien übergegangen war.

Die Vorhersagen 7a und 7b formulierten die Erwartung, daß sich die drei Gruppen in der Diskriminierbarkeit bildhafter Vorstellungen unterscheiden würden. Verwechs-

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[1]Die Anzahl der am richtigen Ort wiedergegebenen Wörter diente in allen Analysen als Indikator der Behaltensleistung.

lungsfehler, das heißt am falschen Ort wiedergegebene Wörter, dienten als Indikator mangelnder Diskriminierbarkeit. Vorhergesagt wurde (a) eine größere Anzahl von Verwechslungsfehlern bei Listen mit einander ähnlichen Wörtern; (b) Gruppenunterschiede im Ausmaß des Anstiegs von Verwechslungsfehlern bei Listen mit einander ähnlichen Wörtern (Vorhersage 7a); (c) Gruppenunterschiede in der Anzahl von Verwechslungsfehlern (Vorhersage 7b). Um Artefakten vorzubeugen, die aus Gruppenunterschieden im Niveau der Behaltensleistungen resultieren könnten, wurden für die verschiedenen Gruppen Versuche mit unterschiedlichen Darbietungszeiten berücksichtigt. Auf diese Weise wurden Gruppenunterschiede in der Anzahl der richtig erinnerten Wörter auf ein nicht signifikantes Niveau reduziert. Da Nullantworten möglich und auch vorhanden waren, führte dieses Verfahren nicht zwangsläufig zu einer Angleichung in der Anzahl an Konfusionen.

Die Ergebnisse entsprachen nicht den Vorhersagen 7a und 7b. Zwar führten Listen mit einander ähnlichen Wörtern zu einer signifikant größeren Anzahl von Verwechslungsfehlern als Listen mit zufällig ausgewählten Wörtern. Die vorhergesagten Gruppenunterschiede in der Anzahl von Verwechslungsfehlern und die vorhergesagten Interaktionen zwischen Gruppe und Listentyp blieben jedoch aus. Insbesondere gab es keine Anzeichen dafür, daß die älteren Graphikdesigner aufgrund ihrer beruflichen Expertise besser unterscheidbare bildhafte Vorstellungen erzeugten als die normalen älteren Probanden.

Die letzte Vorhersage der zweiten Kategorie betraf das Erinnern von Zahlenlisten bei älteren Graphikdesignern und älteren normalen Teilnehmern. Es wurde erwartet, daß der Unterschied in der Behaltensleistung zwischen älteren Graphikdesignern und normalen älteren Probanden im Falle der Verabreichung einer Zahlenliste verschwinden müßte, weil die den Transfer beruflicher Expertise vermittelnde Aufgabenkomponente, das heißt die Erzeugung bildhafter Vorstellungen, bei Zahlenlisten bedeutungslos sein würde (Vorhersage 8). Die Ergebnisse stimmten mit dieser Erwartung überein und ergaben somit einen weiteren Hinweis auf die Bedeutung der Vorstellungskomponente für den beobachteten Unterschied in der Behaltensleistung von älteren Graphikdesignern und normalen älteren Probanden.

Die letzte Kategorie von Vorhersagen betraf die Prädiktion von Behaltensleistungen mit der *Methode der Orte.* Bestätigt wurde die Annahme eines starken Zusammenhangs zwischen psychometrischen Markertests des visuellen Vorstellungsvermögens, die vor Beginn des Trainingsprogramms bearbeitet wurden, und dem Niveau der Behaltensleistung mit der *Methode der Orte* (Vorhersage 9); sowohl die einfache als auch die altersbereinigte Korrelation waren hoch signifikant [$r(18) = .83$; $r(15) = .64$; in beiden Fällen $p < .01$].

Nicht bestätigt werden konnte die Erwartung, daß der ausschließlich altersbezogene, nicht durch psychometrische Tests erklärte Anteil der Varianz in der Behaltensleistung im Laufe des Trainingsprogramms zunehmen würde (Vorhersage 10). Eine Zunahme hätte der theoretischen Annahme entsprochen, daß das chronologische Alter als Einflußgröße in dem Maße an Bedeutung gewinnt, in dem sich die Probanden den oberen Grenzen ihrer Leistungsfähigkeit nähern. Der altersbezogene Varianzanteil war zwar zu jedem Zeitpunkt des Trainingsprogramms signifikant, eine Vergrößerung des Anteils im Laufe des Training ließ sich aber nicht nachweisen. Eine abschließende Deutung dieses Befunds war nicht möglich. Es liegt aber die Vermutung nahe, daß die altersbedingten Unterschiede in der kognitiven Plastizität bereits früher auftraten als erwartet (d.h. bereits als Folge der Instruktion in der Mnemotechnik).

Schließlich wurde erwartet, daß sich die Unterschiede in der Behaltensleistung zwischen älteren Graphikdesignern und normalen älteren Teilnehmern vollständig durch den visuellen Kreativitätstest (Torrance, 1966a, 1966b), der zur Validierung der beruflichen Expertise benutzt wurde, aufklären lassen (Vorhersage 11). Die Bestätigung dieser Erwartung war ein weiterer Hinweis auf den Zusammenhang zwischen beruflicher Expertise und Behaltensleistung in der Gruppe der älteren Graphikdesigner.

Die Literaturübersicht zu Beginn der vorliegenden Untersuchung hatte im wesentlichen drei Ziele. Erstens sollte der Stellenwert der beruflichen Expertise in der vorliegenden Arbeit im Vergleich mit der bisherigen Forschung zur Beziehung zwischen Alter und Beruf deutlich gemacht werden. Zweitens wurde der Begriff des Transfers beruflicher Expertise in Anlehnung an bestehende Konzeptionen näher erläutert. Drittens wurde mit Hilfe einer umfangreichen Recherche die Behauptung abgesichert, daß die Erzeugung bildhafter Vorstellungen eine zentrale Komponente in der Gedächtnistätigkeit mit der *Methode der Orte* darstellt. Schließlich wurde in einem letzten Abschnitt der gegenwärtige Forschungsstand zu Altersunterschieden im visuellen Gedächtnis referiert.

Die oben dargestellten Ergebnisse der empirischen Untersuchung werden im letzten Teil der Arbeit diskutiert. Es wird darauf hingewiesen, daß die höhere Behaltensleistung der Graphikdesigner auch auf anderen Gründen beruhen könnte als auf ihrer beruflichen Expertise. Insbesondere ist es denkbar, daß die „latenten" Fähigkeiten in vorstellungsbezogenen Aspekten der Kognition in einer Stichprobe von Graphikdesignexperten höher ausgeprägt sind als in der normalen Bevölkerung. Mit Fähigkeitsunterschieden sind hier jene Unterschiede zwischen Individuen angesprochen, die nicht Ausdruck beruflicher Erfahrung, sondern Ausdruck der genetischen Disposition (Begabung), der frühen Sozialisation sowie Ausdruck von nicht unmittelbar berufsbezogenen Erfahrungen sind.

Eine abschließende Entscheidung zwischen einer expertisebezogenen und einer fähigkeitsbezogenen Interpretation der hohen Behaltensleistung der Expertengruppe ist im Rahmen der bestehenden Untersuchung nicht möglich. Am wahrscheinlichsten erscheint die Annahme, daß beide Faktoren zusammenwirkten. Demnach verfügten die älteren Graphikdesigner über ein sehr hohes Maß an Übung in aufgabenrelevanten, vorstellungsbezogenen Prozessen, und zwar sowohl kumulativ über die gesamte Lebensspanne hinweg als auch zum Zeitpunkt der Testung, da fünf der sechs Mitglieder der Expertengruppe noch beruflich aktiv waren. Gleichzeitig erscheint es naheliegend, daß die älteren Graphikdesigner überdurchschnittlich hohe Fähigkeiten im Bereich der visuellen Vorstellungskraft aufwiesen.[2]

[2]Eine gegenwärtig durchgeführte Erweiterung der vorliegenden Untersuchung um eine Gruppe junger Graphikdesignstudenten soll dazu dienen, einer Trennung von expertisebezogenen und fähigkeitsbezogenen Anteilen näherzukommen.

Eine exploratische Inspektion der verbalen Protokolle sowie der Zeichnungen ergab, daß der Prozeß des Rekodierens (Tulving, 1983) in größerem Maße zu interindividuellen Unterschieden in der Behaltensleistung beigetragen hatte als ursprünglich angenommen. Während die normalen älteren Erwachsenen relativ selten und nur geringfügig von der gebräuchlichsten Wortbedeutung abwichen, ließen sich bei den älteren Graphikdesignern und bei den jungen Probanden zahlreiche Hinweise einer Entfernung von der gebräuchlichsten Wortbedeutung finden. Wahrscheinlich wurde auf diese Weise die Vorstellbarkeit der Enkodierungen erhöht. Diese Vermutungen bedürfen jedoch der weiteren empirischen Überprüfung.

In der vorliegenden Untersuchung wurde für den Bereich der vorstellungsgestützten Gedächtnistätigkeit der Nachweis erbracht, daß berufliche Expertise den altersbedingten Rückgang an kognitiver Plastizität auf dem Gebiet der Mechanik der Intelligenz wohl vermindern, jedoch nicht beseitigen kann. Die Wahl des Berufsfelds Graphikdesign war das Ergebnis einer Aufgabenanalyse der *Methode der Orte,* und die älteren Experten, die an der Untersuchung teilnahmen, verfügten über ein hohes berufliches Können. Aus diesen Gründen ist eine stärkere Verminderung des Altersunterschieds in der Gedächtnistätigkeit mit der *Methode der Orte* durch berufliche Expertise als die im vorliegenden Fall beobachtete kaum zu erwarten. Ausnahmen sind am ehesten bei älteren Gedächtniskünstlern denkbar. Schließlich könnte die hier angewandte Forschungsstrategie auch in anderen Bereichen der Kognition Anwendung finden, um der Frage weiter nachzugehen, in welchem Ausmaß die Grenzen der Lern- und Leistungsfähigkeit im Alter durch Erfahrung und/oder durch spezifische Fähigkeiten modifizierbar sind.[3]

[3]Das dieser Arbeit zugrundeliegende theoretische Modell geht nicht von einer altersbedingten Reduktion der Plastizität in allen kognitiven Bereichen aus (Baltes, 1987). In bestimmten Bereichen, die ein hohes Ausmaß an „pragmatischem" Wissen erfordern und die gleichzeitig keine besonders hohen Anforderungen an „mechanische" Basiskomponenten stellen, wird ein Anstieg der kognitiven Plastizität mit dem Alter für möglich gehalten (Smith & Baltes, in press; Staudinger, Cornelius, & Baltes, 1989).

PART I: INTRODUCTION

Age-Related Differences in Cognitive Plasticity

The focus of the present investigation is on cognitive plasticity and limits of cognitive plasticity in old age. Plasticity or within-person variability refers to the fact that individuals perform at different functional levels under varying experiential conditions. In particular, the notion of plasticity points to the latent potential of individuals, to what they could do if conditions were optimal (Baltes, 1987). Informed by work on the biology of aging (Fries & Crapo, 1981; Shock, 1977; Strehler, 1962), life-span developmentalists have proposed that an age-related decline in "fluid" intelligence (e.g., the "mechanics" of cognition) reduces the range of cognitive plasticity in old age (Baltes, Dittmann-Kohli, & Dixon, 1984; Cattell, 1971; Horn, 1982; cf. Salthouse, 1985). The mechanics of cognition are largely experience-invariant and refer to the basic characteristics of the brain, such as processing speed, activation level, and elementary cognitive operations (cf. Klix, 1988). Near limits of plasticity, age-related differences in these basic characteristics of the brain are assumed to be an important factor in determining individual differences in performance.

The results of a recent series of experiments in the domain of imagery-based memory functioning were consistent with the notion of age-related differences in cognitive plasticity of the fluid mechanics (Baltes & Kliegl, 1989; Kliegl & Lindenberger, 1989; Kliegl, Smith, & Baltes, 1989a, 1989b; Thompson & Kliegl, 1989). The present study expands this work. In principle, this could be done either by choosing a task from a different domain of intellectual functioning (e.g., reasoning instead of memory), or by selecting samples of older adults who, due to the existence of task-relevant knowledge, everyday practice, and task-related abilities, are less likely to show a reduction in the range of plasticity in a particular domain of cognitive functioning. The latter strategy is adopted in the present study.

The search for experiential antecedents of cognitive plasticity in old age serves to identify the extent to which "crystallized" intelligence (e.g., the "pragmatics" of cognition) compensates for age-related decline in mechanics. In the theoretical framework outlined by Baltes (1987), which is much influenced by the Cattell-Horn distinction between fluid and crystallized intelligence (Cattell, 1971; Horn, 1982; cf. Erdfelder, 1987), the pragmatics of cognition complement the mechanics and refer to knowledge that has been acquired through learning. There is general agreement among cognitive psychologists and life-span theorists alike that knowledge is a powerful modulator of the mind (Anderson, 1983; Chi, 1978; Ericsson, 1985; Hoyer, 1985; Hoyer & Hooker, 1989; Lehman, Lempert, & Nisbett, 1988; Staudinger, Cornelius, &

Baltes, 1989; Tack, 1987; Weinert, Schneider, & Knopf, 1988). However, the effect of specialized knowledge on the magnitude of age-related differences near limits of cognitive plasticity (maximum learning potential) is not well investigated.

The dual-process model of intellectual development (i. e., mechanics vs. pragmatics) makes specific predictions in this regard. Continued potential for intellectual growth in old age is expected in the case of activities that depend on the existence and practice of pragmatic knowledge *and* do not require very high levels of mechanic functioning (Baltes, Dittmann-Kohli, & Dixon, 1984). But how large is the range of activities that fall in this category? To what extent does decline in mechanics limit the positive consequences of pragmatic knowledge in older adults?

The main assumption of the present study is that professional expertise, an important developmental agent in adult life, is a relevant antecedent of cognitive plasticity in old age whenever there is a match between the given professional expertise and the task used to investigate cognitive potential. Expertise refers to high levels of skill in a given activity domain that sometimes occur as a consequence of experience (cf. Salthouse, 1987). The label "expert" is reserved for only a few individuals in our society who acquire exceptionally high levels of performance in their field of specialization.

The more general consequences of this specialized knowledge for the range of cognitive plasticity in old age are not well investigated. Expertise-related effects in performance could be restricted to activities and skills that are an integral part of the profession itself. In this case, the effect of professional expertise on cognitive plasticity would be rather limited. However, it appears more likely that elements of professional skill transfer to other domains of cognitive functioning if these domains involve the same elements (cf. Anderson, 1987; Hilgard & Bower, 1971; Thorndike, 1906). In that case, professional expertise would transfer to tasks that do not belong to the field of professional specialization, and would have the potential to extend the range of plasticity in old age.

Cognitive Engineering of Skill

The focus of this study—the effect of professional expertise on the magnitude of age-related differences in cognitive plasticity—demands an elaborate concept of cognitive plasticity along with a research methodology for its assessment. The research paradigm developed by Kliegl and Baltes (1987; Kliegl, Smith, & Baltes, 1986) is adopted for this purpose.

On the conceptual level, Baltes (1987; Kliegl & Baltes, 1987) proposed three notions which together provide insight into the plasticity of cognitive functioning: (1) baseline performance, (2) baseline reserve capacity (learning potential), and (3) developmental reserve capacity (maximum learning potential). Baseline capacity "indicates a person's initial level of performance on a given task, that is, what a person can do on a specific task without intervention or special treatment" (Baltes, 1987, p. 618). Baseline reserve capacity denotes "the upper range of an individual's performance potential when, at a given point in time, all available resources are called on to optimize an individual's performance" (p. 618). The third notion, developmental reserve capacity, refers to the range and level of performance which an individual can achieve if continued exposure to an optimal environment has extended the initial (i.e., baseline) amount of available resources or reserve capacity. In this case, individuals are expected to approach an asymptote that indicates their maximum level of performance with respect to the behavior under study.

Most measures commonly employed in cognitive aging research do not provide estimates of interindividual differences in maximum learning potential (developmental reserve capacity). Rather, they concentrate on differences in baseline performance as they appear in one-time assessments. According to life-span theory, this limitation of the measurement context may be one of the major reasons for the large amount of overlap in the level of performance among individuals of different ages, which is the rule for most developmental research findings in middle and late adulthood. The expectation of life-span psychologists is that chronological age may become a better predictor of individual differences in performance if the (formerly latent) potential of individuals is being measured near its maximum limits (Baltes, 1987).

These considerations call for research paradigms that lead to a better estimate of reserve capacity than conventional experimental procedures. Kliegl and Baltes (1987) suggested the cognitive engineering of skill as a possible means to this end. Similar to other testing-the-limits or "learning" methodologies (cf. M. Baltes & Kindermann, 1985; Guthke, 1982; Schmidt, 1971; Wiedl, 1984), the cognitive engineering of skill recognizes that repeated measurements are especially suited to gain insight into the latent potential or reserve capacity of an individual. In that respect, the goal of the paradigm is similar to research in the area of child development based on Vygotsky's concept of the "zone of proximal development" (Campione, Brown, Ferrara, Jones, & Steinberg, 1985; Ferrara, Brown, & Campione, 1986; cf. Vygotsky, 1962). In its intent to determine the cognitive potential of an individual, it also resembles Piaget's (1926/1929) "clinical interview" technique.

The two most important components in the cognitive engineering of skill are instruction and training (e.g., guided practice). Individuals are informed about the general architecture of the skill and central task components. The participants are then trained to increase their level of performance through the acquisition of task-specific factual and/or procedural knowledge. Both instruction and training are guided by a task analysis which identifies the basic architecture of the skill and its elements.

Aim of the Present Study

In past research at the cognitive laboratory of the Max Planck Institute for Human Development and Education, Berlin, the cognitive engineering of specific memory-related skills has been employed in order to investigate age-related differences in memory-related aspects of developmental reserve capacity (Kliegl, Smith, & Baltes, 1989a, 1989b; Kliegl, Smith, Heckhausen, & Baltes, 1986, 1987). In most experiments, adults of different ages were instructed and trained in the use of a specific mnemonic device, the *Method of Loci* (Baddeley & Lieberman, 1980; Bower, 1970a; Bower & Reitman, 1972; Christen, 1980; Crovitz, 1969, 1971; DeBeni & Cornoldi, 1985, 1988; Lea, 1975; Roediger, 1980; Volkmann, 1929; Yesavage & Rose, 1984).

Two major results were obtained in these studies (cf. Kliegl, Smith, & Baltes, 1989a). Consistent with the hypothesis of age-related differences in developmental reserve capacity, young adults profited more from the training program than old adults. Compared to serial recall prior to instructions, the amount of overlap in memory performance between young and older adults was drastically reduced as a consequence of mnemonic instruction and training. Thus, a "magnification of age differences" was observed (Kliegl, Smith, & Baltes, 1989a).

At the same time, older adults also improved their level of memory performance in the course of the intervention. This second finding points to the continued existence of cognitive plasticity or learning potential among healthy older adults, and is consistent with the results of intervention programs related to tests of fluid intelligence (Baltes, Dittmann-Kohli, & Kliegl, 1986; Baltes, Sowarka, & Kliegl, 1989; Blieszner, Willis, & Baltes, 1981; Denney, 1979; Hayslip, 1989; Hofland, Willis, & Baltes, 1981; Willis, Blieszner, & Baltes, 1981; for a review, see Baltes & Lindenberger, 1988; Baltes & Willis, 1982). Taken together, the two findings—magnification of age differences and continued existence of cognitive plasticity among healthy older adults—suggest that normal aging is associated with a reduction, but not with a loss of cognitive plasticity or learning potential.

To summarize, the present work is part of the longstanding efforts in life-span and gerontological research to clarify the relationship between aging and experience (Baltes, 1973; Charness, 1981; Salthouse, 1987). An intervention program with the *Method of Loci* is designed with the goal of investigating whether professional expertise in graphic design (intended to reflect a high level of task-relevant experience) moderates age-related differences in mnemonic skill near limits of functioning. Professional expertise in graphic design is predicted to transfer to serial recall with the *Method of Loci* because both activities are assumed to involve the generation of visual images. The predicted transfer of professional expertise to a newly acquired laboratory skill is seen as a means to explore the importance of specialized and highly practiced knowledge on age differences in cognitive plasticity.

The main hypothesis is that transfer of professional expertise attenuates, rather than eliminates, age-related differences in the upper range of cognitive plasticity. Due to transfer of professional expertise, old expert graphic designers are expected to reach higher levels of mnemonic skill than old normal adults of comparable intelligence. At the same time, it is predicted that old experts will not be able to reach the level of young adults, reflecting the age-related reduction in developmental reserve capacity (maximum learning potential).

Overview of Literature Review

The following literature review is subdivided into five major sections. In the first *(Aging and Professional Expertise)*, a brief overview of research on aging and professional expertise is provided. In addition, the emphasis on transfer to other domains of cognitive functioning is described as a characteristic of the present approach. In the second *(Transfer of Identical Elements)*, the notion of transfer as used in the present study is developed on the basis of the theory of identical elements (Anderson, 1987; Thorndike, 1906). These considerations open the way for the third section *(Memory Functioning with the Method of Loci),* which reviews and evaluates research on memory functioning with the *Method of Loci.* The criteria which guide the selection of the group of old expert professionals are defined in this context. In the fourth section, the literature on aging and visual memory is briefly reviewed to locate the present work within the larger context of age differences in visual memory *(Aging and Visual Memory).* Finally, the aim of the present study is restated in more specific terms in order to open the way for the empirical investigation *(Statement of Problem).*

PART II: REVIEW OF LITERATURE

AGING AND PROFESSIONAL EXPERTISE

Overview

The study of occupational aspects of aging, also known as industrial gerontology (Murrell, 1959), has many different facets (cf. Lehr, 1981; Sterns & Alexander, 1987). It includes demographic trends and age-related changes in employment patterns, the relationship between age and job performance, job satisfaction, and withdrawal behavior (absenteeism). To evaluate the relationship between job performance and age, both productivity (output over time) and performance ratings by supervisors or peers have been used (Davies & Sparrow, 1985; Sterns & Alexander, 1987; Waldman & Avolio, 1986). Recent reviews and overview chapters on the relation between age and job performance conclude that there were similar numbers of studies reporting that job performance increases with age, decreases, or remains the same (Davies & Sparrow, 1985; Rhodes, 1983; Sparrow & Davies, 1988; Waldman & Avolio, 1986). In the case of skilled or semi-skilled jobs, many studies report an inverted-U relation between age and performance (Sparrow & Davies, 1988).

To a large extent, this mixed picture may be due to the lack of control over variables that moderate the relationship between age and job performance. For instance, a marked fall in productivity with increasing age, or even a steady decline, "would be unlikely to pass unnoticed either by the employee or by supervisors and managers, and the result might well be a voluntary or involuntary transfer to other work, or, in extreme cases, dismissal" (Davies & Sparrow, 1985, p. 303). At the same time, it is also possible that efficient and productive workers are promoted out of their jobs (cf. Featherman, in press). These two selection processes work in opposite directions and may cancel each other out. In any case, they cloud the meaning of the age variable in most assessments of performance in occupational settings (Welford, 1958).[1] Since the focus of the present study is on professional expertise as an antecedent of cognitive

[1]The reluctance to control for expertise in studies on job performance and aging is paralleled by a neglect of age in studies on cognitive performance and expertise. Recent examples include a study on the influence of expertise on X-ray image processing (Myles-Worsley, Johnston, & Simons, 1988) and a study of the effect of expertise on recognition memory for dogs and human faces (Diamond & Carey, 1986). In both studies, the performance of *young students* was tested against the performance of *older* professionals (e.g., experienced radiologists, dog experts). The situation is different with respect to research on chess skill. Here, Charness (1981) extended the classical work by de Groot (1965) and Chase and Simon (1973) to the study of age-related changes in problem solving.

plasticity in old age, the following review is restricted to studies which investigated the effects of variations in job-related experience on the magnitude of age differences in job performance.

Work Experience, Work Performance, and Age

LaRivière and Simonson (1965) as well as Smith and Greene (1962) reported that age trends in handwriting speed were minimal to nonexistent among adults from clerical and managerial occupations in which handwriting is a common daily activity. However, pronounced age-related declines in handwriting were evident for occupational settings in which handwriting was less frequently used.

Similar interactions were observed by Murrell and colleagues. In a first study, Murrell, Powesland, and Forsaith (1962) compared young novice adults with older novice adults and young expert adults with older expert adults in the speed of operating an industrial mill. Age-related decline was observed among novice adults, but older expert workers were just as fast as young expert workers. A similar result was found in a later study involving the activity of simultaneous translation (Murrell & Humphries, 1978). The study showed that young novices were superior to old novices, but that older professionals did not differ from young professionals.

Cobb (1968) examined relations between chronological age, length of experience, and job performance ratings in air-traffic controllers. Negative correlations between chronological age and job performance were found. Length of experience, when considered independently of age, was found to be of negligible importance. Moreover, no significant interactions between age and experience were discovered. These results were confirmed in a subsequent investigation (Cobb, Nelson, & Mathews, 1973).

Giniger, Dispenzieri, and Eisenberg (1983) examined the variables of age and experience as related to productivity, absenteeism, accidents, and turnover in garment industry workers. A distinction was made between jobs requiring speed ($N = 212$) and those demanding skill ($N = 455$). Older workers surpassed the younger ones in all job categories. Partial correlations between experience and performance, which statistically controlled the effect of age, indicated that experience rather than age was the main determinant of the level of performance.

Sparrow and Davies (1988) investigated the effects of age, tenure, training level, and job complexity on performance using a sample of 1,308 service engineers employed by a multinational office equipment company. Two measures of job performance were derived from production record data, one relating to the quality of servicing and the other to the speed with which services were completed. For the quality of servicing measure, a significant age-by-training interaction was observed, and the relation between age and job performance took the form of an inverted U. For the speed of servicing measure, the main effects of age, tenure, training level, and job complexity were significant. No significant interactions were observed. Age accounted for only a small portion of variance for both performance measures. The authors conclude that training, especially if it is recent, may moderate adverse effects of age on job performance.

Transfer of Professional Expertise

With some exceptions (e.g., Cobb, 1968; Cobb, Nelson, & Mathews, 1973), the results of the studies reported above are consistent with the notion that professional experience attenuates or eliminates age differences in job performance. There are, however, as Salthouse (1987) suggested, opposing views to this interpretation:

> First, it is quite possible that something like a "survival-of-the-fittest" could have occurred among the experienced workers such that the older workers who remain available for performance comparison are more competent in certain occupationally-relevant dimensions than their age cohorts who left the occupation. This type of selective attrition would have the consequence of biasing the contrast of experienced workers in favor of older adults, with no comparable bias working among the inexperienced workers. . . .
>
> A second weakness of the studies . . . is that they were not analytical with respect to how experience could have led to the elimination or attenuation of age effects. In other words, even if one were to accept the interpretation that the absence of age trends among experienced individuals is due to experience somehow compensating for age-related declines, the studies provide no hint as to the mechanisms or processes that might have been used to achieve this compensation. (Salthouse, 1987, pp. 143–144)[2]

A third restriction, which is of particular relevance in the context of the present study, concerns the transfer of professional expertise beyond the world of work. With some exceptions (Featherman, in press; Kohn & Schooler, 1978; Miller & Kohn, 1983), past research did not address the issue whether professional expertise has more general beneficial effects on cognitive functioning in older adults. To name some examples, expertise in simultaneous translation may transfer to other dual-task situations. Similarly, older typists may experience positive effects of typing skill when they start to learn the piano in old age because they have prior practice in independently moving the five fingers of a hand (cf. Gellrich, in press). Finally, to name the theme of the present study, expertise in graphic design may be helpful in the acquisition and use of imagery-based mnemonic devices.

To summarize, the question whether professional expertise of older individuals transfers to tasks that lie outside their field of specialization continues to be of interest. An answer to this question would foster our understanding of the relationship between pragmatic knowledge and age-related decline in cognitive mechanics. If transfer to activities outside the profession were absent, the consequences of job-related pragmatic knowledge on intellectual functioning would appear to be rather limited. Positive effects beyond the world of work, on the other hand, would underscore the general consequences of specialized bodies of knowledge, such as professional expertise, on cognitive functioning in old age.

New Strategies in Research on Aging-Experience Relationships

The three issues reported above—selective attrition, lack of componential analysis, and lack of transfer assessment—challenge the interpretability and the generality of most studies on professional expertise and aging. The first problem, selective attrition,

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[2]See also Davies and Sparrow (1985) and Welford (1958) for similar arguments.

is especially difficult to resolve. An effective strategy would require detailed and longitudinal information about the performance characteristics of individuals who stay on the job and individuals who drop out.

Charness (1981) and Salthouse (1984) introduced a new research paradigm to overcome the second problem (i.e., lack of componential analysis). Their "molar equivalence/molecular decomposition" strategy involves two steps. First, a complex or "molar" activity such as typing, chess, or bridge bidding is selected, and a sample of adults of different ages is selected which exhibits a large amount of variability with respect to molar proficiency. Using objective indices of performance, subjects are selected in such a way that the correlation between age and molar task performance is close to zero. Examples of performance measures include an interval scale for rating chess players on tournament performance (Elo, 1965) and words per time as a measure of proficiency in typewriting (Salthouse, 1984).

In a second step, the task is decomposed into "molecular" units or component processes to examine age-related differences in the composition of skilled performance. By equating adults of different ages on molar proficiency, it "becomes possible to determine how people at different ages, and presumably different degrees of competency on relevant molecular processes, are able to achieve the same level of performance on the molar activity" (Salthouse, 1987, p. 145). Ideally, this strategy leads to an identification of mechanisms that compensate for age-related decline.

The present approach addresses the third issue, the transfer of professional expertise to other domains of life. Specifically, it aims at exploring whether professional expertise can eliminate or attenuate the age-related reduction of reserve capacity in important domains of cognition, such as imagery-based memory functioning. A moderation of the aging process is expected for tasks which centrally involve component processes that have received extensive training in the context of work activities of old expert professionals. In its attempt to extend the scope of occupational research, the present approach is complementary to the "molar equivalence/molecular decomposition" strategy advocated by Charness and Salthouse. While being less analytical than the molar equivalence/molecular decomposition strategy, it does allow for a better judgment of the relevance of professional expertise for cognitive functioning in old age.

TRANSFER OF IDENTICAL ELEMENTS

Overview

The concept of transfer has been widely used in psychology and related fields to describe effects of prior experience on subsequent learning. According to Hilgard (1958), "the study of the effects of old learning in new situations is often discussed as *transfer of training*" (p. 344). In the present study, professional expertise is expected to transfer to laboratory tasks. This prediction is not tied to particular contents but to elements of behavior that have received large amounts of practice in the context of the profession and that are deemed to be relevant in the context of the laboratory task.

Therefore, among the different conceptualizations of transfer (cf. Brown, Bransford, Ferrara, & Campione, 1983; Hilgard & Bower, 1971), the identical-elements view first proposed by Thorndike (1906) is adopted.

The following presentation is organized into four units. First, Thorndike's original thoughts on the issue of transfer are briefly presented. Then, their reformulation within the framework of Anderson's (1983) ACT* theory of knowledge acquisition and knowledge representation is described. This reformulation serves as a template for a molar concept of transfer which is presented in a separate unit. Finally, main results are summarized.

Thorndike's Identical-Elements View of Transfer

About 80 years ago, Thorndike (1906) undertook a program of research which provided little evidence for the existence of transfer of training across tasks. For instance, cancelling letters showed little transfer to cancelling parts of speech, and estimating areas of rectangles of one size and shape was not very helpful in learning to estimate the areas of rectangles of another size and shape. On the basis of these results, Thorndike concluded that "training the mind means the development of thousands of particular independent capacities" (1906, p. 248).[3]

With this position, Thorndike argued against the view that the study of abstract rule systems would train the mind for reasoning about concrete problems. However, Thorndike did not think that transfer between different tasks was impossible. According to his view, the amount of transfer between tasks was a direct function of the number of elements in common to the target task and the trained task. The following quotations from *The Principles of Teaching* (Thorndike, 1906) summarize this conception:

> Of the millions of situations with which life confronts us many are duplicates, many are identical in important features and still more have something or other in common. Where the community is great, the possibility for the use in one process of ability gained in some other process is great; where the identical elements are but a fraction of the whole, the possibility is little.... Improvement in any one mental function or activity will improve others only in so far as they possess elements common to it also. (Thorndike, 1906, pp. 244, 248)

Thorndike's claim that transfer is dependent upon the existence of identical elements was made at a fairly general level. First, he did not provide a definition or a taxonomy of "elements." In his own empirical work, identity between tasks occurred at the level of task materials, rules and operations, or attitudes. Recent research has shown that the amount and the consequences of transfer depend to a large degree on the level of analysis at which identity between different tasks is present (Klauer, 1987, in press;

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[3]This position is still endorsed by many theorists today. For example, Newell (1980) stated, "the modern (i.e., experimental psychology) position is that problem-solving skills are, in general, idiosyncratic to the task" (p. 184). Recently, however, there was new empirical evidence in favor of the existence of some domain-general pragmatic inferential rules that are acquired by experience in specific domains, such as graduate training in psychology (Lehman, Lempert, & Nisbett, 1988; Nisbett, Fong, Lehman, & Cheng, 1987).

Lehman, Lempert, & Nisbett, 1988; Nisbett, Fong, Lehman, & Cheng, 1987; Novick, 1988; Singley & Anderson, 1985). In the domain of reasoning, for instance, equality of surface features paired with inequality of structural features may lead to negative consequences because individuals erroneously apply the same problem-solving strategy (Novick, 1988).

Second, Thorndike believed that the amount of transfer depends directly on the number or the proportion of identical elements. It is possible, however, that elements of skilled performance differ in importance: Some elements may be much more important in the context of a given task than others. In this case, it is important to know whether the set of identical elements includes elements that are important for reaching a high level of performance on the target task. Predictions based on the number of identical elements alone would not capture this aspect of the relationship between two tasks.

One way to overcome these shortcomings is to identify elements of performance and the relationship among them with the help of a well-specified task-analytic procedure. Recent theories of skill acquisition are trying to develop such procedures (Anderson, 1983; Neches, 1987; Neches, Langley, & Klahr, 1987; Neves & Anderson, 1981; Wallace, Klahr, & Bluff, 1987). Among these, a recent extension of Anderson's (1983) ACT* theory of knowledge acquisition and knowledge led to a reformulation of Thorndike's notion of identical elements.[4]

Transfer Among Skills in ACT*

In a recent article, Anderson (1987) proposed a strategy for predicting transfer of elements of skilled behavior. This strategy is formulated in the terminology of ACT* theory (Anderson, 1983). To gain a better understanding of Anderson's concept of transfer, the most important notions of ACT* theory are introduced.

A Brief Description of ACT* Theory

In ACT*, *productions* form the units of procedural knowledge, that is, they "define the steps in which a problem is solved" and they are "the units in which knowledge is acquired" (Anderson, 1987, p. 196).[5] Cognitive processing is represented as the activation of productions. Productions, in the most general sense, are "condition-action pairs that specify that if a certain state occurs in *working memory,* then particular mental (and possibly physical) actions should take place" (p. 193). In working memory, *declarative* (i. e., not yet proceduralized) knowledge can be accessed, and currently active parts of the goal structure of a given task can be brought to consciousness.

Goal structures in ACT* are hierarchically organized. They guarantee the sequencing of productions in problem solving, and serve to indicate which elements of

[4]See also Klauer (1987, in press) and Holyoak (1984) for similar attempts.

[5]In the following, all citations refer to Anderson (1987).

declarative knowledge belong together in the context of a given task and can be compiled into new, domain-specific productions. This process of *knowledge compilation* is the central process of skill acquisition in ACT*. Starting out with domain-general productions that specify weak (i.e., widely applicable) problem-solving methods (such as analogy, means-end analysis, working backward, etc.), knowledge is compiled into specialized, domain-specific productions. Two steps of knowledge compilation are distinguished: *proceduralization,* the process of transforming declarative knowledge into procedural knowledge, and *composition,* the process of collapsing a sequence of formerly independent productions into a single production. "It needs to be emphasized that proceduralizing weak methods does not eliminate weak methods, nor does composing smaller productions into larger productions eliminate smaller productions" (p. 197).

Transfer in ACT*

In contrast to neural models of parallel distributed processing (McClelland & Rumelhart, 1986) or to schema systems (Schank & Abelson, 1977), the ACT* production system represents knowledge as a *collection of elements* (productions). As a consequence, Thorndike's identical-elements conception of transfer can be directly applied to ACT* theory:

> The commitment to productions as the units of procedural knowledge has some interesting empirical consequences. In particular it leads to some strong predictions about the nature of transfer between two skills. Specifically, the prediction is that there will be positive transfer between skills to the extent that the two skills involve the same productions. (Anderson, 1987, pp. 197–198)

Thus, Anderson's (1987) concept of transfer refers to basic elements of action-relevant knowledge that have been acquired in the context of a given task and will become active in the context of another task providing that an overlap in goal structures exists.[6] Therefore, predictions regarding transfer among skills on the basis of ACT* theory require the formulation of an appropriate production system for both the trained and the target task. The precision of the predictions depends on the veridicality of the production-system analysis which, in turn, is largely determined by the extent to which the experimenter can retrace the knowledge compilation process. In a small number of exploratory studies, Anderson's concept of transfer prediction has been successfully applied to the acquisition of different text-editing systems (Anderson, 1987; Kieras & Bovair, 1986; Polson & Kieras, 1985; Singley & Anderson, 1985).

Transfer of Professional Expertise

Predicting transfer among skills which were all acquired within the laboratory (e.g., text editing) differs markedly from predicting transfer of professional expertise to laboratory tasks. Professional expertise involves the acquisition of an interrelated set

[6]A peculiar consequence of the identical-elements theory is that "it does not directly predict any negative transfer among skills in the sense of one procedure running less effectively because another has been learned" (Anderson, 1987, p. 200).

of skills over a long period of time. Due to this circumstance, the experimenter does not have any detailed evidence regarding the acquisition phase of the skill. Therefore, predictions of transfer cannot be easily based on assumptions regarding the system of productions. Instead, the idea of predicting transfer among skills on the basis of identical elements has to be recast on a molar level of analysis.

Transfer Among Skills: A Molar Redefinition

In Anderson's (1987) theory, elements refer to individual productions, and in Thorndike's (1906) original conceptualization the level of analysis is not clearly defined. For the purpose of the present study, it is assumed that a task can be decomposed (theoretically and experimentally) into a number of discrete steps or components. Elements of skill are defined *in relation to these task components.* In contrast to Anderson (1987), transfer is predicted on the molar level of components, rather than on the molecular level of productions; the number of productions comprised in a single element of skill is left undefined and may vary within individuals over time, across individuals, and across components.

In past research, the theoretical concern for age-related differences in cognitive plasticity has led to the construction of training programs in mnemonic skill (Kliegl & Baltes, 1987). In addition to age, the present research explores, in an illustrative manner, the importance of professional expertise as an antecedent of cognitive plasticity in old age as measured by memory performance in serial word recall with one mnemonic device, the *Method of Loci* (Bower, 1970a). Therefore, the selection of the profession has to be based on a componential analysis of the laboratory task (i. e., the *Method of Loci*), and not vice versa.

Criteria for the Selection of Expert Professionals

The appropriate strategy for expert selection consists of two steps. The first step is to identify *critical,* or at least *important,* elements of skill in the target task. Elements of skill are defined as critical if they meet three criteria: *necessity, variability,* and *exhaustiveness.* An element of skill is necessary if it must be applied to a task component to allow successful performance. The element is called variable if proficiency in the application of this element, or in the quality of the element itself, varies across individuals.[7] Finally, elements of skill are exhaustive if it is known with certainty that no other necessary and variable elements are present, that is, if one knows for sure that all elements of skill contributing to interindividual differences in performance have been identified. If elements of skill are necessary and variable, but not exhaustive, they are called *important.*

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[7]Not all elements which are necessary need to be variable. In the case of the *Method of Loci,* for instance, it is necessary that all individuals understand the mnemonic instructions, are able to read to-be-learned materials, and are able to utter a response. However, all these elements are not critical because experimental procedures (e. g., subject selection, instruction) largely reduce interindividual variability in these regards.

The choice of a profession constitutes the second step of the strategy. This choice is guided by the knowledge about critical elements of skill in performance on the target task. A profession is looked for in which the same elements are likely to be relevant. Experts from that profession should show high proficiency in performance related to these elements. Ideally, all critical elements of the target task should be relevant in the context of the profession. In that case, it would seem very likely that transfer of professional expertise to the target task would occur.

Predictability of transfer could be impaired for at least three reasons. First, it is possible that only a subset of the critical elements identified in the context of the target task are practiced in the context of the profession. Second, if the criterion of criticality could not be met, other elements of skill that are not part of the professional expertise would also contribute to interindividual differences in performance on the target task. Finally, the profession in question may involve many additional elements of skill, thereby reducing the overall amount of practice in the elements deemed critical or important.

Summary

The identical-elements view of transfer is adopted for the present study. Transfer is thought to depend upon the existence of elements of skill that are common to the target task and to the trained task. As can be seen in Thorndike's (1906) original formulations, problems arise if these elements are not clearly defined.

Anderson's (1987) reconceptualization overcomes these problems. Here, the units of procedural knowledge (productions) function as elements of transfer in skill acquisition if the goal structure of a new task overlaps with the goal structure of an old task. This concept of transfer, while being theoretically attractive, is not directly applicable to the present study because it presupposes detailed knowledge about the process of skill acquisition in both task domains. This knowledge is not available in the case of professional expertise.[8]

The present notion of identical elements is analogous to Anderson's but formulated at a molar level. Elements of skill are said to correspond to task components. Elements are called important if they are necessary for reaching high levels of performance and if their quality or ease of application varies across individuals. They are called critical if they are the only determinant of interindividual differences in performance. Since the focus of the present study is not on a particular profession but on antecedents of cognitive plasticity as assessed by instruction and training in a mnemonic skill, the best research strategy is first to identify important, if not critical elements of skill in the context of the mnemonic task and subsequently select experts from a profession in which these elements are likely to be trained.

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[8]See also Tack (1987) for a general discussion of problems associated with psychologists' representations of knowledge (e.g., the representation of representations).

MEMORY FUNCTIONING WITH THE *METHOD OF LOCI*

Overview

This section provides a detailed review of the psychological literature on the *Method of Loci*. The major aim of the review is to identify one or more important, if not critical elements of memory functioning with the *Method of Loci*. As argued above, the identification of important elements of skill is a precondition for the selection of a group of expert professionals. Another aim of the review is to elucidate major aspects of memory functioning with the *Method of Loci* in order to optimize the instruction and the training program of the empirical investigation.

The review is organized into five units. In the first, a general description of the *Method of Loci* and its close variant, the peg-word mnemonic, is presented. The second unit provides a synopsis of research with the two mnemonic devices. Then, the notion of a cognitive cuing structure (Bellezza, 1981) is introduced to describe the architecture of peg-type mnemonics, and recent research pertaining to this issue is discussed. In the fourth unit, the relevance of visual imagery in memory performance with the *Method of Loci* is evaluated in the light of evidence emanating from different lines of research. Finally, a profession is identified in which the attainment of expert levels of performance is presumed to be associated with a high amount of practice in the generation of visual images.

Introduction to Mnemonic Devices and the *Method of Loci*

Mnemonic Devices in Modern Psychology

Mnemonic devices have been known in Western culture for a long time and were successfully used to learn speeches, lists of unrelated words, and numbers (Bellezza, 1981; Graumann, 1986; Feinaigle, 1813, cited in Paivio, 1971; Volkmann, 1929; Yates, 1966). However, except for case studies of expert mnemonists and mental calculators (Binet, 1894, cited in Ericsson, 1985; Müller, 1911, 1913, 1917; Susukita, 1933, 1934), these devices were not frequently studied by psychologists in the first half of this century. Rather, most psychologists interested in memory and learning confronted their subjects with "nonsense" syllables presented at a fast rate to ensure that rote learning took place.

But even under these adverse conditions subjects tried to use strategies allowing for meaningful encoding of to-be-learned material. With the advent of cognitive psychology, more attention was paid to subjective organization (Tulving, 1962), rehearsal (Atkinson & Shiffrin, 1968), and imagery (Bower, 1969; Paivio, 1971). Eventually, some psychologists began to study memory functioning with mnemonic devices, such as the *Method of Loci* (Paivio, 1971; Ross & Lawrence, 1968), the peg-word mnemonic (Smith & Noble, 1965; Wood, 1967), the link mnemonic (Delin, 1969), and the story mnemonic (Bower & Clark, 1969). Only the peg-word mnemonic and the *Method of Loci* are considered here.[9]

Description of the *Method of Loci* and the Peg-Word Mnemonic

In the *Method of Loci,* subjects overlearn a set of locations or loci in an invariant order (see also Table 1). After acquisition of this cognitive routing map, to-be-learned items are sequentially associated with each of the locations on the map. Most ancient sources, textbooks, and experimenters give the advice that one should form vivid and interacting visual images between the set of to-be-learned items and the corresponding set of locations. To recall the items, subjects "visit" each location, try to remember the association formed at encoding, and retrieve the target item. On the basis of an anonymous medieval source, the *Ad Herrenium,* Yates (1966) notes the following characteristics of the device:

> A *locus* is a place easily grasped by the memory, such as a house, an intercolumnar space, a corner, an arch, or the like. Images are forms, marks or simulacra . . . of what we wish to remember. . . . If we wish to remember much material we must equip ourselves with a large number of places. It is essential that the places should form a series and must be remembered in their order. . . . The formation of the loci is of the greatest importance, for the same set of loci can be used again and again for remembering different material. (Yates, 1966, pp. 6–8)

The peg-word mnemonic is included in the present review because it functions similarly to the *Method of Loci* (Bower & Reitman, 1972; Roediger, 1980). The system

Table 1
Description of the *Method of Loci*

Strategy	Illustration
1. Acquire a fixed sequence of locations	Radio tower Berlin Wall Egyptian Museum . . . .
2. For each to-be-remembered item, form a visual image	Rooster → A rooster impaled on the tip of the radio tower
3. Encode visual image and move to next item	Cake → A cake enclosed in the barbed wire of the Berlin Wall
4. At time of recall, retrieve visual image of first location and decode the to-be-remembered item; move to the next location, etc.	

Note. Adapted with minor modifications from Baltes and Lindenberger (1988).

[9]For a more comprehensive account of mnemonic devices in psychological research, the reader is referred to Bellezza (1981).

involves the overlearning of an ordered series of peg words rather than locations. A new series of words can then be remembered in the order given, by forming an association between new words and previously memorized pegs. Again, most experimenters tell their subjects to create vivid and interacting visual images between a set of new items and a set of memory pegs. In the case of the most commonly used peg-word mnemonic (cf. Miller, Galanter, & Pribram, 1960), each peg rhymes with the number referring to its serial position on the list: one is a bun, two is a shoe, three is a tree, etc. To summarize, both the *Method of Loci* and the peg-word mnemonic consist of a series of memory pegs. These memory pegs function as a cognitive cuing structure which facilitates the formation, sequencing, and retrieval of mental associations.

Synopsis of Research

Table 2 summarizes psychological research on the *Method of Loci* and the peg-word mnemonic. In an initial phase, two lines of research can be distinguished. First, researchers tried to show that the instruction of mnemonic devices does indeed lead to higher performance levels as compared to rote memory or verbal rehearsal, given that the presentation rate for each of the to-be-learned items is sufficiently long (e.g., Bower, 1969; Briggs, Hawkins, & Crovitz, 1970; Bugelski, 1968; Bugelski, Kidd, & Segmen, 1968; Crovitz, 1969, 1971; Ross & Lawrence, 1968).

Second, attempts were made to detect important components of the devices. A special effort was made to determine the role of imagery in enhancing recall. Mnemonic systems were administered with instructions suggesting verbal versus imaginal mediation (Bower, 1969; DiVesta & Sunshine, 1974; Foth, 1973; Groninger, 1971, 1974; Paivio, 1968, cited in Paivio, 1969; Santa, Ruskin, & Jun Han Yio, 1973; Wood, 1967; Wood & Bolt, 1970), and both the memory pegs and the to-be-learned items were varied in the degree of imageability (Delprato & Baker, 1974; DiVesta & Sunshine, 1974; Paivio, 1968, cited in Paivio, 1969; Santa, Ruskin, & Jun Han Yio, 1973; Wippich, 1977; Wood, 1967; Wood & Bolt, 1970).[10]

The results of this first phase indicated (a) that the *Method of Loci* and the peg-word mnemonic are effective in facilitating recall, (b) that imagery is important in the use of both mnemonic devices (Bower, 1969, 1970a, 1970b; Paivio, 1969), (c) that most untrained individuals need at least four seconds to generate a visual image (Bugelski,

[10]In the verbal learning literature, the terms concreteness versus abstractness and high-imagery level versus low-imagery level are often used interchangeably. Although correlations between ratings of imageability and concreteness on a 7-point scale are around .85 (Baschek, Bredenkamp, Öhrle, & Wippich, 1977; Paivio, Yuille, & Madigan, 1968), it can be argued that the two dimensions are conceptually distinct. For instance, some concepts may easily evoke visual images without representing concrete objects. Nouns having a high score on imagery but a low score on concreteness, such as *Gespenst* (ghost; C = 3.36, I = 6.00) or *Eifersucht* (envy; C = 3.00, I = 5.00), are empirical evidence for this assumption (Baschek, Bredenkamp, Öhrle, & Wippich, 1977). As is argued below, the relevant dimension in memory functioning with peg-type mnemonics, such as the *Method of Loci* or the peg-word mnemonic, is imageability, not concreteness. Therefore, the term imageability, or imagery level, is adopted for the present study.

1970), (d) that the effectiveness of the method decreases with low-imagery materials (Bower, 1969), (e) that high imagers (defined as scoring high on spatial ability tests) recall more items than low imagers when both groups are instructed to use imaginal mediators (DiVesta & Sunshine, 1974), and (f) that interference due to repeated use of the same list of locations or pegs in consecutive trials tends to be very small (Bower, 1969; Bugelski, 1970; Crovitz, 1971; Luria, 1968). In sum, the results of this first phase of research underscored the effectiveness of visual imagery in the *Method of Loci* and the peg-word mnemonic.

In a more recent phase of interest in mnemonic devices, research has taken three different directions. First, the *Method of Loci* and, to a lesser extent, the peg-word mnemonic were used as training instruments in applied settings. In particular, training has been directed toward helping older persons alleviate their memory problems (Anschutz, Camp, Markley, & Kramer, 1985; Cermak, 1980; Heineken & Gekeler, 1985; Hellebusch, 1976; Mason & Smith, 1977; Robertson-Tchabo, Hausman, & Arenberg, 1976; Rose & Yesavage, 1983; Poon, Walsh-Sweeney, & Fozard, 1980; Winograd & Simon, 1980; Yesavage & Rose, 1983, 1984; for reviews, see Greenberg & Powers, 1987; Fleischmann, 1982). Opinions vary as to whether these attempts were successful (Cermak, 1980; Fleischmann, 1982; Poon, Walsh-Sweeney, & Fozard, 1980).[11] Some investigators also tried to teach the *Method of Loci* to persons with closed head injury or other kinds of brain trauma (Crovitz, Harvey, & Horn, 1979; Wilson, 1982; for a review, see Richardson, Cermak, Blackford, & O'Connor, 1987). These studies revealed large individual differences in the extent to which brain-damaged patients are able to profit from training (cf. Richardson, Cermak, Blackford, & O'Connor, 1987).

Second, several investigators suggested that the operation of mnemonic devices may provide insight into more general questions of memory functioning (Bower, 1970a; Roediger, 1980). In this context, two major themes can be distinguished. One concerns the architecture of mnemonic devices (Battig & Bellezza, 1979; Bellezza, 1981, 1982; Bjork, 1978; Bower, 1969; Bower & Reitman, 1972; Christen, 1980; Lea, 1975; Roediger, 1980), and the other relates to the nature of visual imagery in mnemonic functioning (Baddeley & Lieberman, 1980; Cornoldi, Calore, & Pra Baldi, 1979; DeBeni & Cornoldi, 1988; Logie, 1986; Steiner, 1980; Steiner, Bischof, & Froeschl, 1984).

Third, Kliegl and Baltes (1987) and their colleagues used the *Method of Loci* to investigate age-related differences in the plasticity of memory functioning (Baltes & Kliegl, 1989; Kliegl & Lindenberger, 1989; Kliegl, Smith, & Baltes, 1986, 1989a, 1989b; Kliegl, Smith, Heckhausen, & Baltes, 1986, 1987; Thompson & Kliegl, 1989). Adults of different ages were instructed and trained in the use of mnemonic devices. During this process, the context of measurement was shifted away from an assessment of baseline performance to an estimation of baseline and developmental reserve capacities (Baltes, 1987). In addition, Kliegl and Baltes (1987) proposed that instruction and training of

[11] Research regarding this issue is reviewed below (Imagery and Mnemonic Aids, pp. 54–56).

Table 2
Overview of Research on the *Method of Loci* and the Peg-Word Mnemonic

		(1)	(2)	(3)	(4)
Kliegl	(in prep.)	mol pw other	y o	microgenesis of expert memory; formation of specialized knowledge; age-related differences in memory reserve capacity	28
Kliegl et al.	(1989a, 1989b)	mol	y o	demonstration of cognitive plasticity in young and old adults; magnification of age differences in memory performance	61
Kliegl & Lindenberger	(1989)	mol	y o	formal modeling of age-related susceptibility to intrusion errors	81
DeBeni & Cornoldi	(1988)	mol	+	congenitally blind subjects show memory impairments related to the lack of visual experience	40
Logie	(1986)	pw	y	evidence for involvement of spatial and/or visual working memory components in memory functioning with mol	90
Reddy & Bellezza	(1986)	pw other	y	interference between pw instruction and spontaneous categorization	72
Anschutz et al.	(1985)	mol	o	low maintenance and everyday usage of mol in older adults	10
DeBeni & Cornoldi	(1985)	mol	y	high levels of recall through combination of mol with link mnemonic	84
Heineken & Gekeler	(1985)	mol	o	relationship between mol instructions and motivational factors	48
Yesavage & Rose	(1984)	mol	o	combination of mol instructions with pleasantness judgments of visual images	37
Rose & Yesavage	(1983)	mol	y o	magnification of age differences in memory performance	67
Yesavage & Rose	(1983)	mol other	o	effectiveness of mol when preceded by imagery training	35
Bellezza	(1982)	pw other	y	exploration of memory updating via temporal and/or list tags	48
Baddeley & Lieberman	(1980)	mol pw	y	evidence for involvement of spatial and/or visual working memory components in memory functioning with mol	40
Christen	(1980)	mol	y	little evidence for build-up of PI with repeated use of mol	228
Roediger	(1980)	mol pw	y	special effectiveness of mol and pw in preserving serial position information	150
Crovitz et al.	(1979)	mol	*	long-term mnemonic training following closed-head injury	3
Mason & Smith	(1977)	pw	y o	age differences in effectiveness of pw instruction and use of imagery	430
Wippich	(1977)	mol	y	mol instructions most effective with high-imagery material	48
Robertson et al.	(1976)	mol	o	only partial success of mol instruction in old adults	35
Lea	(1975)	mol	y	chronometric decomposition of task components in memory functioning with mol	24
Delprato & Baker	(1974)	pw other	y	pw instructions more effective with high imagery	148
DiVesta & Sunshine	(1974)	pw	y	better serial recall with pw for subjects with high scores on spatial reasoning tasks	88
Groninger	(1974)	mol	y	facilitation of long-term retention with mol	121
Foth	(1973)	mol pw	y	mnemonic instruction facilitates recall	200
Santa et al.	(1973)	pw other	y	pw instruction only effective with high-imagery material	363
Bower & Reitman	(1972)	mol pw	y	post-session recall differences as a function of instruction (elaboration vs. separate images)	30
Crovitz	(1971)	mol	y	recall of order information as a function of repeated use of the same set of loci in one trial	70
Groninger	(1971)	mol	y	facilitation of long-term retention with mol	72
Briggs et al.	(1970)	mol	y	influence of experimenter-provided images on memory functioning with mol	50
Morris & Reid	(1970)	pw	y	no decrease in recall performance due to repeated use of pw	54
Wood & Bolt	(1970)	pw	y	equal effect of imageability of verbal material on recall with pw and standard paired associates instructions	108
Berla et al.	(1969)	pw	y	learning-to-criterion with pw vs. standard paired associates instructions	56
Bower	(1969)	pw other	y	relationship between link and pw mnemonic	-
Crovitz	(1969)	mol	y	influence of experimenter-provided loci sequence on recall	12
Keppel & Zavortink	(1969)	pw	y	facilitation of recall with pw instruction	96
Bugelski	(1968)	pw	y	facilitation of recall and reduction of interference with pw instruction	36
Bugelski et al.	(1968)	pw	y	4 s per word at encoding as minimum time for pw use	90
Ross & Lawrence	(1968)	mol	y	facilitation of recall and reduction of interference with mol instruction	6
Wood	(1967)	pw	y	facilitation of recall with pw and/or imagery instructions	318

Legend: (1) Type of task: method of loci (mol), peg-word mnemonic (pw), other; (2) subjects: young adults (y), older adults (o); (3) research objective and/or research findings: method of loci (mol), peg-word mnemonic (pw); (4) total number of subjects; (5) type of instruction: imagery (i), verbal rehearsal (v), categorization (c); (6) to-be-learned items: high in imagery (high), low in imagery (low), or both; (7) total number of trials per subject; (8) presentation rate: self-paced (s-p), seconds per item (s), minutes per list (m l.; all other entries refer to items); (9) number of locations per list; (10) scoring: total number of items recalled (lenient), total number of items in correct serial position (strict); (11) recall: immediate (i.), post-session (p.-s.), delayed (del.).

Note. *: Head-injured persons of different ages; +: blind adults and sighted matched controls of different ages; -: information not available.

(Table 2 cont.)

(5)	(6)	(7)	(8)	(9)	(10)	(11)
i	both	20– > 400	s-p to 0.5 s	20 40	strict	i. p.-s. del.
i	high	19–84	s-p to 1 s	30 40	strict	i.
i	high	10–22	s-p to 1.5 s	20 30	strict	i. p.-s.
i	both	3	10 s	18 36 54	both	i.
i v	high	3–10	ca. 5 s	7–10	strict	i.
i	high	1	6 s	42	lenient	i.
i	high	–	5 m l.	10	lenient	i.
i	high	1	10 s	20	strict	i.
i	both	6	4 s	12	lenient	i.
i	high	1	4 m l.	18	lenient	i. p.-s.
i	both	ca. 8	4 m l.	18	lenient	i.
i	high	3	4 m l.	18	lenient	i. p.-s.
i	high	3	10 s	16	strict	i. del.
i v	both	4	6 s	10	lenient	i.
i	both	1–5	6.5 s	20	both	i. p.-s. del.
i v	high	4	7 s	20	both	i. del.
i	high	–	–	–	–	–
i v	both	1 4	5 s-p	10 20	lenient	i.
i	both	2	8 s	12	lenient	i.
i	high	5	s-p	16	lenient	i.
i	high	1	–	12	–	i.
i	both	2	4 s	10	lenient	i.
i v	both	4	s-p	10	strict	i. p.-s.
i c	high	1	s-p	25	lenient	del.
i v	both	2	6 s	10	lenient	i.
i v	both	6	1 ¼ m l.	10	lenient	p.-s.
i	high	5	10 s	20	strict	i. del.
i	high	1	10 s	1–32	strict	i.
i	high	1	s-p	25	both	del.
i	high	1	ca. 5 s	20	strict	i.
i	high	6	8 s	10	strict	i.
i v	high	2	4 5 s	10	strict	i.
i v	high	1	5 s	20	strict	i.
i	high	5	5 s	1–20	strict	i. p.-s.
i	high	1	8 s	40	strict	i.
i	high	1	s	10	lenient	i.
i	high	6	s-p	10	strict	i. p.-s.
i	high	2	2 4 8 s	10	strict	i.
i	high	4 5	s-p	20 40 50	strict	i. del.
i v	both	1–6	2 5 s	40	strict	i.

mnemonic skill are potentially helpful in identifying aging-sensitive task components and in testing hypotheses about compensatory processes by means of specific interventions.

Cognitive Cuing Structures and Mnemonic Performance

Bellezza's Taxonomy of Mnemonic Devices

Bellezza (1981, 1982) provided a general definition and a taxonomy of mnemonic devices which bridged the gap between research on mnemonics[12] and theory-driven research on memory skill (Chase & Ericsson, 1981, 1982; Ericsson, 1985), cue-dependent forgetting (Bäckman, Mäntylä, & Erngrund, 1984; Mäntylä, 1986; Tulving, 1983), and the discriminability of memory traces (Ashby & Perrin, 1988; Corter, 1987; Einstein & McDaniel, 1987; Eysenck, 1979; Jacoby & Craik, 1979; McDaniel & Einstein, 1986; Norman & Bobrow, 1979). Bellezza's framework can be used to organize the overview of recent research on memory functioning with the *Method of Loci* and the peg-word mnemonic.

A mnemonic device is defined as a "strategy for organizing and encoding information with the sole purpose of making it more memorable" (Bellezza, 1981, p. 252). To this end, the encoding and organizing operations prescribed by the mnemonic device create a *cognitive cuing structure* which is used by the learner to encode and later remember a set of information through a self-cuing process. In the case of the *Method of Loci* and the peg-word mnemonic, the encoding operations specified by the device consist in the generation of visual images connecting the units of to-be-learned information with the invariant sequence of pegs (Bugelski, 1970; Paivio, 1971). At recall, the locations or pegs are activated in the same order as at encoding, the compound visual images are retrieved, and the original units of information (the test items) are recalled.[13]

Mnemonic Properties of Cues

Cues are the elements used to build the cuing structure of a mnemonic device. In the *Method of Loci,* cues refer to locations (of a city, a house, a garden, etc.) which form sequentially the mental route of the mnemonist. Bellezza (1981) lists four properties of cues which are necessary for the effective functioning of a cognitive cuing structure: (a) Cues need to be *constructable* so that they can be easily generated whenever the desired

[12]The term "mnemonics" is used as a shortened form for "mnemonic devices."

[13]In his taxonomy, Bellezza (1981) draws a distinction between organizational and encoding mnemonics. *Encoding* mnemonics transform units of information into some other, more memorable form (e.g., two-digit numbers into nouns). *Organizational* mnemonics combine units of information in memory that at first appear unrelated (e.g., by means of a fixed sequence of cues). The *Method of Loci* and the peg-word mnemonic are classified as *organizational, multiple use, peg-type* mnemonics. At the same time, the *Method of Loci* and the peg-word mnemonic also specify optimal operations for the encoding of information (e.g., the generation of visual images). Thus, the distinction between encoding and organizational mnemonics is not very strong and will not be pursued here.

information is to be encoded or recalled, (b) they need to be *discriminable* to prevent confusion during encoding and recall, (c) they must be *associable* so that they can be easily connected with to-be-remembered information, and (d) they need to be *invertible* to ensure that the memory trace (i. e., the compound of cue and item, most frequently a visual image) is an effective cue for the retrieval of the item itself.

To summarize, it appears that successful recall with a mnemonic device depends on the quality of the cuing structure created. With the *Method of Loci* and the peg-type mnemonic, two aspects are especially important: (a) the facilitation of encoding by means of visual images, and (b) the preservation of order information (Bellezza, 1981; Roediger, 1980).[14]

Research on the Cuing Structure of the *Method of Loci*

Research on memory functioning with the *Method of Loci* can be interpreted as a close examination of Bellezza's (1981) claims. For instance, Battig and Bellezza (1979) administered the peg-word mnemonic under different conditions in order to investigate cuing, chunking, and mnemonic organization. They concluded that self-cuing is a main feature of organizational mnemonics. Similar conclusions were reached by Roediger (1980) who compared the effectiveness of four mnemonic devices (link method, simple imagery, peg-word mnemonic, *Method of Loci*). The results indicated that both the peg-word mnemonic and the *Method of Loci* are especially effective in ordering recall.

Bjork (1978) noted that the same cuing structure provided by a mnemonic device is used repeatedly for the retention of different information. This characteristic of the mnemonic device, Bjork argued, points to the updating of information as a general feature of human memory. To function in a successful manner we need to remember that "updates" frequently change in value. For instance, we must remember where we last parked our car, left our glasses, or placed a particular book.

Bjork (1978) proposed that the updating of information can assume "destructive" or "structural" forms. Destructive updating involves the replacement or destruction of old information by new information. Structural updating, on the other hand, does not involve the destruction of past information. Rather, "successive inputs are encoded as a series in which some underlying structure specifies which input is most recent" (Bjork, 1978, p. 238). According to Bjork, the cuing structure of some mnemonic devices, such as the *Method of Loci* and the peg-word mnemonic, seem to facilitate memory updating. The lack of proactive interference reported in earlier studies supports this view (Bower, 1969; Bugelski, 1970; Christen, 1980).[15]

One may wonder whether mnemonic devices are more likely to induce destructive or structural updating mechanisms. Two studies bear directly upon this issue. Bower

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[14]Bellezza's four mnemonic criteria—constructability, discriminability, associability, and invertibility—not only describe properties of mnemonic cues but are also helpful in characterizing to-be-learned material and in predicting individual differences in mnemonic skill.

[15]This notion of memory updating has its historical precursor in the associationist concept of unlearning as an account of proactive interference in paired-associate learning (cf. Bjork, 1978).

and Reitman (1972) studied interference in multi-list learning as a function of task instruction. Using both the peg-word mnemonic and the *Method of Loci,* some subjects were instructed to visualize words from successive lists in entirely new associative scenes (separate images) whereas other subjects were asked to incorporate the current list's words into scenes from earlier lists (progressive elaboration). Post-session recall was better for the progressive-elaboration group than for the separate-images group, who showed a retroactive interference curve across lists. In the terminology of Bjork (1978), the progressive-elaboration instruction induced structural updating to a greater extent than the separate-images instruction.

In another experiment related to memory updating, Bellezza (1982) investigated the hypothesis that retrieval can be based on the temporal attributes of memory traces. In his Experiment 3 (peg-word mnemonic), the retrieval-by-temporal-attributes notion was tested by reducing the information typically available to the subject concerning the time the tested items were presented for study. Recall performance in this condition was inferior to the control condition in which the temporal organization of the lists was maintained. Bellezza concluded that the precise mechanism of retrieval-by-temporal-attributes remains unclear. He suggested that there may exist "some sort of internal clock in each person that tags each experienced event" (Bellezza, 1982, p. 323).

In an age-comparative training study with young and older adults of above-average intelligence, Kliegl and Lindenberger (1989) investigated the importance of contextual cues ("list tags") in memory performance with the *Method of Loci.* Using an experimental design entailing the same set of to-be-learned items permutated over an invariant sequence of loci (an A-B, A-Br design in classical verbal learning terminology), they specified a formal model which successfully predicted intrusion errors from earlier lists on the current list. Subjects' level of recall was equated by the manipulation of presentation rate at encoding. At equal levels of correct recall, older adults showed a higher number of intrusion errors than young adults. According to the model, this finding was due to the fact that old adults were less likely to encode the list membership of a given memory trace (i.e., a deficit in encoding contextual information).

Visual Imagery in the *Method of Loci*

Researchers generally agree that visual imagery is an important aspect of mnemonic performance with the *Method of Loci* (Bower, 1970a; Bugelski, 1970; Roediger, 1980; Wippich, 1984).[16] An element of skill must meet two criteria, necessity and variability, to allow for transfer predictions which are based on the notion of identical elements. To qualify as an important, if not critical element of skill in memory performance with

[16]The classical debate between defendants of a "pictorial" view of imagery (e.g., Farah, Finke, Paivio, Shepard, Kosslyn, Neisser) and a "propositional" view (e.g., Anderson, Norman, Pylyshyn, Rumelhart) will not be discussed here (for reviews, see Kolers & Smythe, 1979; Kosslyn, 1980). In the meantime, new behavioral and neurophysiological evidence provides additional support to a revised variant of the pictorial view, which stresses the existence of partial isomorphisms between visual perception and visual imagery (Farah, 1988; Kosslyn, 1988).

the *Method of Loci,* the generation of visual images would need to be indispensable for attaining high levels of recall, and individuals would have to differ in their degree of efficacy in generating memorable images. In the following, three lines of research —post-learning questionnaires, psychometric data, and secondary-task studies—are reviewed to examine whether these two assumptions are likely to be true.

Post-Learning Questionnaires

The efficacy of visual imagery for the retention of verbal material has become commonplace in the verbal learning literature (Bellezza, 1981; Bugelski, 1970). In fact, visual imagery was frequently used as an explanatory construct to account for the superiority of mnemonic strategies over verbal rehearsal (Bugelski, 1970; Paivio, 1971, 1986). However, only a few attempts were made to provide instructions that induce interactive *verbal* connections between the peg word and the to-be-learned item. It may be argued, therefore, that portions of the gain in recall performance attributed to the generation of visual images might be due to the general advantage of interactive connections between pegs and to-be-learned items, regardless of whether verbal or imaginal processes are involved.

An early study by Wood (1967) seems to support this contention. In Experiment 1, Groups 1 and 4 were told to use 40 peg words for the recall of a 40-item list (peg-type mnemonic). Group 1 was told to make "mental pictures" which "incorporate the response word and the peg word" (Wood, 1967, p. 3) whereas Group 4 was told to make "verbal connections" between each of the word pairs. Both groups showed high levels of recall as well as a rather flat serial position curve which can be used as an indicator of method use (cf. Roediger, 1980). Differences in recall between the two groups were not significant.

This finding challenges the necessity of visual images for reaching high levels of recall with mnemonic devices. However, a close reading of the actual instructions casts some doubts on the validity of the experimental manipulation and on the entire notion of interactive encoding without visual imagery. In the "verbal-connection instruction," subjects were told the following:

> Basically, your task is to link each answer-sheet word and each taped word by a verbal connection. . . . If you want to link the answer-sheet word *automobile* with the taped word *saltshaker,* you might construct a sentence using *saltshaker* and *automobile* as key words (e.g., *The saltshaker is on the automobile*). (Wood, 1967, p. 27)[17]

The crucial question is whether the substitution of "verbal connection" for words like "mental picture" or "visual image" prevented subjects from generating visual images, especially if both the peg words and the to-be-learned items are highly imageable. Actually, it seems farfetched to assume that subjects who formed sentences like "The saltshaker is on the automobile" did not generate visual images. Unfortunately, the study provided no additional evidence on this issue.

[17]Complete instructions are listed in Wood (1967), Appendix B.

A more direct way to examine both the use and the efficacy of different encoding operations is to ask subjects to describe the strategies which they have employed to recall lists of words and relate these self-report data to objective measures of recall performance. A number of studies administered post-learning questionnaires for this purpose. In the questionnaire, subjects were asked to indicate for each item pair the type of encoding operation that they had employed (e. g., "imagery," "verbal," "repetition," or "none").

In the case of highly imageable nouns, these studies have shown, with no exception, that the reported use of imagery is positively related to recall level (Janssen, 1976; Paivio & Yuille, 1967, 1969; Paivio, Yuille, & Smythe, 1966; Paivio, Smythe, & Yuille, 1968; Richardson, 1978, 1985; Wells, 1972). Moreover, it was found that imagery instructions increase the use of visual imagery but not its efficacy (Janssen, 1976; Richardson, 1978, 1985), and that the efficacy of visual imagery for low-imagery words is generally low. It follows that imagery instructions should have a greater effect on the recall of high-imagery words than low-imagery words. This interaction has been found in a variety of different studies (Gupton & Frincke, 1970; Janssen, 1976; Morris & Reid, 1974; Paivio & Yuille, 1967; Richardson, 1985; Yuille & Paivio, 1968).

Some studies also explored interindividual differences in the use of visual imagery in verbal learning tasks (Richardson, 1978, 1985; Wells, 1972). In these studies, interindividual differences in self-reports of visual imagery were positively correlated with interindividual differences in recall. Richardson (1978), for instance, found a correlation of $r(26) = .80$ between the reported use of visual imagery and the proportion of correctly recalled items. In a subsequent analysis, subjects were classified as high or low imagers, depending upon whether the proportion of self-reported imaginal mediators fell above or below the median. The two groups reported using imaginal mediators for 87% and 43% of the pairs, and their mean correct recall was 68.9% and 28.1%, respectively. Differences in recall performance between the two groups were highly significant.

In sum, the self-report data provide strong support for both the importance and the variability of imagery-based encoding operations in verbal learning tasks. One may challenge these results on methodological grounds, saying that many types of cognitive processes are, in principle, inaccessible to conscious recollection, and that any verbal report is based on subjective and implicit theories of the processes involved. In a recent summary of his work, Richardson (1985) defends the validity of the post-learning questionnaires:

> There are no grounds for believing that short-term retrospective judgments are not entirely valid and at least moderately accurate accounts of the use of different categories of mediators.... The use of imagery mnemonic instructions constitutes an experimental manipulation of the availability of imaginal mediators, and thus the findings of the present investigation directly implicate the use of mental imagery as a causal determinant of human memory performance. (Richardson, 1985, p. 213)

If one is willing to accept Richardson's (1985) assertions, the implication is that the generation of visual images constitutes an important, if not critical element of skill in many verbal learning tasks. There is no good reason to assume that visual imagery should play a less important role in memory functioning with mnemonic devices such as the *Method of Loci*, which, by definition, ask for the use of visual imagery (cf. Bellezza, 1981; Bower, 1969; Groninger, 1974). Thus, it appears that the attainment of high levels of memory performance with the *Method of Loci* depends upon the generation of visual images at encoding.

Spatial Visualization and Mnemonic Performance

Another source of concededly indirect evidence in favor of the relevance of interindividual differences in visual imagery for recall performance with mnemonic devices comes from the psychometric tradition. Several studies reported a positive relation between marker tests of spatial visualization and recall performance (Christiansen & Stone, 1968; DiVesta & Sunshine, 1974; Hollenberg, 1970). Other studies reported mixed (DiVesta & Ross, 1971; Kliegl, Smith, & Baltes, 1989a, 1989b) or null results (Ernest & Paivio, 1969). In the present context, two studies are especially relevant because they involved the use of the peg-word mnemonic (DiVesta & Sunshine, 1974) or the *Method of Loci* (Kliegl, Smith, & Baltes, 1989b).

In a study with college students, DiVesta and Sunshine (1974) used scores from spatial visualization tests (i.e., Flags, Space Relations, and Memory-for-Design) to define groups of high and low imagers. The two groups differed significantly in the immediate serial recall of items within each list as well as in the post-session serial recall of items from all four lists. Kliegl, Smith, and Baltes (1989b) instructed and trained 18 young adults and 19 old adults in the *Method of Loci*. In old adults, scores on a spatial orientation test (Card Rotation) administered at pretest were positively correlated with *Method-of-Loci* performance at posttest [$r(19) = .57$]; in young adults, no significant correlations were found.

The correlations observed in these studies point toward the importance of image generation for mnemonic performance, especially if one considers that the demands of the two types of measures (spatial visualization vs. mnemonic performance) do not have much in common except that both seem to involve visual imagery.[18]

Further Evidence: The Secondary-Task Paradigm

A third line of research contributing to knowledge about visual imagery in verbal learning tasks comes from studies employing a secondary-task paradigm (Baddeley & Lieberman, 1980; Logie, 1986; Steiner, Bischof, & Froeschl, 1984). In an exploratory study, Steiner, Bischof, and Froeschl (1984) investigated the effect of different types of visual distractors on good and bad imagers in paired-associate learning. Good imagers were operationally defined as having scored above the median on two imagery questionnaires. The distracting stimuli were white shapes moving on a green background. The stimuli were presented either in a central round area covering about 3.2° of the visual angle (central distractor) or on the entire screen with the exception of the central

[18]In contrast, self-ratings of the vividness of visual-imagery experiences tend to be uncorrelated with objective performance tests (Ernest, 1977; Paivio, 1986).

area (peripheral distractor). It was found that good imagers were more affected by the central distractor than by the peripheral distractor, whereas the reverse was true for bad imagers. As a possible explanation, the authors suggested that the images generated by good imagers are centrally focused. Therefore, good imagers were not distracted by information which was located at the periphery of the visual field.

Baddeley and Lieberman (1980) explored the role of imagery in verbal learning using a model of working memory comprising a central executive and two hypothetical subsystems, an articulatory loop, and a visuo-spatial scratch pad (see Baddeley & Hitch, 1974). In Experiments 3 (peg-word mnemonic) and 4 *(Method of Loci)* of their study, they examined whether the concurrent administration of a visuo-spatial task (pursuit tracking) would disrupt verbal learning aided by imagery mnemonics. In both experiments, two learning instructions, mnemonic and rote, were combined with the presence or absence of the tracking task to yield four different task conditions. In the mnemonic instructions, subjects were encouraged to generate visual images, whereas verbal rehearsal was encouraged in the case of rote learning. A significant interaction was observed between type of learning instruction and tracking in the two experiments: The tracking task interfered with the use of imagery mnemonics, but no comparable effect was found in the case of verbal rehearsal.

In Experiment 5, the procedure was identical to Experiments 3 and 4 except that subjects were asked to use a supposedly verbal rather than imaginal mnemonic which was based on the initial letters of the words to be recalled. In contrast to Experiments 3 and 4, no interaction between presence or absence of tracking and type of learning instruction was found. The authors argued that this result seems to rule out the explanation that tracking interferes with any kind of mnemonic strategy apt to increase the degree of memory organization. According to the authors, the findings seem to indicate that the disruption of verbal learning caused by tracking is specific to imagery-related processing.

In a related study, Logie (1986) put forward that the results found by Baddeley and Lieberman (1980) might also be interpreted by the notion of general-purpose resources rather than by the less parsimonious assumption of specialized subsystems of working memory. Logie (1986) tried to exclude this possibility by reducing the complexity of the interfering task. With one exception (Experiment 1), visual presentation of unattended patterns served as a secondary visual suppression task. Throughout, the disrupting effect of secondary visual processing on memory performance with the peg-word mnemonic was investigated, with rote rehearsal serving as a control. In Experiment 4, unattended speech was used as a secondary task. It was expected that unattended speech would selectively disrupt rote rehearsal, whereas the presentation of visual patterns would disrupt only memory performance with the peg-word mnemonic. The results were consistent with these predictions.

In sum, the studies by Baddeley and Lieberman (1980) and Logie (1986) provide evidence regarding both the structure of working memory and the importance of spatial and/or visual processing for the functioning of the *Method of Loci* and the peg-word mnemonic. The findings seem to support the hypothesis of two subsystems of working memory, an articulatory loop and a visuo-spatial scratch pad. However, it remains unclear whether the visuo-spatial subsystem really constitutes a unitary construct, or whether a more fine-grained analysis would lead to further differentiation (cf. Steiner, 1983).[19]

Conclusion

Three different lines of research—post-learning questionnaires, correlations with psychometric tests of spatial visualization, and experimental manipulations with the dual-task paradigm—converge upon the notion that visual imagery is an important, if not critical, element of skill in memory functioning with the *Method of Loci.* In particular, the analysis of post-learning questionnaires revealed that high levels of recall performance exhibit a strong positive relationship to the use of visual imagery at encoding (Richardson, 1978, 1985).[20] Therefore, the generation of visual images can be invoked as a guiding criterion in the selection of old expert professionals. The search should be directed towards older persons who, given their success as professionals, are likely to exhibit high levels of practice and skill in the generation of interactive visual images.

The selection of a group of older professionals with a high level of practice in visual imagery is a necessary condition for predicting transfer of professional expertise to memory functioning with the *Method of Loci.* However, it should be kept in mind that a superiority of old experts over old normal adults in memory functioning with the *Method of Loci* would be open to alternative interpretations. First, it is probable that both the *Method of Loci* and any profession with a high emphasis on visual imagery also involve other aspects of cognitive functioning. Therefore, it cannot be excluded with certainty that "identical elements" other than visual imagery would contribute to the superior performance of the old expert group.

Second, the selection of older experts from a profession with a high emphasis on visual imagery maximizes the chance to sample individuals whose "latent" visualization ability is above average. For this reason, high levels of performance with the *Method of Loci* in old experts could reflect the joint effects of professional experience (e.g., practice) and ability, rather than the effects of professional experience alone.

Choice of Criterion Group: The Profession of Graphic Design

As a result of the preceding review, it was concluded that the generation of interactive visual images on the basis of verbal material is an important, if not critical element of

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[19]In the light of recent behavioral, neuropsychological, and neurophysiological evidence, difficulties in separating spatial and visual aspects of imagery in mnemonic performance are no longer surprising. It now appears that both visual (stored memories of parts of appearances) and spatial (equivalence classes of relations among parts) aspects are necessary for the generation of an intact visual image (Farah, 1988; Kosslyn, 1987, 1988; Kosslyn, Holtzman, Farah, & Gazzaniga, 1985). Baddeley's (1983) identification of a unitary visuo-spatial subsystem of working memory may reflect this fact on a more molar level.

[20]A recent study with congenitally blind adults has provided further evidence in favor of the importance of visual imagery in memory functioning with the *Method of Loci* (DeBeni & Cornoldi, 1988). Lower recall levels for blind subjects indicated that they employed interactive imagery less effectively than sighted controls.

skill in memory performance with the *Method of Loci.* Unfortunately, interindividual differences in visual imagery are not directly indexed by overt behavior. Therefore, the selection of a profession with a high emphasis on visual imagery has to be guided by indirect evidence. As a guideline, the products of professional activity should make it highly probable that visual imagery is required for their creation.

The profession of graphic design seems to fulfill this criterion. Graphic designers working as freelance artists create posters, art catalogues, advertisements in newspapers and news magazines, as well as other kinds of pictorial representations. These pictures generally serve the purpose of drawing attention to a certain product, be it a commodity (e.g., a car, a cigarette, a household item, etc.) or another artist's work (e.g., a poster for an exhibition). Graphic designers are informed about the intended pictorial representation both verbally and visually, in part by conversations with the client. They have to integrate this information into the development of the pictorial presentation. Frequently, this process requires the creation of pictorial symbols that tie concepts and emotional states to the target product. As an illustration, a news advertisement of a cowboy smoking a certain brand of cigarette may try to convey the notion that buying this brand of cigarette has something to do with freedom and adventure.[21]

The fact that graphic designers create pictures with the purpose of promoting products has an important practical consequence. It implies that these pictures need to be both discriminable (salient) and memorable in order to optimize the promotion of the product (Six, 1983). Thus, professional expertise in graphic design, as described here, is assumed to require a rich experience with the generation of discriminable pictorial material.[22]

AGING AND VISUAL MEMORY

Overview

In the previous section of the literature review, it was shown that memory functioning with the *Method of Loci* centrally involves the generation of visual images. As a consequence, age differences in mnemonic performance should be viewed in the more general context of age-related changes in visual memory performance. The present section gives a brief summary of relevant research about visual memory in old age.

Two important differences between the present approach and other approaches to the aging of visual memory should be mentioned at the outset. First, similar to other domains of cognition, past age-comparative research on visual memory has limited itself, for the most part, to the "normal range of functioning" (Baltes, 1987). With the exception of the work reported earlier by Kliegl, Baltes, and colleagues, no attempts

[21]Some authors have provided descriptions of the semiotic structure of advertisements (Barthes, 1957; Eco, 1984).

[22]Details regarding the recruitment of old expert graphic designers and a validation of their professional expertise are reported below (pp. 66–70).

were made to assess age-related differences in visual memory after optimized instructions and extensive training, that is, near limits of performance. Thus, the work presented below primarily addresses age differences at baseline. The second difference to past research concerns the use of imagery-based peg-word mnemonics as a means of alleviating the memory problems of older adults. Employing the *Method of Loci* as a diagnostic of cognitive plasticity, as is intended in the following research, does not entail any commitment regarding its appropriateness as a memory aid.

The following presentation is organized into two units: (a) a summary of age-comparative work on visual memory, with an emphasis on the question of whether aging-related decline in visual memory is steeper than in verbally mediated forms of memory performance, and (b) a brief report about the use of peg-word mnemonics in gerontological intervention work.

Visual Memory in Old Age

Age differences in visual memory during the adult life span have been studied under a variety of task conditions such as paired-associate learning with imagery instructions, incidental recognition, and memory for pictures. A major theoretical motivation for this research was the hypothesis that age-related decrements in visual processing, and visual memory in particular, are more pronounced than decrements in verbal forms of processing (Hulicka & Grossman, 1967; Mason & Smith, 1977).

As suggested by Winograd and Simon (1980), this hypothesis can be phrased as a developmental extension of dual-coding theory (Paivio, 1971, 1986; von Eye & Dixon, 1984). In this theory, the general assumption is made that there are two classes of phenomena handled cognitively by separate subsystems, one specializing in the representation and processing of information concerning nonverbal objects and events (imagery subsystem) and the other specializing in the representation and information processing of language (verbal subsystem). The developmental extension of Paivio's dual-coding theory states that the imagery system shows a more pronounced decline in old age than the verbal system (cf. Winograd & Simon, 1980). In such a case, older adults' performance should be especially compromised by tasks that afford visual processing.

At first glance, evidence from the verbal learning literature seems to support this contention. Numerous verbal learning studies reported that older adults experienced greater difficulties than young adults in the spontaneous use of visual imagery for the retention of verbal material (Canestrari, 1968; Hulicka, 1965, 1966, cited in Canestrari, 1968; Hulicka & Grossman, 1967; Rowe & Schnore, 1971). Following Hulicka's observation that older adults often experienced the word pairs as being too odd to form a visual connection (Hulicka, 1966, cited in Canestrari, 1968), later studies examined the effect of more explicit and detailed instructions such as connecting phrases (Canestrari, 1968; Poon & Walsh-Sweeney, 1981), specific suggestions for visual images provided by the experimenter (Treat, Poon, & Fozard, 1981; Treat & Reese, 1976), imagery pretraining (Yesavage & Rose, 1983), and long anticipation intervals (Treat & Reese, 1976). Generally, these facilitative task manipulations reduced the age difference (Canestrari, 1968; Poon & Walsh-Sweeney, 1981; Treat & Reese, 1976; for a review, see also Bäckman, Mäntylä, & Herlitz, in press), although ceiling effects in the young sometimes precluded a meaningful interpretation of the age-by-treatment interaction (Treat, Poon, & Fozard, 1981).

In sum, although it appeared that older adults were less efficient in the spontaneous use of visual imagery, they were able at the same time to profit from prestructured task conditions which facilitate its use (Yesavage & Rose, 1983). It may be argued that this situation is not clearly explained by the hypothesis of a disproportionately large age decrement in visual memory. As an alternative account, it may be said that visual memory tasks, like other cognitive tasks, differ in the demands they place on general-purpose processing resources (Craik, 1983; Hasher & Zacks, 1979). The notion of resource demands refers to a common metric of cognitive difficulty (complexity) that is not tied to specific forms of processing. More demanding tasks are generally associated with larger age differences in performance (Craik, 1983; Salthouse, 1988a).

From a resource perspective, large age differences in paired-associate learning with imagery instructions would indicate that performance in this type of task is highly demanding (e.g., resource-dependent). Moreover, the reduction of age differences through experimenter-provided visual images and other forms of contextual support would be consistent with the expectation that age differences are less pronounced in the presence of task conditions which have the effect of lowering the resource demands of the original task (e.g., compensatory task conditions; cf. Bäckman, 1985; Bäckman, Mäntylä, & Herlitz, in press). To give an example, subjects who are told by the experimenter how to visualize a given set of paired associates do not have to invest their resources to find a visual image that integrates the information of the two items into a single unit.

If the magnitude of age differences in visual memory tasks turned out to be predictable as a function of resource demands, the idea of a more pronounced age-related decrement in the "visual code," as opposed to the "verbal code," would be less convincing. Two specific predictions can be made in this regard. First, verbal memory tasks demanding a high level of resources should produce as large an age difference as visual memory tasks having demand characteristics of similar magnitude. Second, the decline in visual memory performance with age should be small when task demands are low.

Relevant research has been carried out with respect to both predictions. Regarding the first, some age-comparative studies provided verbal and visual task conditions of comparable difficulty within the same experiment (cf. Bäckman, Mäntylä, & Herlitz, in press). For instance, Eysenck (1974) examined the effects of age and different types of orienting tasks on the incidental recall of a word list. There were four different orienting tasks. Two of them were meant to induce processing at a "surface" level (letter counting and rhyming); in the other two, subjects were instructed to process the meaning of words either by finding suitable modifying adjectives or by forming visual images. Analysis of the free-recall data showed that the semantic processing tasks (i.e., adjective and imagery) led to much higher levels of recall in both young and old adults than the nonsemantic orienting tasks. An age interaction indicated a more pronounced difference in young subjects. However, no age interaction was found within the two semantic orienting tasks: The two groups showed a parallel (nonsignificant) tendency to perform better with imagery instructions. This result does not support the hypothesis of a specific deficit in visual memory among older adults.

The second line of evidence concerns memory for pictures and words. Presenting pictures, rather than asking subjects to visualize words, should reduce the resource demands of visual memory. In young adults, recall ratios in favor of pictures over words in the proximity of 2 to 1 were observed (Paivio & Csapo, 1973). As proposed by Winograd and Simon (1980), testing the maintenance of this picture superiority effect in old age would be a valid strategy to examine the existence of a particularly strong aging loss in visual (as opposed to verbal) memory:

> We proposed to compare recall for lists of pictures and words between an aged sample and a younger control group. The question was whether a picture superiority would be found among the aged at all, and if so, would it be less than among the young. What if the elderly show no picture superiority at all in recall and the younger subjects do? Such an interaction would be consistent with a deficiency hypothesis that assumes the absence of, or failure to retrieve, visual codes. . . . Most aging research can be summarized by the following generalization: The more difficult the task, the poorer the performance of older relative to younger subjects. In this experiment, the opposite is expected, namely, a greater disadvantage for the older subjects when the memory task is easier, as it is with remembering pictures. (Winograd & Simon, 1980, pp. 491–492)

To date, several studies on memory for pictures in old age have been conducted (Keitz & Gounard, 1976; Park, Puglisi, & Smith, 1986; Park, Puglisi, & Sovacool, 1983, 1984; Pezdek, 1987; Rissenberg & Glanzer, 1986; Winograd & Simon, 1980; Winograd, Smith, & Simon, 1982). In these studies, it was found that the retention of pictures remains superior over the retention of words in healthy older adults (Keitz & Gounard, 1976; Park, Puglisi, & Sovacool, 1983; Rissenberg & Glanzer, 1986, Experiment 2; Winograd, Smith, & Simon, 1982, Experiments 2 and 3; for opposing results, see Rissenberg & Glanzer, 1986, Experiment 1; Winograd, Smith, & Simon, 1982, Experiment 1).

In this context, a recent study is especially noteworthy (Park, Puglisi, & Smith, 1986). The authors reported a complete absence of age differences in recognition memory performance for pictures of meaningful and complex real-world scenes. The age effect was absent even when subjects had to study the pictures under divided attention conditions (Experiment 3). The article concludes that "the present studies present an unusually optimistic view of age-related memory changes with respect to complex, meaningful pictures. In healthy, well-educated older adults, decline in this type of memory appears to be limited. The present series of studies, in fact, provide little experimental evidence for the presence of any real decline" (p. 16). It should be noted that age differences in recognition memory were observed for schematic drawings (Winograd, Smith, & Simon, 1982) or geometric designs (Arenberg, 1978).[23] Again, this pattern of results is well explained by the notion of differential resource demands if one assumes that less self-initiated processing is required to memorize a real-world scene than to memorize more abstract pictorial material.

To summarize, it does not seem justified to assume that visual memory undergoes a more pronounced decline with age than verbal memory. More demanding visual

[23]Age-comparative research on memory for faces is not reported here (cf. Ferris, Crook, Clark, McCarthy, & Rae, 1980; Yesavage, Rose, & Bower, 1983).

memory tasks show larger age differences, and easier tasks, such as picture recognition, show smaller age differences. When verbal and visual memory tasks are about equally demanding, age differences of about the same magnitude are observed.

Imagery and Mnemonic Aids

One general strategy of gerontological and life-span research has been to examine whether aging losses obtained descriptively are modifiable by intervention programs (Baltes, Reese, & Lipsitt, 1980). Thus, it is not surprising that gerontologists have begun to teach older individuals the use of mnemonic devices in order to alleviate the memory problems they encounter in their daily lives (Greenberg & Powers, 1987; Scogin & Bienias, 1988; Scogin, Storandt, & Lott, 1985; Treat, Poon, Fozard, & Popkin, 1978; Wippich, 1984). Both the peg-word mnemonic (Hellebusch, 1976; Mason & Smith, 1977) and the *Method of Loci* were employed (Anschutz, Camp, Markley, & Kramer, 1985; Heineken & Gekeler, 1985; Robertson-Tchabo, Hausman, & Arenberg, 1976; Rose & Yesavage, 1983; Yesavage & Rose, 1984).

A study by Rose and Yesavage (1983) may serve as an illustration of the general approach. In the study, the effectiveness of memory training with the *Method of Loci* was assessed in young, middle-aged, and older adults. Three group training sessions of 2.5 hours' duration each were used to teach the method. As part of their training, subjects practiced the mnemonic with several lists distinct from those used at pre- and posttest. Subjects in all groups significantly improved their performance. An age-by-practice interaction was found in that young adults showed the greatest amount of improvement whereas old adults showed the least amount of improvement. According to an explanation offered by the authors, "[i]t is possible that the widening gap in recall found after training in the mnemonic might be due to age differences in the ability to generate and retrieve visual images" (Rose & Yesavage, 1983, p. 296). At the same time, the authors retained that the *Method of Loci* "could potentially help elderly adults to function more effectively in natural settings" (p. 297).

When comparing the body of research on age differences in paired-associate learning with the findings from recent training programs with the *Method of Loci,* a discrepancy can be observed. On the one hand, all available mnemonic training studies with young and old adults led to a *magnification* of age differences in serial word recall as compared to age differences under standard (pretraining) task conditions (Baltes & Kliegl, 1989; Kliegl & Lindenberger, 1989; Kliegl, Smith, & Baltes, 1989a, 1989b; Mason & Smith 1977; Rose & Yesavage, 1983; Thompson & Kliegl, 1989). On the other hand, other age-comparative studies on visual memory often reported a *reduction* of age differences as a consequence of instructions or other task modifications (for a review, see Bäckman, Mäntylä, & Herlitz, in press).

The apparent conflict between magnification and reduction of age differences disappears if one recognizes that the task conditions differed in processing demands. Some task conditions used in verbal learning research externalized (prestructured) processes that were under the subject's effortful control in the standard task situation.

Experimenter-provided "connecting phrases" are a good example of this type of modification because subjects do not have to search for an interactive relationship between noun pairs. In such cases, the resulting decrease in processing demands will result in a reduction of age differences. The situation is different with the *Method of Loci*. Here, the effectiveness or helpfulness of the instructions directly depends on the amount of self-initiated processing. Utilization of the technique is based on the generation of interactive visual images, and no suggestions regarding the content of these images are made by the experimenter. Thus, mnemonic instructions with the *Method of Loci* differ from the provision of compensatory task conditions because the experimenter does not prestructure the content of thought and visualization.

Opinions vary as to whether evidence argues against the usefulness of imagery-based mnemonics for the functioning of everyday memory (Cermak, 1980; Poon, Walsh-Sweeney, & Fozard, 1980; Winograd & Simon, 1980). In some studies, the difference in performance between the experimental and the same-age control group was insignificant or not very impressive (Robertson-Tchabo, Hausman, & Arenberg, 1976, Experiment 2). When assessed, maintenance of the skill on later occasions tended to be rather low (Anschutz, Camp, Markley, & Kramer, 1985; Robertson-Tchabo, Hausman, & Arenberg, 1976). Poon, Walsh-Sweeney, and Fozard (1980) noted that imagery mnemonics may be beneficial in memory intervention programs for old adults but that more needs to be known about imagery, memory tasks suited for imagery, and conditions that facilitate learning and retrieval. Winograd and Simon (1980) were more skeptical about the usefulness of imagery mnemonics, stressing the importance of individual differences in preferred modes of information processing, and urging that "research on memory skill training employ broader techniques than the traditional imagery device" (Winograd & Simon, p. 504). Finally, Cermak (1980) chose "to sound an empty note into this arena of illusions and propose that imagery might best have remained relegated to its place in history" (Cermak, 1980, p. 507).

The diverging opinions regarding the usefulness of the *Method of Loci* in gerontological intervention work may be due in part to differences in theoretical perspective. If the goal is to provide older adults with a mnemonic device which is directly applicable to the situations of daily living, less demanding mnemonic devices with a stronger compensatory effect are probably more appropriate. *External memory aids*, such as writing shopping lists, taking notes, writing out a plan for the day, and keeping a diary, may be especially helpful (Cermak, 1980; Harris, 1980; Weinert, 1983).[24]

The situation is different if the primary goal of the intervention is not to provide older individuals with a specific memory aid but to change their cognitive ability (competence) in the domain of imagery-based memory functioning.[25] In that case, instruction and training with the *Method of Loci* would serve the purpose of modifying

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[24]As Schönpflug (1986a, 1986b, 1987) has noted, external memory aids would be helpful if the costs of the acquisition of sufficient internal knowledge about the externally stored information do not exceed the gains associated with external storage itself. Using the same external memory aid over a long period of time would be one way to minimize costs.

[25]See also Overton (1985) for a discussion of the distinction between competence and performance.

an underlying latent construct, and it would be possible that other imagery-based memory activities, perhaps including those involved in daily living, were positively affected by mnemonic training.

The latter research strategy would be similar to intervention programs that were conducted in the domain of fluid intelligence (for a review, cf. Baltes & Lindenberger, 1988). In those studies, transfer of training was observed, but the scope of transfer was in most cases fairly narrow (i.e., restricted to the specific subabilities that were trained). More training research in the domain of memory functioning with the provision of appropriate transfer tasks needs to be conducted to investigate the modifiability of memory ability in older adults. Training programs with the *Method of Loci* may play a major role in this research effort.

STATEMENT OF PROBLEM

Current research in life-span cognitive development is characterized by the joint recognition of continued plasticity (learning potential) and limits of plasticity in old age (Baltes, 1987; Uttal & Perlmutter, 1989). On the one hand, older adults demonstrate evidence for substantial cognitive reserves, even in areas such as memory and inductive reasoning where one typically expects marked aging loss (Baltes & Lindenberger, 1988). On the other hand, when adults of different ages are tested to investigate maximum levels of performance, the evidence points to larger age differences than are observed in the normal range of functioning (Kliegl, Smith, & Baltes, 1989a, 1989b). Thus, although cognitive plasticity is preserved among healthy older adults, there is evidence in favor of an age-related reduction of plasticity near limits of functioning.

The main hypothesis guiding the present investigation is that professional expertise attenuates, rather than eliminates, age-related losses in cognitive plasticity. Specifically, it is hypothesized that expert professionals in the field of graphic design possess a larger amount of developmental reserve capacity (maximum learning potential) in imagery-based memory functioning with the *Method of Loci* than old normal adults of comparable general intelligence, but that they have a smaller amount of developmental reserve capacity in this domain than young adults.

This main hypothesis is derived from the following argument. The process of visual image generation is identified as an important, if not critical, element of skill in memory performance with the *Method of Loci.* Graphic design is viewed as a profession which requires high levels of practice in visual image generation as a precondition for attaining expert levels of performance. Therefore, it is assumed that old expert graphic designers have acquired specialized knowledge in visual image generation, and that this knowledge is applicable to the visual image generation component of the *Method of Loci.* This transfer of professional expertise is predicted to expand the range of mnemonic reserve capacity in old expert graphic designers beyond the range that is normally available to healthy older adults. At the same time, professional expertise is not expected to overcome the reduction of developmental reserve capacity associated with aging. Therefore, old graphic designers are expected to reach higher levels of mnemonic skill than old normal adults, but lower levels of mnemonic skill than young adults.[26]

Specialized knowledge in visual image generation can develop and function in several ways. For example, it can enhance professional performance or, through continued practice, prevent otherwise occurring aging losses. Parts of this knowledge may also evolve as a compensatory reaction to age decrements in expertise-related component processes. The present work does not allow for an empirical dissociation of these different subprocesses of aging-experience relationships (cf. Baltes & Baltes, in press; Salthouse, 1987; Uttal & Perlmutter, 1989). Rather, the assumption is that these subprocesses jointly contribute to the specialized imagery-related knowledge of old expert graphic designers.

By investigating the effects of professional expertise on skilled memory performance in old age, the present work is part of the longstanding effort in life-span and gerontological research to determine the effects of experience on age differences in cognitive functioning and the relationship between aging and experience in general (Baltes, 1973; Salthouse, 1987). Two opposing views on this issue can be discerned. Some authors argue that the greater amount of cumulative experience associated with age probably results in an underestimation of losses in cognitive abilities associated with aging (Salthouse, 1985). In contrast, others argue that age differences in cross-sectional cognitive research may lead to an overestimation of aging loss because the life ecologies of older adults provide less opportunity for mental activity than the life ecologies of younger adults (Brozek, 1951). Whereas the first view emphasizes the accumulation of experience over the life span, the second view, also termed the "disuse hypothesis," stresses the importance of current environmental contingencies in producing intelligent behavior (Labouvie, 1973).

To clarify the relationship between aging and experience, research has evolved in different directions. Cognitive intervention programs have aimed at exploring the degree to which cognitive aging is modifiable as a function of experiential life conditions (Baltes & Willis, 1982; Denney, 1979; Willis, 1987). These intervention studies have shown that healthy older adults possess the capacity to improve their performance in tests of intelligence and other indicators of cognitive efficacy. Improvement has been observed as a result of both self-guided learning and tutor-guided training in cognitive skills (Baltes, Sowarka, & Kliegl, 1989).

Studies on professional expertise have added mixed evidence to this picture of intellectual plasticity in old age. On the one hand, age differences in occupational performance tend to be less pronounced among experts than among novices (Salthouse, 1987; Waldman & Avolio, 1986); moreover, experimental analyses of real-life skills, such as typing, chess, and bridge, suggest that older adults are able to develop or refine elements of skill as a compensatory reaction to age decrements in basic cognitive

[26]The hypothesis that loss of mnemonic reserve capacity is attenuated in old expert graphic designers can also be based on ability rather than expertise. According to this alternative or complementary view, drawing a sample from the population of old graphic design experts maximizes the chance of selecting individuals whose "latent" abilities in imagery-related domains of cognition are above the average of the general population.

processes (Charness, 1981; Salthouse, 1984). On the other hand, more recent experimental evidence on aging and expertise suggests that the influence of age-related factors on certain aspects of cognitive functioning, such as spatial visualization, may be relatively independent of experience (Salthouse, Babcock, Skovronek, Mitchell, & Palmon, 1989).

Finally, substantial differences in the amount of aging loss have been found as a function of educational background, current cognitive activity level, and physical exercise. The results of these studies demonstrated the necessity to examine more than one group of older people, and more than one group of younger people, in order to obtain a more complete picture of cognitive changes with age (Craik, Byrd, & Swanson, 1987).

Taken together, the evidence from different lines of research indicates that current or cumulative experience often is a more important determinant of cognitive performance than age. This has led some researchers to estimate how much practice on a task is needed to bring the performance of older adults to the level of untrained younger adults (Baltes & Willis, 1982; Charness, 1989). As Salthouse (1985) noted, the "point of this exercise is not necessarily to suggest that the same mechanisms are involved in the two types of behavioral change, but rather to indicate the small size of the age effects relative to the amount of change induced by increased experience" (p. 89).

The main difference between the present work and most prior research on aging and experience, however, is the intent to focus on performance near maximum levels of functioning. Most of the present evidence on aging and experience is restricted to the normal range of functioning (baseline level of performance) or to the upper range of functioning at a given point in time (baseline reserve capacity). Under these conditions, interindividual differences in task-related experience, preexperimental knowledge, and task-specific abilities may well be better predictors of performance than interindividual differences in chronological age. The situation is expected to differ with respect to interindividual differences in maximum learning potential (developmental reserve capacity). If normal aging is primarily associated with a reduction in the amount of developmental reserve capacity, chronological age is expected to become an increasingly better predictor of performance as individuals approach their limits of functioning.

The instruction and training of mnemonic skill is regarded as a tool to uncover interindividual differences in developmental reserve capacity in the domain of imagery-based memory performance (Kliegl & Baltes, 1987). In recent age-comparative training studies with the *Method of Loci,* minimal amounts of overlap in performance between age groups were found. These results were consistent with the present view of an age-related decline in the "mechanics" (or broad fluid aspects) of cognition and can be interpreted as a manifestation of neurophysiological limits of the aging brain (cf. Kliegl, Smith, & Baltes, 1989a).

PART III: EMPIRICAL INVESTIGATION

OVERVIEW OF STUDY

Three groups of subjects participated in the study: old graphic design experts, old normal adults, and young adults. Table 3 provides an overview of the empirical investigation, listing the content, topic, and predictions covered by each of the 28 sessions of the experiment.

Psychometric testing took place in Sessions 1 and 2. Here, the goal was to validate the professional expertise of old graphic designers, to match subject groups on indicators of general intelligence and short-term memory, and to measure abilities that were conceived as potential predictors of mnemonic performance. Specifically, the professional expertise of old graphic designers was validated with a test of visual creativity, and the two groups of old adults were matched on measures of fluid intelligence (Digit Symbol Substitution), crystallized intelligence (Vocabulary), and short-term memory (Digit Span). A comprehensive description of the recruitment process and of subject characteristics is provided below (pp. 64–70).

Memory performance with the *Method of Loci* was distributed over a total of 21 sessions. These sessions were subdivided into a 7-session Training Phase (Sessions 6–12) and a 14-session Test Phase (Sessions 13–25). Five lists of nouns were administered in each session, totaling 35 trials for the Training Phase and 70 trials for the Test Phase. The decision to have a relatively small number of training sessions followed by extensive testing was based on the results of previous studies. In these studies, most of the improvement in serial recall occurred immediately after mnemonic instruction or in the first few sessions of mnemonic training. Moreover, interindividual differences in serial recall stabilized soon after mnemonic instructions (Kliegl, Smith, & Baltes, 1989b).

During the Training Phase (Sessions 6–12), task difficulty was kept at a relatively low level to facilitate memory functioning with the *Method of Loci.* During the Test Phase (Sessions 13–26), average task difficulty was increased on a number of different dimensions, including presentation rate, list length, imageability, and within-list discriminability. This was done in order to obtain reliable estimates of interindividual differences in cued serial recall with the *Method of Loci* (e.g., testing-the-limits of mnemonic skill). Some task variations also were relevant in determining group differences at the processual level of analysis. For example, lists with similar and dissimilar nouns were administered to investigate the existence of group differences in the discriminability of visual images, and a list of two-digit numbers was administered to disable the visual image generation component of the *Method of Loci.*

Table 3
Overview of Study

Session	Content	Purpose	Predictions
1–2	Psychometric assessment	Validation of professional expertise	
		Matching of subject groups	
		Predictors of mnemonic skill	9 10 11
3–5	Incidental memory task[a]		
6–26	Training program with the *Method of Loci*		
6–12	Training Phase	Gain in cued serial recall (Training Phase)	1
13–25	Test Phase	Group differences in cued serial recall	2 3
		Processual analyses of group differences	5 6 7a 7b 8
		Gain in cued serial recall (Test Phase)	4
27	Psychometric assessment[a]		
28	Drawing session	Exploration of sources of group differences in mnemonic skill	

[a]Not related to dissertation.

Throughout the entire experiment, a total number of eleven different lists was presented. Lists were shown repeatedly across sessions, but the same list did not appear more than once in a given session. To avoid repetition effects, it was ensured that a given landmark–noun combination was never presented more than once to a given subject for the entire duration of the experiment.[1]

In a certain number of cases, subjects were asked to remember and verbalize the "thoughts or images" they had formed at encoding. These verbalizations were recorded on tape. In the last session of the experiment (Session 28), subjects listened to their own verbal protocols and were asked to provide a small number of pictorial representations of their visual images.[2]

RESEARCH PREDICTIONS

Research predictions were subdivided into three sets (see also Table 4). The first set (Predictions 1–4) referred to group differences in cued serial recall with the *Method of Loci.* The second set of predictions (5–8) specified expected group differences at the level of processual analyses. Finally, the third set of predictions (9–11) explored the relationship between mnemonic skill, cognitive abilities, and chronological age. Predictions pertaining to each of the three sets are described below.

[1]For procedural details, see the Method section, pp. 72–75.
[2]Verbal protocols and drawings are available upon request.

Table 4
Overview of Research Predictions

Group Differences in Mnemonic Skill

1 Subjects in all groups will improve their level of cued serial recall during the Training Phase, documenting the existence of cognitive plasticity (learning potential) in both young and old adults.

2 Due to transfer of professional expertise and/or task-relevant ability in visual image generation, old graphic designers will reach higher levels of mnemonic skill than old normal adults.

3 As a consequence of the age-related reduction in developmental reserve capacity (maximum learning potential), young adults will reach higher levels of mnemonic skill than old graphic designers.

4 Individuals in the three groups will show stable levels of performance during the Test Phase, indicating that they have approximated their functional limits.

Processual Analyses of Group Differences

5 Group differences in recall performance will be maximized at levels of difficulty that still allow most subjects in one group to use the *Method of Loci* but disrupt mnemonic functioning in most subjects belonging to the other group.

6 Decrements in the level of cued serial recall will be accompanied by an increase in primacy effects, indicating a shift in processing away from the *Method of Loci* to other forms of encoding (e.g., verbal rehearsal, retention of visual images in working memory).

7a Lists of similar nouns will lead to a higher number of confusion errors than lists of dissimilar nouns. At equal levels of correct recall, this effect of within-list similarity will be most pronounced in old normal adults and least pronounced in young adults, reflecting group differences in the discriminability of visual images.

7b At equal levels of correct recall, old graphic designers will commit fewer confusion errors (i.e., nouns recalled at a wrong location) than old normal adults and more confusion errors than young adults.

8 When confronted with material that cannot be visualized in the context of city landmarks such as two-digit numbers, old graphic designers and old normal adults will show equally low levels of recall performance because the advantage of old graphic designers is confined to visual imagery.

Predictors of Mnemonic Skill

9 Spatial visualization, operationally defined as the composite of two psychometric tests (Card Rotation and Surface Development), will be highly predictive of interindividual differences in mnemonic skill because both tasks assess the ability to visualize and transform two- and three-dimensional objects.

10 The approximation of functional limits in the course of the experiment will uncover "novel" age-related variance (i.e., variance not explained by psychometric tests of intellectual functioning at baseline).

11 Group differences in mnemonic skill between old normal adults and old graphic designers will disappear when the best available index of professional expertise in graphic design, the "Parallel Lines" subtest of the Torrance, is introduced as a covariate.

Group Differences in Mnemonic Skill

In this category, group differences in the level of cued serial recall with the *Method of Loci* were addressed. Prediction 1 was related to the Training Phase of the experiment. Besides documenting the existence of cognitive plasticity in young and old research participants, the predicted increase in recall performance in all three groups constituted a validity check on the effectiveness of the training schedule. Predictions 2 and 3 applied to the Test Phase of the experiment. Taken together, they reflected the main hypothesis of the present study: that professional expertise in graphic design would attenuate, rather than eliminate, age-related differences in mnemonic skill. Prediction 4 investigated whether research participants had reached their maximum levels of mnemonic skill in Session 13 or whether performance continued to improve during the Test Phase.

Prediction 1: It was predicted that subjects in all groups would profit from mnemonic training as evidenced by a significant increase in recall performance during the Training Phase of the experiment. This increase was assumed to reflect the existence of learning potential, or cognitive plasticity, in all three groups.

Prediction 2: It was predicted that old graphic designers would reach higher levels of mnemonic skill than old normal adults. The generation of interactive visual images was regarded as a central element of professional expertise in graphic design. This element was assumed to be equally important in cued serial recall with the *Method of Loci.* Given that old graphic designers and old normal adults did not differ in chronological age and had been matched on indicators of fluid intelligence, crystallized intelligence, and short-term memory, the transfer of professional expertise in graphic design was expected to result in a superiority of old graphic designers over old normal adults.

Prediction 3: It was predicted that young adults would reach higher levels of mnemonic skill than old graphic designers. This prediction was based on the theoretical assumption that normal aging is associated with a reduction of maximum learning potential (developmental reserve capacity). Therefore, it was expected that task-relevant, pre-experimental knowledge in the form of professional expertise as well as task-relevant ability differences would not be sufficient to eliminate the effect of chronological age.

Prediction 4: Although such an outcome was unlikely because of the brevity of the training program, it was predicted that individuals in the three groups would show stable (i.e., asymptotic) levels of performance during the Test Phase. This outcome, which was tested by comparing mnemonic performance at the beginning and the end of the Test Phase, would signify that individuals probably have approximated maximum levels of performance (i.e., their functional limits of mnemonic skill).

Processual Analyses of Group Differences

The aim of Predictions 5 to 8 was to provide a more fine-grained picture of important aspects of memory performance and to relate group differences in recall level to differences in processing characteristics. Predictions 5 and 6 investigated variations in processing as a function of group and task difficulty. Predictions 7a and 7b focused on the possible existence of group differences in the discriminability of visual images. Finally, the goal of Prediction 8 was to provide a direct test of the hypothesis that the superiority of old graphic designers over old normal subjects was confined to the visual image generation component of the *Method of Loci.*

Prediction 5: It was predicted that group differences in recall performance would be maximized at levels of difficulty that still allowed most subjects in one group to use the *Method of Loci* but disrupted mnemonic functioning in most subjects belonging to the other group. As a consequence of the transitive relationship between Predictions 2 and 3, this maximization of group differences was expected to occur at a lower level of task difficulty with respect to old normal adults and old graphic designers, and at a higher level of task difficulty with respect to old graphic designers and young adults.

Prediction 6: It was predicted that decrements in cued serial recall would be associated with an increase in primacy effects. This increase would reflect the prevalence of encoding strategies which selectively increase the recall probability for early item information (e. g., verbal rehearsal or prolonged retention of the first few visual images in working memory). In contrast, memory performance with the *Method of Loci* was expected to be accompanied by a relatively flat serial position curve, indicating an equally high probability of visual image generation for all segments of the landmark sequence.

Prediction 7a: It was predicted that lists with similar nouns would lead to a higher number of confusion errors than lists with dissimilar nouns. This similarity effect was assumed to interact with group. At equal levels of correct recall, the increase in confusion errors was expected to be most pronounced in old normal adults and least pronounced in young adults.

Prediction 7b: It was predicted that the three groups would reliably differ in the number of within-list confusion errors, that is, in the number of nouns recalled at a wrong location. At equal levels of correct recall, old graphic designers were expected to commit a lower number of confusion errors than old normal adults and a higher number of confusion errors than young adults.

Predictions 7a and 7b were based on two assumptions. First, the discriminability (distinctiveness) of information was expected to decrease with age (cf. Craik & Byrd, 1982). Second, it was assumed that old graphic designers would possess factual and procedural knowledge related to operations that enhance the discriminability of visual or pictorial representations (e. g., adding specific details, varying color, size, and shape of visual images, etc.). Therefore, the professional expertise of old graphic designers was expected to attenuate age-related decrements in discriminability.[3]

Prediction 8: It was predicted that old graphic designers and old normal adults would show equally low levels of recall performance when confronted with material

[3]Discriminability was not considered as the main source of group differences in cued serial recall. Instead, it was regarded as an additional (secondary) dimension of mnemonic skill. Therefore, groups were matched on correct recall before analyzing group differences in confusion errors. This was achieved by selecting trials with different presentation rates.

that cannot be visualized in the context of city landmarks such as two-digit numbers. This prediction was based on the assumption that the advantage of old graphic designers over old normal adults would be restricted to the visual image generation component of the *Method of Loci.* A disruption of this component by the presentation of inadequate material such as digits was expected to eliminate the advantage of old graphic designers over old normal adults.

Predictors of Mnemonic Skill

The predictions falling under this category investigated the relationship between psychometric marker variables, chronological age, and mnemonic skill. Taken together, they served the purpose of obtaining a more complete understanding of the importance of different subject characteristics (e. g., spatial visualization ability, visual creativity, mental speed, chronological age) in predicting interindividual differences in mnemonic skill. Specifically, Prediction 9 addressed the relationship between objective measures of spatial visualization and mnemonic skill, Prediction 10 explored whether novel age-related variance (i. e., variance not explained by other variables) appeared in the course of the experiment, and Prediction 11 was a further test of the hypothesis that the professional expertise of old graphic designers would be the major source of differences in mnemonic skill between old graphic designers and old normal subjects.

Prediction 9: It was predicted that spatial visualization, operationally defined as the composite of two psychometric markers, Card Rotation and Surface Development, would be highly predictive of interindividual differences in cued serial recall with the *Method of Loci.* Performance in these tests presumably requires the ability to generate and transform visual representations of two- or three-dimensional objects under time constraints. It was assumed that the generation of interactive visual images with the *Method of Loci* would require the same kind of ability.

Prediction 10: It was predicted that age group would account for an increasingly large portion of the variance not accounted for by initial individual differences in cognitive abilities. This would be consistent with the assumption that the importance of chronological age in predicting interindividual differences in mnemonic skill increases as individuals approach maximum levels of performance (functional limits).

Prediction 11: It was predicted that group differences in mnemonic skill between old normal adults and old graphic designers would no longer be significant when the "Parallel Lines" visual creativity test (Torrance, 1966a) is entered as a covariate. The "Parallel Lines" subtest was regarded as the best estimate of professional expertise in graphic design. Therefore, controlling for expertise differences on this measure was expected to account for group differences in cued serial recall.

SUBJECTS

Six old graphic designers (age range: 64–81; $x = 69.9$ years), six normal older adults (age range: 64–80; $x = 70.5$ years), three young graphic design students (age range: 22–24; $x = 23.4$ years), and three normal young students (age range: 22–23; $x = 22.5$

years) participated in the experiment. In the following analyses, the six young subjects were treated as a single group ($x = 22.9$ years).[4]

There was an equal number of males and females in each of the three groups. Except for two old graphic designers and two old normal subjects, all research participants had completed approximately 13 years of schooling *(Abitur)*. The remaining four subjects had completed nine years of schooling *(Mittlere Reife)*. All subjects reported to be in good health. The older adults (both graphic design experts and normal) had lived in Berlin for more than 30 years. Old graphic designers had practiced their profession for over 35 years. Normal old adults had worked as civil servants or had been employees in the private sector.

Young subjects had spent at least the last three years of their life in Berlin. At the time of testing, all young subjects were undergraduates at Berlin universities. Those not specializing in graphic design were studying at the Free University of Berlin, one in the field of law and two in medicine.

Recruitment Process

Old normal adults were recruited by means of an advertisement in a local newspaper. Graphic design students were recruited by announcements in art schools in Berlin. The other young participants were recruited by personal contact.[5]

With respect to old graphic designers, the recruitment process was more complex. First, the dean of the graphic design department at the Berlin School of Arts *(Hochschule der Künste Berlin)* was informed about the study and was asked to help in locating old graphic designers. He provided a listing of all graphic designers who were members of the Berlin section of the German Graphic Design Association *(Bund Deutscher Grafik-Designer Gruppe Berlin e.V.)*, marking the names of those members who, according to his knowledge, were beyond 65 years of age. Based on this information, 18 letters asking for participation in the study were sent out. Four individuals chose to participate in the study as a consequence of this letter. The remaining 14 old graphic designers did not partake in the recruitment process for one of the following reasons: no interest (4); too young (2); ill health or death (4); change of address (i.e., no contact established) (3); poor knowledge of German (1). The four positive respondents provided names of other graphic designers who had not been included in the first round of letters. The first two of these individuals were willing to participate in the study.

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[4] It is planned to extend the present study to obtain a two-by-two matrix based on age and specialization in graphic design, with an equal number of subjects in each cell. The extension will help to separate effects of aging, professional expertise, and expertise-extraneous ability differences. In all analyses reported below, young adults were treated as a single group. Therefore, data were not presented separately for young normal adults ($N = 3$) and young graphic design students ($N = 3$). On average, the mnemonic performance of the three young graphic design students was somewhat better than the performance of normal young adults. This difference (which, of course, never attained statistical significance given the small number of subjects) was mainly due to the fact that one of the young normal adults performed below the remaining five young subjects (graphic design students or other).

[5] Material documenting the recruitment process is available upon request.

Description of Old Graphic Designers

All six old graphic designers were "experts" in the sense that they had been successful professionals. Five of them were members of the Berlin section of the German Graphic Design Association. At the time of testing, five were still active in their field of specialization. These five would qualify as experts even if a very restrictive usage of this term is preferred.[6]

The first old graphic designer was the president of the Berlin section of the German Graphic Design Association. At the time of testing, he was one of the two or three leading graphic designers in Berlin and a member of prestigious juries and committees. Since 1967, he has won 21 prizes for outstanding work in graphic design. In addition, his artwork has been presented in several exhibitions in Germany, Japan, and the United States. The second expert graphic designer was an emeritus faculty member of the graphic design department of the Berlin School of Arts. At the time of testing, this person was 75 years of age and was still giving private drawing lessons. The third individual has worked as a cartoonist for numerous European journals and newspapers. It is noteworthy that this person was also the creator of the *smile* (a smiling yellow face with a mouth and egg-shaped eyes). During the testing phase, he was awarded the order of the Federal Republic of Germany for his outstanding professional achievements *(Bundesverdienstkreuz am Bande)*. Similar to the first individual, the fourth expert specialized in posters for exhibitions. She has won prizes for outstanding work, both alone and together with her husband, a former president of the Berlin section of the German Graphic Design Association. The fifth individual has had an increasing number of exhibitions in the last 20 years. Starting her career as an ordinary graphic designer, she specialized in patchwork and has reached high levels of expertise in this particular technique. The sixth specialized in the decoration of shop windows; she also worked as a teacher at a Berlin graphic design school.[7]

Validation of Professional Expertise

A standard psychometric measure of visual creativity—the Torrance Tests of Creative Thinking: Thinking Creatively with Pictures (Torrance, 1966a, 1966b)—was employed to validate the professional expertise of old graphic designers. The expectation was that the group of old graphic designers would demonstrate the highest level of performance among the three groups because visual creativity was assumed to represent a central aspect of the professional expertise of graphic designers.

One problem shared by all relevant measures is that visual creativity is assessed by the help of some kind of externalization in the form of drawings or pictures. It appears that this problem is minimized in the third subtest of the Torrance called "Parallel

[6]Personal information is revealed with the consent of the participants.

[7]Material documenting the professional expertise of old graphic designers is available upon request.

Lines." In this subtest, individuals have to complete a large number of simple line drawings, and they are allowed to make written comments to avoid ambiguities that may result as a consequence of poor drawing skill. A detailed description of this subtest is provided below.

> Subjects are given a limited amount of time (10 min) to convert a great number of parallel lines into different objects by adding lines with a pencil. Subjects are free to label their pictures with text if they are not sure whether the drawing is intelligible. Scoring is computed using the following categories: fluency, flexibility, originality, and elaboration. The fluency score represents the sum of different drawings completed. Flexibility represents the number of different categories to which these drawings belong. Originality is the sum of frequency ratings for each drawing. Frequency ratings range between 0 (very common) and 4 (very rare) depending upon how often these drawings occur in the population. Finally, the elaboration score represents the total number of details which go beyond the basic idea of each of the drawings. If, for instance, a subject would convert parallel lines into a house, smoke coming out of the chimney would qualify as an additional detail whereas a door and two windows would not. A test booklet including category norms, frequency norms, and a scoring guide with annotated examples is available (Torrance, 1966a).[8]

Average scores on the additive composite of the four dimensions were 69.0 ($SD = 25.1$), 52.3 ($SD = 47.7$), and 103.7 ($SD = 30.2$) for young adults, old normal adults, and old graphic designers, respectively. A one-way analysis of variance with a repeated contrast on Group was computed to analyze the data. Both contrasts were significant, indicating that old graphic designers scored significantly higher than both old normal adults [$t(15) = 3.7$; $p < .01$] and young adults [$t(15) = 2.5$; $p < .025$].[9]

The superiority of old graphic designers on a test of visual creativity validated their professional expertise. To gain a more detailed picture of group differences in performance, Table 5 shows the results on the Torrance broken down by group and scoring

Table 5
Means (SD) for the Fluency, Flexibility, Originality, and Elaboration Scales of the "Parallel Lines" Subtest of the Torrance Visual Creativity Test Broken Down by Group

	Old normals	Old experts	Young adults
Fluency	16.2 (4.1)	21.7 (7.7)	18.5 (6.2)
Flexibility	10.5 (1.5)	15.0 (5.1)	13.0 (4.0)
Originality	22.2 (10.5)	41.5 (18.9)	30.7 (12.6)
Elaboration	3.5 (3.4)	25.5 (10.6)	6.8 (2.9)

Note. Scores are based on the "Parallel Lines" subtest of the Torrance Tests of Creative Thinking: Thinking Creatively with Pictures, Form A (Torrance, 1966a, 1966b). Scores were computed following the scoring guide provided by Torrance (1966a).

[8]The category and originality norms were validated with North-American high school samples (Torrance, 1966a), and they are probably not an accurate representation of the frequencies and categories that would be found with German adults using the same validation procedure. Since no other norms were available, the original norms were used in the present study.

[9]The α-level for rejecting the null hypothesis was adjusted to $p = .50/2 = .025$. The test for homogeneity of variances was not significant (Bartlett-Box $F = 1.37$; $p > .1$).

dimension. Old graphic designers did especially well on the originality and elaboration dimensions. In other words, they were more likely to convert parallel lines into unusual objects and to elaborate on their drawings by adding some detail which was not part of the basic idea of the object.[10]

The Torrance tests were originally developed to measure "creative thinking with pictures" (Torrance, 1966a, 1966b; for a critical review, cf. Bollinger, 1981). It has been suggested repeatedly that creative performance and visual imagery are intertwined (cf. Mumford & Gustafson, 1988). The present results confirm this view and add a qualifying note to studies in which creativity has been found to decline with age (Alpaugh & Birren, 1977; McCrae, Arenberg, & Costa, 1987; Salthouse, 1982). In contrast to the assumption of a general decline in creative performance across persons and domains, the high performance of old experts in graphic design suggests—aside from the possibility of extraordinary differences in native endowment or talent—that some older adults who train relevant processes in the context of their profession may be able to maintain high levels in specific aspects of creative performance.

Matching of Subject Groups

The two groups of old subjects were matched on the Vocabulary test (crystallized intelligence), Digit Span (nonvisual short-term memory), and the Digit Symbol Substitution test (perceptual/clerical speed/broad fluid) of the HAWIE (Wechsler, 1964). The tests are widely used in psychological research and have satisfactory reliabilities (see also Table 7, p. 70). Brief descriptions are provided below.

In the Vocabulary test of the HAWIE, subjects are asked to provide definitions for 42 different words. Definitions are scored on a three-point scale with the help of a scoring guide (Wechsler, 1964). In the Digit Span test, digit strings of increasing length are read aloud by the experimenter at a rate of 1 s per digit. The subject is asked to repeat the strings in original (Forward Digit Span) or reverse (Backward Digit Span) order. Scores indicate the length of the longest string that a subject was able to repeat in correct order. In the Digit Symbol Substitution test, the subject is shown a test key in which each of the digits 1 through 9 is paired with a simple geometric figure. The subject is then asked to write down the geometric symbol below each digit of a long list of digits presented at random. In doing so, the subject is allowed to refer to the test key. Scoring is based on the number of correct symbols written down within 90 seconds.

Table 6 displays means and standard deviations for the four measures broken down by group. *T*-tests contrasting the performance of old graphic designers and old normal adults as well as the performance of old graphic designers and young adults are also reported. With respect to Vocabulary, Forward Digit Span, and Backward Digit Span, none of the two contrasts was significant. Old graphic designers displayed lower levels

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[10]In the analysis reported above, raw scores on the four dimensions were simply added. It may be argued that this procedure exaggerated the impact of group differences in specific dimensions on group differences in the total score (see also Table 5). Therefore, a second analysis was computed, with the average of T-transformed scores (i. e., $x = 50$, $SD = 10$) on the four dimensions as the dependent variable. According to this analysis, old graphic designers scored above the level of old normal adults [$t(15) = 3.2$; $p < .01$]. At the same time, the superiority of old graphic designers over young adults was reduced to a marginally significant level [$t(15) = 2.1$; $.025 < p < .1$]. Given the small sample size, the results of this analysis were considered satisfactory. The test for homogeneity of variances was not significant (Bartlett-Box $F = 1.59$; $p > .1$).

Table 6
Means (SD) and *T*-Tests for Vocabulary, Forward Digit Span, Backward Digit Span, and Digit Symbol Substitution

	Old normals	Old experts	Young adults	Old experts vs. old normals	Old experts vs. young adults
Vocabulary	70.3 (8.0)	63.3 (7.8)	68.5 (7.2)	−1.58 ns	−1.16 ns
Forward Digit Span	6.3 (1.0)	6.5 (0.8)	7.2 (0.8)	+0.33 ns	−1.30 ns
Backward Digit Span	5.5 (1.0)	5.7 (1.0)	6.2 (0.9)	+0.28 ns	−0.85 ns
Digit Symbol Substitution	47.7 (9.4)	45.4 (6.6)	58.9 (7.8)	−0.49 ns	−2.92 $p < .01$

Note. Tests were administered according to Wechsler (1964). Numbers regarding the two contrasts refer to *T*-values ($df = 15$; trends with $.025 < p < .1$ are reported; *ns* = not significant).

of performance on the Vocabulary test than both old normal adults and young adults, but these differences were not statistically significant. In contrast, young adults had much higher scores than both groups of old subjects with the Digit Symbol Substitution test.[11]

The Digit Symbol Substitution test is moderately or highly correlated with all other tests of the HAWIE battery (Matarazzo, 1982). In factor-analytic work, the test generally helps to define the first-order factor of perceptual speed and usually exhibits high loadings on the second-order factor of fluid intelligence (Stankov, 1988; cf. Horn, 1978, 1982). Compared to other standard measures of intellectual functioning, age-related decrements in performance are especially pronounced with this test (Salthouse, 1985).[12] In the present context, it is also important to note that interindividual differences in Digit Symbol Substitution performance were found to be highly predictive of interindividual differences in cued serial recall after instruction in the *Method of Loci.* For instance, Kliegl, Smith, and Baltes (1989b) reported a significant correlation between older adults' Digit Symbol Substitution score at pretest and skilled memory performance with the *Method of Loci* at the end of the training program [$r(19) = .68$; $p < .05$].

To summarize, any attempt to relate the memory performance of old graphic designers to professional expertise in graphic design requires, as a precondition, that old graphic designers do not differ from old normal subjects in more general aspects of

[11]As part of the screening procedure, two applicants in the old normal group had to be replaced by other subjects after the psychometric assessment because their scores on the Digit Symbol Substitution test were too low.

[12]As indicated by the high loadings on the factor of fluid intelligence, the test seems to involve, despite its apparent simplicity, other aspects of intelligent behavior besides perceptual speed, such as memory and accuracy of response execution. A recent componential analysis of the test supports this contention (Laux & Lane, 1985).

cognition, such as fluid intelligence and nonvisual short-term memory. For this reason, it was made sure that the two groups of old subjects displayed the same level of performance on the Digit Symbol Substitution test, Forward Digit Span, and Backward Digit Span. It was particularly important that the two groups did not differ in Digit Symbol Substitution performance because performance on this test was found to predict interindividual differences in limits of mnemonic skill among older adults. Finally, both groups of old subjects displayed the typical pattern of cognitive aging, with stability in a measure of crystallized intelligence and decrements in a marker test of the broad fluid domain.

METHOD

Research participants were tested individually by the author or by a research assistant. For each session, subjects received DM 20. The experiment consisted of two different parts (see also Table 3, p. 60): psychometric assessment (Sessions 1 and 2) and memory performance with the *Method of Loci* (Sessions 6–26 and Session 28).[13]

Psychometric Assessment

Psychometric testing served three different goals: (a) matching of subject groups, (b) validation of professional expertise, and (c) prediction of mnemonic performance (see also Table 7). In Session 1, the two subtests of the Torrance Tests of Creative Thinking: Thinking Creatively with Pictures, Form A (Torrance, 1966a) were used as warm-ups.

Table 7
List of Psychometric Measures

Purpose	Indicator	Source	Reliability
Matching of subject groups			
Crystallized intelligence	Vocabulary	HAWIE (1964)	.94 (Matarazzo, 1982)
Mental speed (broad fluid)	Digit Symbol Substitution	HAWIE (1964)	.94 (Oswald et al., 1986)
Short-term memory	Digit Span	HAWIE (1964)	.69 (Oswald et al., 1986)
Validation of professional expertise			
Visual creativity	"Parallel Lines"	Torrance (1966a)	.71 (Torrance, 1966b)
Predictors of mnemonic skill			
Spatial visualization	Card Rotation	Ekstrom et al. (1976)	.85 (Scholl, 1976)
	Surface Development	Ekstrom et al. (1976)	.92 (Ekstrom et al., 1976)
Self-rated imagery vividness	VVIQ	Marks (1973)	.74 (Marks, 1973)

[13]Sessions 3 to 5 and Session 27 were not related to topics covered in the dissertation. Therefore, the content of these sessions is not part of the present report.

Then, the "Parallel Lines" subtest of the Torrance and the Vividness of Visual Imagery Questionnaire (VVIQ, Marks, 1973), a self-rating scale of imagery vividness, were administered. Session 2 started with tests from the HAWIE in the following order: Forward Digit Span, Backward Digit Span, Vocabulary, and Digit Symbol Substitution (Wechsler, 1964). After that, the Card Rotation test (Ekstrom, French, & Harman, 1976) and the Surface Development test (Ekstrom, French, & Harman, 1976) were given.

The selection of psychometric measures was guided by considerations of construct validity and reliability. As documented in Table 7, most of the measures are widely used in psychological research and have satisfactory or good reliability. Detailed descriptions of the measures and specific reasons underlying their selection are provided in the corresponding sections of the dissertation.

Memory Performance with the *Method of Loci*

Apparatus

Apple IIe PCs were used for stimulus presentation, timing, and response collection. Stimuli were presented in standard 40-column Apple font on a monitor using a green display on black background.

Materials

List of Berlin Landmarks

All subjects received the same set of 20 well-known Berlin landmarks as memory pegs (Appendix A, Table A-1). The sequence of locations was geographically meaningful and corresponded to a fictitious sightseeing tour.[14]

20-Item Noun Lists

A total of nine 20-item noun lists was employed (see also Tables A-2 and A-3 in Appendix A). For the five lists displayed in Table A-2 and for the high-imagery, low-similarity list in Table A-3, nouns were taken from the norms provided by Baschek, Bredenkamp, Öhrle, and Wippich (1977; cf. Paivio, Yuille, & Madigan, 1968). These six lists were matched in mean imagery, concreteness, meaningfulness, word length, and word frequency. All nouns in these lists were highly imageable, with an imagery rating above 6.00 on a 7-point scale.[15]

[14]Evans, Brennan, Skorpanich, and Held (1984) reported that young and old citizens recalled highly used or symbolically significant landmarks with equal frequency. All landmarks used in the present study fell under at least one of the two categories (cf. Appleyard, 1969).

[15]The characteristics of nouns from the five lists of Table A-2 and the high-imagery, low-similarity list of Table A-3 were subjected to analyses of variance. As documented in Table A-6, lists did not differ in imagery [$F(5,114) = .01$], concreteness [$F(5,114) = .14$], meaningfulness [$F(5,114) = .05$], word length [$F(5,114) = .02$], and word frequency [$F(5,96) = .03$]. All these factors are known to influence the probability of correct recall (Rubin & Friendly, 1986). No attempt was made to match lists with respect to age of acquisition (Gilhooly & Logie, 1980) because German norms for this variable were not available. However, in a carefully controlled study (with college students serving as subjects), Coltheart and Winograd (1986) found that age of acquisition does not affect episodic memory. To avoid effects related to cohort, care was taken that the nouns were neither "dated" nor "modern."

The four 20-item noun lists in Table A-3 in Appendix A varied systematically on the dimensions of imageability (high vs. low) and within-list similarity (high vs. low). The variations in within-list similarity were needed in the context of Predictions 7a and 7b (group differences in discriminability). Further details regarding the construction of the lists are provided below (pp. 88–89).

Digit List

One list with digits was generated by randomly selecting 20 two-digit numbers without replacement from a pool of 100 different two-digit numbers (see also Table A-4 in Appendix A).

60-Item Noun List

One list with 60 nouns was used (see also Table A-5 in Appendix A). No norms were available for most of the items of this list; however, all items can be regarded as highly imageable because they refer to concrete familiar objects. In the context of the *Method of Loci,* they were also similar to each other because they all referred to objects which can be carried along on a sightseeing trip through the city (passport, journal, pen, comb, glasses, notebook, etc.).

Procedure

Old graphic designers, old normal adults, and young adults constituted three experimental groups with six subjects in each group. Within groups, half of the subjects received the sequence of Berlin landmarks in reverse order. At encoding, the landmark and the target item appeared almost simultaneously on the screen, with the landmark preceding the noun by 0.1 s. Interpair intervals (i. e., time intervals with no item being presented) were fixed at 0.4 s. After the last landmark–noun combination of a given trial had been presented, subjects initiated the recall phase by pressing the return key.[16]

In contrast to most other studies with the *Method of Loci,* recall was cued by presenting landmarks in the same serial order as at encoding. This was done to eliminate the failure to retrieve landmarks in correct order as a possible source of incorrect responses. In this way, possible group differences in confusion errors could be linked with greater confidence to differences in the discriminability of visual images (see also Predictions 7a and 7b). Subjects verbalized their responses, and the experimenter entered digit codes corresponding to each of the to-be-learned items on a numeric keyboard. Null responses ("don't know") were allowed. The response time limit was set at 30 s, and latencies for individual responses were collected. Sessions were administered on different days, with the interval between sessions generally not exceeding four days.[17]

Instruction in the Method of Loci

At the beginning of Session 6, subjects were informed in detail about the *Method of Loci.* First, they were told about the historical origins of the method. Then, the

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[16]Throughout this text, the administration of a *list* is called a *trial.*

[17]Due to scheduling problems, distance between two consecutive sessions exceeded four days in some cases. These occasions occurred about equally as often in all three experimental groups.

functioning of the method was explained to them using concrete examples. The generation of interactive visual images between landmark cues and to-be-learned words was highlighted as the critical feature of the method. Old graphic designers were asked to recollect aspects of their work performance that involved different forms of interactive visual imagery, and it was suggested to them that they consider the acquisition of the *Method of Loci* as a peculiar task which somehow is related to their professional expertise. Other subjects were asked to think of situations in which they employed interactive visual imagery. They were told that they were expected to engage in this kind of activity in the following sessions.

Next, all subjects were given a list of the 20 Berlin landmarks in experimental sequence and were told about their function in the *Method of Loci*. A city map of Berlin was provided by the experimenter, and subjects were asked to locate the landmarks on the map in correct order. All subjects were able to do this. As they located the landmarks, subjects were asked to give detailed descriptions of them. Then, the landmarks were shown to the subjects in experimental sequence on the screen (without to-be-learned items).

Sessions 6 to 13 and 26

The five 20-item noun lists shown in Table A-2 in Appendix A were administered. Within sessions, each of the five lists appeared once. To-be-remembered nouns were presented at the following rates: (a) self-paced in Sessions 7 and 8, (b) 7.5 s per word in Sessions 9 and 10, (c) 4.5 s per word in Sessions 6, 11, and 12, and (d) 1.5 s per word in Sessions 13 and 26. This procedure allowed the assessment of gains during the Training Phase (Session 6 vs. Session 12) and the assessment of further gains during the Test Phase (Session 13 vs. Session 26). In the remaining sessions of the Training Phase (Sessions 7–11), presentation rates were gradually increased from self-paced to 4.5 s per word.[18]

Sessions 6, 12, 13, and 26. To allow the assessment of gains in recall performance, the order of trials was the same for all subjects and did not vary across sessions (i.e., the five lists in Table A-2 were administered in ascending numerical order). Different item orders (i.e., serial positions of target items within lists) were generated at random for each list with the constraint that no item was allowed to appear more than once at the same location. Item order was identical for all subjects.

Sessions 7 to 11. Six different trial orders were generated at random with two constraints: (1) each of the five different lists appeared once in each of the five sessions, and (2) over the five sessions, each list appeared once as the first, second, third, fourth, and fifth measurement occasion within a session. For each list, six different sets of item orders were generated comprising the same 20 items in five different orders. Within each set, no item appeared more than once at the same location. Across groups, subjects were matched on list order and item order. Thus, sets of three subjects (one from each group) were exposed to the same stimulus configuration.

Training (guided practice) in Sessions 7 to 11. After completion of a trial, the tutor commented on the performance of the subject and made suggestions for further improvement. For instance, the tutor stressed the importance of creating interactive visual images that combined landmark and noun information, and encouraged the

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[18]The average encoding rates under self-paced conditions were 12.9 s (SD = 8.3), 14.8 s (SD = 5.1), and 11.9 s (SD = 6.1) for old normal subjects, old expert graphic designers, and young subjects, respectively. Differences among groups were not statistically reliable.

subject to concentrate ("zoom in") on those aspects or details of a location that the subject considered to be most imageable. In earlier studies in the same laboratory, similar forms of guided practice were employed (Kliegl, Smith, & Baltes, 1989a).

Sessions 14 to 25

The difficulty of task conditions in Sessions 14 to 25 was manipulated on the dimensions of presentation rate, imageability, within-list discriminability, and list length. A summary overview of variations in task difficulty is provided in Table 8.

Trial order. With respect to the four 20-item noun lists displayed in Table A-3, a counterbalancing scheme was implemented to control for order effects. This was necessary because Predictions 7a and 7b related group differences in response characteristics (correct recall, confusion errors) to variations in list characteristics (within-list similarity and imageability). The four 20-item noun lists were presented at rates of 7.5, 4.5, and 1.5 s per word. Each combination of lists and presentation rate was administered four times, resulting in twelve trials per list or a total of 48 trials. These 48 trials were equally distributed over the first four measurement occasions of the twelve sessions. A different trial order was generated for each of the six subjects within a group. The following constraints were met in the generation of trial orders: (a) Within sessions, each of the four lists appeared exactly once; (b) within sessions, one of the three presentation rates was administered twice and the other two were administered once; and (c) across all sessions, each combination of list and presentation rates appeared once in the first, second, third, and fourth measurement occasion within a session.

Table 8
Overview of Variations in Task Difficulty During the Test Phase

	Imagery level	Within-list similarity	Presentation rate[a]		
20-item noun lists					
HI LS	high	low	7.5	4.5	1.5
HI HS	high	high	7.5	4.5	1.5
LI LS	low	low	7.5	4.5	1.5
LI HS	low	high	7.5	4.5	1.5
60-item noun list	high	high	7.5	2.5	
Digit List	very low				1.5

Note. The table refers to Sessions 14 to 25 of the Test Phase. 20-item noun lists are described as a combination of imagery level (HI = high, LI = low) and within-list similarity (LS = low, HS = high). Difficulty of task conditions increased as a function of imagery level (from high to low), within-list similarity (from low to high), presentation rate (from slow to fast), and list length (from short to long). Each combination of list type and presentation rate was administered four times, totaling 60 trials (five in each session). Lists of to-be-remembered material are reproduced in Appendix A.

[a]Seconds per word.

The Digit List (cf. Table A-4) was administered with a presentation rate of 1.5 s per word at the fifth measurement occasion of Sessions 14, 17, 20, and 23. Similarly, the 60-item noun list (cf. Table A-5) was always presented at the fifth measurement occasion of a given session. Two different presentation rates, 7.5 s per word and 2.5 s per word, were employed for this list. The faster rate was administered in Sessions 15, 18, 21, and 24, and the slower rate was administered in Sessions 16, 19, 22, and 25. To summarize, a total of 60 trials (48 with 20-item noun lists, eight with the 60-item noun list, and four with the Digit List) was equally distributed over twelve sessions, with the Digit List and the 60-item noun list always appearing at the end of a session.

Item orders within trials. A different set of item orders was generated for each of the six subjects within a group. Corresponding to the total number of trials per subject, each set consisted of twelve different item orders for the four 20-item noun lists, eight different orders for the 60-item noun list, and four different orders for the Digit List. Within a set, item orders were generated by random with the constraint that no item appeared more than once at the same location (i. e., in the same serial position). Across groups, subjects were matched so that sets of three subjects—one from each group—were exposed to the same stimulus materials.

The 60-item noun list: Modification of procedure. To accommodate the increase in the number of to-be-learned words from 20 to 60, each of the 20 Berlin locations was presented three times in immediate succession. Subjects were instructed to generate three visual images at the same landmark. Retention of order information within landmarks was not emphasized; all nouns recalled at the correct locations were counted as correct.

Verbal protocols. For further explorations of group differences in imagery, memory performance with the four 20-item noun lists presented at the three different presentation rates was recorded on tape. Only the last of the four trials with a given combination of list and presentation rate was taped, yielding a total number of twelve verbal protocols for each subject. Immediately after the recall phase of a trial, to-be-remembered items were shown in correct order on the screen, together with the landmarks to which they belonged. Subjects were asked to remember and verbalize the "thought or image" they had formed at encoding regardless of whether they had been able to recall the items during the regular retrieval phase. In all three groups, some subjects spontaneously verbalized at encoding. In these cases, the encoding phase was also recorded on tape.[19]

Drawing session. In Session 27, subjects listened to their verbal protocols of the four different 20-item noun lists presented at the 7.5 s rate. For each trial, subjects were asked to select two self-reports of visual images of landmark–noun combinations and to "draw a picture of that image." This resulted in a total of eight pictures per subject. Each drawing was made on a separate sheet of white paper (DIN A4 format). Subjects had available lead and colored pencils.[20]

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[19]Verbal protocols for lists presented at a 7.5 s rate are available upon request.

[20]Drawings are available upon request.

RESULTS

The predictions of the present study fall into three different categories (see also Table 4, p. 61). The presentation of results follows this outline. Group differences in cued serial recall for different phases of the experiment are reported first (Predictions 1–4). Then, processual analyses are undertaken to provide a more fine-grained picture of group differences in select aspects of memory performance (Predictions 5–8). In a third part, the predictive power of psychometric ability markers and chronological age for interindividual differences in mnemonic skill is examined (Predictions 9–11).[21]

Group Differences in Mnemonic Skill

Continued Existence of Cognitive Plasticity in Older Adults (Prediction 1)

It was expected that subjects in all groups would show an increase in cued serial recall during the Training Phase of the experiment. This would be consistent with the assumption that subjects in all groups possess a sufficient amount of cognitive plasticity to profit from mnemonic training. The relevant data are displayed in Figure 1. The figure represents the average level of cued serial word recall at the beginning and at the end of the Training Phase broken down by group.

It was planned to analyze the data with a Group (3) x Session (2) analysis of variance with repeated measures on the second factor. However, when variance-covariance matrices were tested for homogeneity using Box's *M* test, it was found that the homogeneity assumption was violated [$F(6,5607) = 2.67; p < .05$]. Therefore, separate analyses of variance were computed to examine the existence of training gains, with Session (2) as a within-subject factor. The observed increase in cued serial recall was significant in all three groups [old normal adults: $F(1,5) = 30.59; p < .01$; old graphic designers: $F(1,5) = 6.71; p < .05$; young adults: $F(1,5) = 12.35; p < .05$].[22] The results were consistent with Prediction 1. The fact that old normal adults were able to profit from mnemonic training documented the continued existence of cognitive plasticity in this group. This finding is paralleled by similar findings in the domains of imagery-based memory performance (Kliegl, Smith, & Baltes, 1989a; Rose & Yesavage, 1983; Yesavage & Rose, 1983, 1984) and fluid intelligence (Baltes & Willis, 1982; Denney, 1979).

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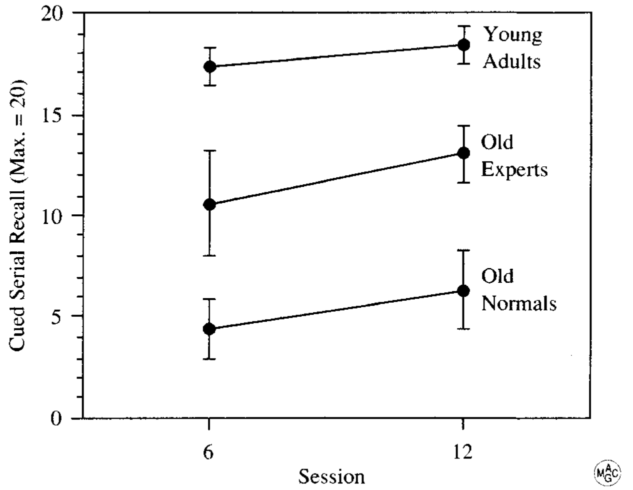
[21]As noted earlier, three of the six young adults participating in the present study were graphic design students. In all analyses reported below, young adults were treated as a single group. Therefore, data were not presented separately for young normal adults ($N = 3$) and young graphic design students ($N = 3$). On average, the mnemonic performance of the three young graphic design students was somewhat better than the performance of normal young adults. This difference (which, of course, never attained statistical significance given the small number of subjects) was mainly due to the fact that one of the young normal adults performed below the remaining five young subjects (graphic design students or other).

[22]Throughout this text, analyses of variance with repeated measures were computed using the MANOVA routine of the Statistical Package for the Social Sciences (SPSSX; cf. O'Brien & Kaiser, 1985; Olson, 1974).

Figure 1
Gain in Recall Performance
During the Training Phase



Note. Vertical lines indicate the 90% confidence interval of the mean.
Lists were presented at a rate of 4.5 s per word.

As can be seen in Figure 1, it appears that subjects in the three groups did not differ considerably in the rate of improvement. This seems to be inconsistent with two other studies which reported a magnification of age differences in cued serial recall with the *Method of Loci* as a consequence of mnemonic instruction and training (Kliegl, Smith, & Baltes, 1989a; Yesavage & Rose, 1984). One explanation for the difference in results is that young adults in the present study had little room for further improvement given that they recalled about 86% of the words in correct serial position at pretest. Another explanation is related to the first point of measurement (i.e., pretest assessment). In Kliegl, Smith, and Baltes (1989a) as well as in Yesavage and Rose (1984), serial word recall was assessed prior to instruction in the *Method of Loci.* In the present study, pretest assessment took place before training, but after instruction. Thus, the difference in results could indicate that age-differential gains in cued serial recall occur primarily as a consequence of mnemonic instruction (cf. Kliegl, Smith, & Baltes, 1989b).[23]

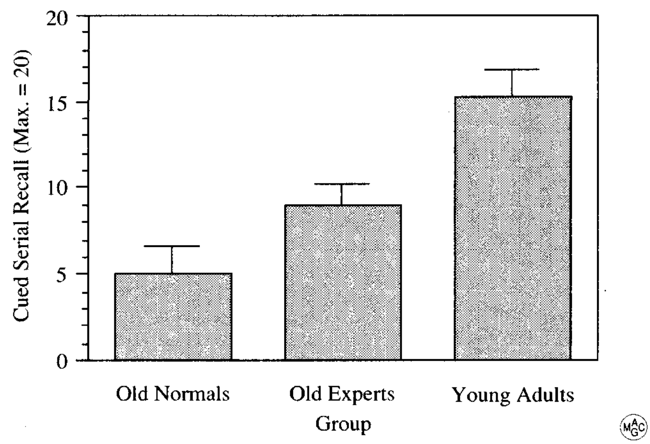
[23]In the present study, it was not possible to assess cued serial recall prior to instructions because information about the *Method of Loci* was revealed to participants during the recruitment process. This was necessary because some old expert graphic designers, due to their professional commitments, had very little extra time. In these cases, the *Method of Loci* had to be explained during the first contact to arouse the interest of the individual to participate in the study.

Group Differences in Cued Serial Recall (Predictions 2 and 3)

The main hypothesis of the present study was that the professional expertise of old graphic designers would attenuate, but not eliminate, the age-related reduction of developmental reserve capacity in the domain of imagery-based memory performance. Thus, it was predicted that old graphic designers would perform above the level of old normal adults (Prediction 2) and below the level of young adults (Prediction 3). Memory performance during the Test Phase was used to test these predictions. Two analyses were performed, one regarding 20-item noun lists and the other regarding the 60-item noun list.

In the first analysis, the average score of 48 trials with 20-item noun lists administered during the Test Phase served as a dependent variable.[24] Cronbach's α for this measure was $r(18) = .99$ in the total sample, $r(6) = .98$ in old normal adults, $r(6) = .97$ in old graphic designers, and $r(6) = .98$ in young adults (all $ps < .01$). Thus, interindividual differences in cued serial recall were measured reliably, both across and within groups. Figure 2 shows the performance with 20-item noun lists broken down by group. A one-way analysis of variance with a repeated contrast specified for Group

Figure 2
Cued Serial Recall with 20-Item Noun Lists as a Function of Group



Note. Vertical lines indicate the upper boundary of the 90% confidence interval of the mean.

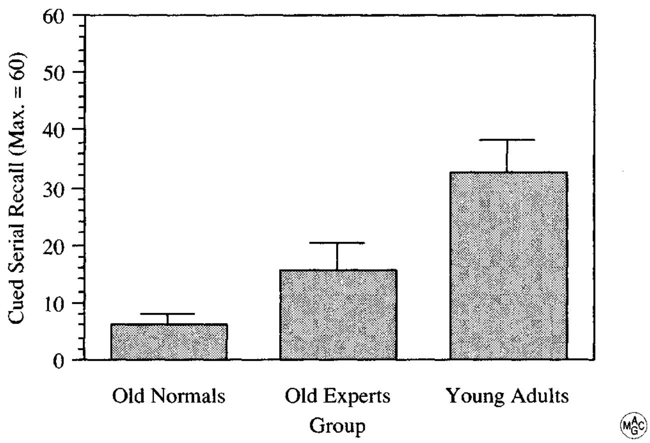
[24]Lists from Sessions 13 and 26 were not included in this score to allow an independent analysis of the existence of performance gains during the Test Phase (Prediction 4). The remaining trials were administered in Sessions 14 to 25. They comprised performance on four different lists, administered four times at three different presentation rates (7.5 s per word, 4.5 s per word, and 1.5 s per word). For details, see the Method section (pp. 74–75).

showed that old graphic designers recalled more words in correct serial position than old normal adults [$t(15) = 3.06; p < .01$], and that young adults recalled more words in correct serial position than old graphic designers [$t(15) = 4.77; p < .01$].[25]

The second analysis concerned the average level of performance with the 60-item noun list. Performance with this list is shown in Figure 3.[26] Cronbach's α for the composite measure comprising eight trials was $r(18) = .96$ in the total sample, $r(6) = .70$ in old normal adults, $r(6) = .90$ in old graphic designers, and $r(6) = .86$ in young adults (all $ps < .01$). A one-way analysis of variance revealed that old graphic designers recalled more words at the correct location than old normal adults [$t(15) = 2.65; p < .025$], and that young adults recalled more words at the correct location than old graphic designers [$t(15) = 4.73; p < .01$].[27]

The results of the two analyses were consistent with the main predictions of the present study. Old graphic designers performed above the level of old normal adults

Figure 3
Cued Serial Recall with the 60-Item Noun List as a Function of Group



Note. Vertical lines indicate the upper boundary of the 90% confidence interval of the mean.

[25]The repeated contrast for the Group factor was used throughout. The contrast reflects the transitive character of the main expectation of the study: that old graphic designers would perform above the level of old normal adults, and that young adults would perform above the level of old graphic designers. The α-level for rejecting the null hypothesis was adjusted to $p = .50/2 = .025$. The test for homogeneity of variances was not significant (Bartlett-Box $F = 0.23; p > .1$).

[26]With the 60-item noun list, three nouns had to be recalled at the same landmark. Nouns recalled at the correct location were counted as correct independent of order information within landmarks because instructions did not focus on the conservation of order information within landmarks.

[27]The α-level for rejecting the null hypothesis was adjusted to $p = .50/2 = .025$. The test for homogeneity of variances was not significant (Bartlett-Box $F = 2.20; p > .1$).

matched on standard measures of intelligence (Vocabulary, Digit Symbol Substitution) and short-term memory (Digit Span). At the same time, they performed well below the level of young adults. These findings support the claim that professional expertise and/or superior levels of imagery-related ability attenuate, rather than eliminate, age differences in developmental reserve capacity in the domain of imagery-based memory functioning.

This claim is further substantiated by the inspection of individual data points. In the case of 20-item noun lists, only one individual in the group of old normal subjects performed above the average level of old graphic designers, and only one old graphic designer performed above the level of the lowest-achieving young subject. Thus, the amount of overlap among groups was small with respect to old normal subjects and old graphic designers, minimal with respect to old graphic designers and young adults, and nonexistent with respect to old normal adults and young adults.

Gains in Recall During the Test Phase (Prediction 4)

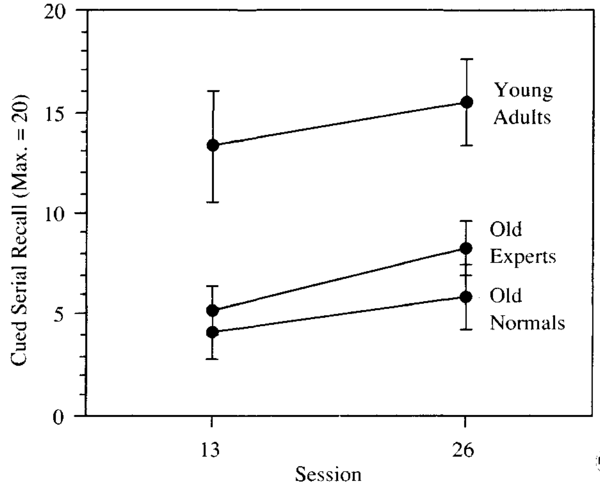
The present work was guided by the theoretical orientation that the consequences of cognitive aging are accentuated (magnified) when individuals approach, and possibly reach, the limits of their capabilities (their functional maximum). The notion of limits is closely tied to the concept of developmental reserve capacity or maximum learning potential (cf. Baltes, 1987). Individuals are expected to approach their limits through the activation of developmental reserve capacity. An asymptotic level of performance is assumed to indicate that an individual has come close to his or her limits. Based on these considerations, it was important to know whether individuals in the present experiment had reached a relatively stable level of performance when they entered the Test Phase.

The relevant data are displayed in Figure 4. The figure displays the level of cued serial recall in the three groups at the beginning (Session 13) and the end (Session 26) of the Test Phase. The two sessions were identical in format and consisted of five 20-item noun lists presented at a rate of 1.5 s per word. Data were analyzed using a Group (3) x Session (2) analysis of variance with repeated measures on the second factor.[28] A repeated contrast was specified for Group. Old graphic designers showed a lower number of correctly recalled items than young subjects [$F(1,15) = 26.50$; $p < .01$] and performed marginally better than old normal subjects [$F(1,15) = 3.62$; $.025 < p < .1$]. In all three groups, recall performance in Session 26 was better than in Session 13 [$F(1,15) = 46.37$; $p < .01$]. No significant group-by-session interactions were observed (both $ps > .1$).

Contrary to Prediction 4, subjects in all groups continued to improve their level of cued serial recall. This was inconsistent with the hypothesis that subjects had come close to the upper limits of their mnemonic capabilities at the beginning of the Test Phase. Another finding was that the difference in cued serial recall between old graphic designers and old normal adults was relatively small. This was probably due to the fact

[28]Variance-covariance matrices were tested for homogeneity using Box's *M* test before carrying out the actual analysis. Box's *M* was not significant [$F(6,5607) = 1.10$; $p > .1$].

Figure 4
Gain in Recall Performance
During the Test Phase



Note. Vertical lines indicate the 90% confidence interval of the mean.
Lists were presented at a rate of 1.5 s per word.

that all lists in Sessions 13 and 26 were presented at the fastest, most difficult rate (i. e., 1.5 s per word). As is shown in the context of Prediction 5, the difference between old graphic designers and old normal adults was inversely related to task difficulty.

One may wonder whether further experience with the *Method of Loci* would result in patterns of improvement which substantially affect the observed age differences in mnemonic skill. This would imply that old normal adults and/or old graphic designers would exhibit greater gains than young adults. Given the magnitude of observed group differences, the absence of group-by-time interactions in favor of old graphic designers and/or old normal adults, and the high stability of interindividual differences, such an outcome does not appear to be likely. Thus, although individuals did not reach their functional limits, it appears justified to assume that the present data reflect group differences in developmental reserve capacity in the domain of imagery-based memory functioning.

Processual Analyses of Group Differences

In the previous section, the existence of group differences was documented at the molar level of analysis. In line with the main hypothesis, it was found that professional expertise in graphic design attenuates, rather than eliminates, age-related differences in imagery-based memory performance.

The analyses reported in the following section serve to support this global picture at the level of component processes. First, the magnitude of group differences in cued serial recall was analyzed as a function of task difficulty (Prediction 5), and the relationship between recall level and the shape of serial position curves was investigated (Prediction 6). In both cases, the guiding assumption was that low levels of recall are associated with processing strategies that are extraneous to the *Method of Loci.*

The second focus of the analyses was on group differences in discriminability (Predictions 7a and 7b). As a more specific consequence of professional knowledge and/or ability, it was predicted that old graphic designers would form more discriminable visual images than old normal adults. This prediction was tested in a series of analyses with the number of confusion errors as the dependent variable. The last issue also referred to the visual imagery component of the *Method of Loci.* It was predicted that the two groups of old adults would not differ in the recall of two-digit numbers because the generation of interactive visual images according to the *Method of Loci* would be rendered impossible by this type of to-be-remembered material (Prediction 8).

Group Differences as a Function of Task Difficulty (Prediction 5)

Memory functioning with the *Method of Loci* affords the execution of a number of component processes at encoding and retrieval, including the generation of visual images. Faster presentation rates as well as less imageable and more similar nouns make it more difficult to execute these component processes successfully (Bower, 1969; Bugelski, Kidd, & Segmen, 1968; Crovitz, 1969; Foth, 1973; Paivio, 1971; Wippich, 1984, 1977; Wood, 1967; Wood & Bolt, 1970). When task conditions exceed a certain level of difficulty, mnemonic processing is no longer possible, and less effective forms of remembering, such as rote rehearsal, prevail (Roediger, 1980). A more direct test of this shift-in-processing hypothesis is provided below (Prediction 6).

Based on the existence of mean differences in cued serial recall, one may expect that the shift from memory processing with the *Method of Loci* to other, less effective forms of remembering occurred at different levels of task difficulty in old normal adults, old graphic designers, and young adults. Group differences would be greatest whenever most subjects in one group were still able to use the *Method of Loci,* whereas most subjects in the other group engaged in other, less effective forms of remembering. Given the group differences in cued serial recall reported in the context of Predictions 2 and 3, it was expected that this maximum difference in performance would occur at lower levels of task difficulty for old graphic designers and old normal adults than for young adults and old graphic designers.

To test this prediction, the 48 trials which formed the basis of Predictions 2 and 3 were ordered on a continuum of increasing task difficulty. Cued serial recall averaged over all groups served as an index of task difficulty. Then, the recall scores of neighboring groups were subtracted to obtain the recall advantage of young adults over old graphic designers and of old graphic designers over old normal adults, respectively. Figures 5 to 7 give an overview of the data. Figure 5 displays the average level of cued serial recall as a function of task difficulty in the three groups. The subtracted values for adjacent groups are represented separately in Figures 6 and 7.

Figure 5
Cued Serial Recall as a Function of Task Difficulty and Group

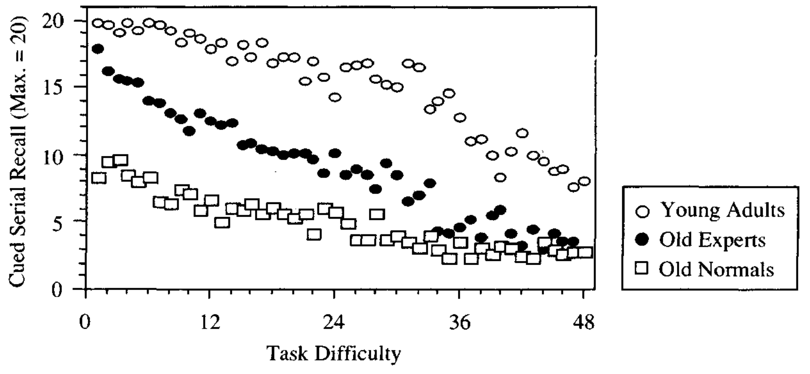


Figure 6
Recall Advantage of Young Adults Over Old Experts

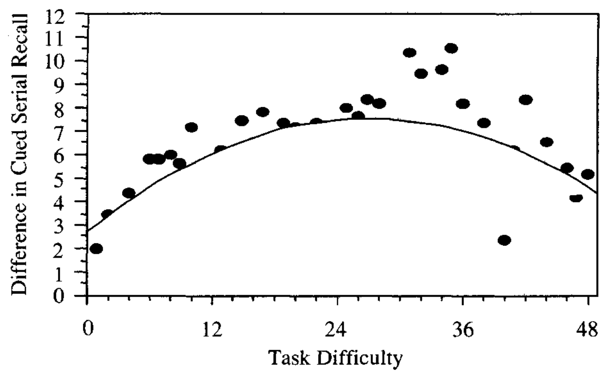
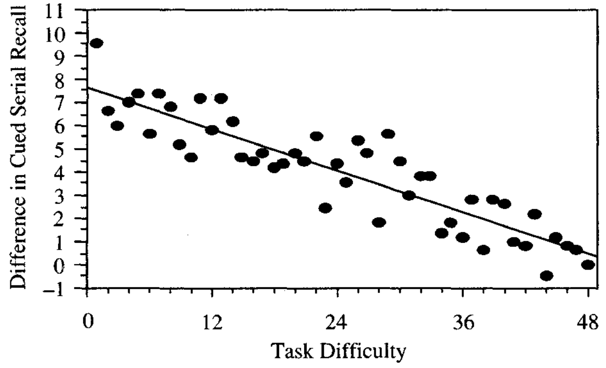


Figure 7
Recall Advantage of Old Experts Over Old Normal Adults



Young adults and old graphic designers were maximally separated around the third quartile of task difficulty. Including a quadratic term in the regression equation resulted in a significant improvement in fit (R^2-change = .36; $p < .01$). It appears that task conditions in the third quartile were too difficult for old graphic designers but were still within the reach of young adults. In contrast, the difference in recall performance between old graphic designers and old normal adults decreased linearly with task difficulty [$R^2 = .81; p < .01$]. The best separation of old graphic designers and old normal adults was achieved in the first quartile of task difficulty.

In sum , the following two equations were obtained:

(1) Young Adults - Old Experts: $y = 2.719 + 0.358x - 0.0066x^2$ $R^2 = .43$
(2) Old Experts - Old Normal Adults: $y = 7.671 - 1.49x$ $R^2 = .81$

The data were consistent with Prediction 5. Group differences in cued serial word recall varied systematically as a function of task difficulty. Specifically, the maximum difference in serial word recall between old graphic designers and old normal adults was observed at a lower level of task difficulty than the maximum difference between old graphic designers and young adults. Thus, more difficult task conditions were needed to maximally separate young adults from old graphic designers than old graphic designers from old normal adults.

Methodologically, the findings document the necessity to provide a wide range of task difficulty in order to assess group differences in skilled memory performance. Whereas ceiling effects reduced the difference between young adults and old graphic designers at low levels of task difficulty, floor effects reduced the difference between old graphic designers and old normal adults at high levels of task difficulty. A more restrictive range of task difficulty would have led to a less informative and potentially misleading picture of group differences in mnemonic skill.

Primacy Effects at Different Levels of Correct Recall (Prediction 6)

With the *Method of Loci,* the generation of interactive visual images is not expected to differ across locations. Therefore, different parts (segments) of the landmark sequence are assumed to contribute a similar proportion of correct responses to the total number of correct responses. This assumption has gained support in earlier studies (Roediger, 1980). It also is in agreement with processing models of memory functioning with the *Method of Loci* (cf. Lea, 1975).

A major advantage of the *Method of Loci* over other forms of encoding exists in the provision of a series of visual templates or cues in the form of a landmark sequence. These visual templates facilitate the formation of interactive visual images. It is plausible to assume that a certain amount of "attentional resources" or "mental energy" is required to form an interactive visual image for a given landmark–noun combination. Thus, the time which is needed to generate the visual image will depend, among other things, upon the amount of available attentional resources.[29]

[29]See also Salthouse (1988b), for a critical discussion of the concept of "mental energy" and related notions in the context of aging research.

Table 9
Distribution of Trials Over Recall Categories Broken Down by Group

	Number of words recalled in correct serial position				
	0	1-5	6-10	11-15	16-20
Old normal adults	8 (2)	180 (6)	76 (6)	22 (2)	2 (2)
Old graphic designers	4 (1)	79 (6)	93 (6)	83 (6)	29 (5)
Young adults	0 (0)	18 (3)	44 (6)	52 (6)	174 (6)

Note. Values without parentheses refer to the total number of trials in a given recall category. Values in parentheses refer to the number of individuals contributing to this total number.

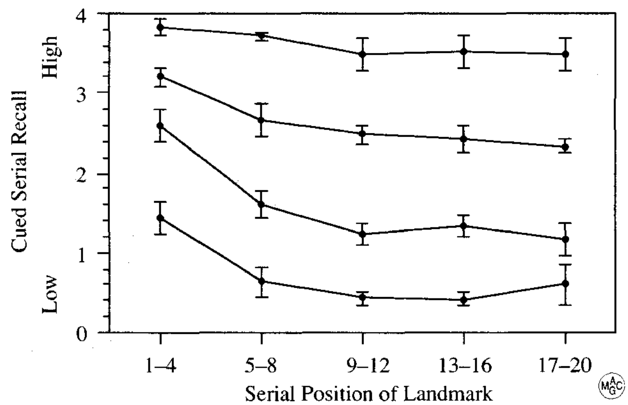
When the difficulty of task conditions increases beyond a certain point, either by presenting low-imagery nouns (which presumably need more mental energy to be visualized) or by presenting items at a faster pace, it was expected that individuals would be no longer capable of completing the image generation process for a given landmark–noun combination before the next item is presented on the screen. In that situation, the landmark sequence would no longer be functional, and individuals were expected to switch to other, less demanding (but also less effective) forms of encoding. For example, they would verbally rehearse the first few items of a given trial, or they would generate interactive visual images for the first few items only. During the rest of the trial, they would either continue to verbally rehearse the first few items, or they would try to hold the visual images pertaining to the first few landmarks in working memory. In both cases, an increase in primacy effects at retrieval was expected because the probability of forming memory traces for items presented at later locations would be drastically reduced. For these reasons, it was predicted that decrements in recall level would be accompanied by an increase in primacy effects.

To test this prediction, the 48 trials known from earlier analyses were categorized on the individual level into five different levels of recall: (a) 0 items correct, (b) 1 to 5 items correct, (c) 6 to 10 items correct, (d) 11 to 15 items correct, and (e) 16 to 20 items correct. Table 9 shows the total number of trials falling into each of the five categories broken down by group. The group differences in the distribution of trials over categories reflect previously analyzed differences in recall performance.

Serial position curves for the four recall categories with a recall level above 0 are displayed in Figure 8. A Recall Level (4) x Serial Position (5) analysis of variance with repeated measures on both factors was computed to analyze the data. To explore the existence of primacy effects, an orthogonal contrast was specified for serial position. The contrast tested serial recall in the first landmark segment (locations 1–4) against the average level of serial recall in the remaining four segments (locations 5–8, 9–12, 13–16, and 17–20). A repeated contrast was specified for recall level in order to explore whether primacy increased between adjacent recall levels.[30]

[30]The α-level for rejecting the null hypothesis was adjusted to $p = .50/2 = .025$.

Figure 8
Serial Position Curves Broken
Down by Recall Level



Note. Vertical lines indicate the 90% confidence interval of the mean.

The effect of serial position was highly significant [$F(1,9) = 32.19$; $p < .01$]; on average, subjects were more likely to recall items from the first four locations of a trial than from remaining locations. This effect was qualified by interactions with recall level. Recall scores in the range of 11 to 15 items were accompanied by a stronger primacy effect than recall scores in the range of 16 to 20 items [$F(1,9) = 19.04$; $p < .01$]. Similarly, scores in the range of 6 to 10 items were accompanied by a stronger primacy effect than scores in the range of 11 to 15 items [$F(1,9) = 9.04$; $p < .025$]. The difference in primacy between the two lowest recall categories (i.e., 1–5 vs. 6–10) failed to reach statistical significance [$F(1,9) = 3.33$; $.2 < p < .1$].[31]

It could be possible that the magnitude of the primacy effect at identical recall levels differed across groups. To examine this question, a Serial Position (5) x Group (3) analysis of variance with repeated measures on serial position was computed. The analysis was restricted to the recall category with 6 to 10 items in correct serial position because this was the only category with contributions from all subjects (i.e., $N = 6$ in each group). A repeated contrast was defined for Group. The contrast for serial position was defined in the same way as before. Again, a significant effect of serial position was found [$F(1,15) = 61.51$; $p < .01$]. The interaction with group was not significant ($p > .1$ for both contrasts). Thus, the magnitude of the primacy effect did not differ across groups.[32]

[31] From the total sample ($N = 18$), eight subjects (four old normal adults, one old graphic designer, and three young adults) did not contribute trials to all four recall levels. Therefore, the analysis was restricted to ten persons. As an alternative to a single analysis for all four recall categories, separate analyses for adjacent recall levels with 13 subjects (16–20 items vs. 10–15 items), 14 subjects (10–15 items vs. 6–10), and 15 subjects (6–10 vs. 1-5 items) were also computed. The same results were obtained.

[32] Box's *M* test for homogeneity of variance-covariance matrices was not significant [$F(30,712) = 1.13$; $p > .1$].

To summarize, decrements in cued serial recall were associated with an increase in primacy effects. This result is consistent with Prediction 6. With 10 to 15 correct items per trial, about 25% of the total number of correct responses were given at the first four locations of the landmark sequence. With 6 to 10 items per trial, the contribution of the first four locations increased to one third. Finally, with 1 to 5 correct responses, the first four locations contributed to about 45% of the total score.

By implication, the results suggest that group differences in the average level of cued serial recall were related to differences in processing. Young adults used the *Method of Loci* under most conditions of the experiment. Old normal adults did not use the *Method of Loci* under most conditions. Instead, they frequently switched to encoding strategies which selectively increased the recall probability for the first few items of a trial. Again, old graphic designers fell in between the two extremes.

Group Differences in Discriminability (Predictions 7a and 7b)

The tendency to focus and elaborate on typical and distinct features of objects and concepts is an important element of skill in graphic design (Schmitt, August 1988, personal communication). This tendency was assumed to transfer to memory functioning with the *Method of Loci.* Old graphic designers were expected to utilize distinct and typical aspects of nouns and landmark cues for visual image generation. Therefore, professional expertise in graphic design was assumed to attenuate age-related decrements in the discriminability of stored information (cf. Craik & Byrd, 1982; Hess & Higgins, 1983; Kliegl & Lindenberger, 1989; Rankin & Kausler, 1979).

Throughout the following analyses, confusion errors were employed as an indicator of discriminability: the more confusion errors, the lower the discriminability.[33] Discriminability was defined as a property of visual images in relation to other visual images. In line with extant theories of similarity and discrimination (Ashby & Perrin, 1988; Corter, 1987; Mensink & Raaijmakers, 1988), visual images were assumed to consist of elements or features, and the degree of discriminability was seen to depend on the proportion of unique and shared features. Thus, the assumption was that a visual image with a high proportion of unique features would most likely be retrieved at the correct location. On the other hand, a visual image sharing most of its features with one or more other visual images would have a high probability of being retrieved at a wrong location.

Group differences in discriminability were expected to result in group-by-treatment interactions. Lists with similar nouns were expected to result in less discriminable visual images than lists with dissimilar nouns (main effect of list). Young adults were expected to generate more discriminable visual images than old graphic designers, and old graphic designers were expected to generate more discriminable visual images than old normal adults (main effect of group). An interaction was expected in the sense that

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[33]The term *confusion error* refers to all incorrect responses except null responses. Almost all confusion errors consisted of nouns from the actual trial that were recalled at a wrong location. Other cases, such as intrusions from other lists or nouns from outside the experiment, accounted for less than 1% of the total number of incorrect responses.

the difference in confusion errors between high-similarity and low-similarity lists would be greater in old normal adults than in old graphic designers, and greater in old graphic designers than in young adults.

Stimulus Materials

The analyses were based on a selection of the 48 trials with 20-item noun lists administered in Sessions 14 to 25. The 48 trials consisted of four different lists presented four times at three different presentation rates (7.5 s per word, 4.5 s per word, and 1.5 s per word). The four lists are displayed in Table A-3 of Appendix A. Within-list similarity of nouns (low vs. high) was varied at two levels of imagery (high vs. low). Nouns for the low-similarity lists were taken from the norms provided by Baschek, Bredenkamp, Öhrle, and Wippich (1977). According to the norms, average imagery scores were 6.34 for the high-imagery, low-similarity list and 3.91 for the low-imagery, low-similarity list.[34] High-similarity lists were constructed with the sole purpose of maximizing similarity. The high-imagery, high-similarity list consisted of names representing 20 different fluid-holding containers. The low-imagery, high-similarity list was made up of 20 nouns which denote cause-effect relationships.

Since no imagery norms were available for most of the nouns in the high-similarity lists, nouns from all four lists were rated for imagery, using the procedure described by Baschek, Bredenkamp, Öhrle, and Wippich (1977; cf. Paivio, Yuille, & Madigan, 1968). The aim of the rating was to make sure that the high-similarity lists were matched in average imagery with their low-similarity counterparts. Ten adults (mean age: 26.3 years; age range: 24–32 years) participated in the rating process. Nouns from all four lists were presented in two different random orders. Table 10 displays the mean imagery ratings of the four lists averaged across raters. Data were analyzed with a list (4) repeated measures analysis of variance. Three orthogonal contrasts were specified. The first tested the two high-imagery lists against the two low-imagery lists. The second and the third contrast tested for differences in imagery level between lists which were expected to be equally imageable. As expected, only the first contrast was significant [$F(1,9) = 347.38; p < .01$; $p > .5$ for the two remaining contrasts]. There was no overlap in the mean rating of nouns assigned to the two imagery levels.[35]

Data Analysis

An inspection of the data revealed that the three groups differed markedly in the average number of confusion errors (old normal adults: $x = 4.0$; $SD = 1.2$; old graphic designers: $x = 2.9$; $SD = 1.3$; young adults: $x = 1.0$; $SD = 0.3$). These overall differences in confusion errors may be interpreted as group differences in discriminability. The more parsimonious interpretation, however, is to consider the differences as an artifact of group differences in correct recall. As has been reported in the context of Predictions

[34]The high-imagery, low-similarity list was matched in imagery, concreteness, meaningfulness, word length, and word frequency with the five lists administered in Sessions 6 to 13 and Session 26 (see also Table A-6 in Appendix A).

[35]When average imagery ratings regarding the two low-similarity lists are compared with the ratings provided by Baschek et al. (1977), it appears that the present raters tended to give lower ratings than reported by Baschek et al. (1977) in the case of the low-imagery list (2.45 vs. 3.91), and that they did not differ much from the norms in the case of the high-imagery list (6.23 vs. 6.34). The presence of lower values for the low-imagery list in the present sample of raters was probably due to the fact that extremely low-ranking words were less frequent in the present rating procedures than in the set of nouns used by Baschek et al. (1977), and that nouns in the middle range (i.e., with a rating between 4.50 and 6.00) were rare.

Table 10
Mean Ratings of Imageability (I)

List		I
HI LS	(High imagery, low similarity)	6.23 (.6)
HI HS	(High imagery, high similarity)	6.32 (.5)
LI LS	(Low imagery, low similarity)	2.45 (.7)
LI HS	(Low imagery, high similarity)	2.41 (.6)

Note. $N = 10$. Rating procedures followed Baschek, Bredenkamp, Öhrle, and Wippich (1977).

2 and 3, young adults recalled about 76% of the words in correct serial position, old graphic designers 45%, and old normal adults about 25%. Thus, the opportunity to commit confusion errors differed considerably across groups.

A better way to provide valuable evidence with respect to the issue of group differences in discriminability is to investigate whether groups differed in the number of confusion errors at equal levels of correct recall. Under equal recall conditions, differences in confusion errors would point directly to group differences in discriminability. For this reason, groups were equated in the level of correct recall on a given list before analyzing the possible existence of group differences in confusion errors. As can be seen in Table B-2 in Appendix B, the approximation of equal recall levels was achieved by help of the fact that the four 20-item noun lists had been administered at three different presentation rates.

A total of three matches in recall level could be obtained, two regarding old graphic designers and young adults and one regarding old graphic designers and old normal adults. With respect to high-imagery lists, old graphic designers working with a 4.5 s presentation rate had about the same number of correct responses as young adults with a 1.5 s presentation rate. Second, with respect to low-imagery lists, old graphic designers needed 7.5 seconds to achieve the same level of correct recall as young adults with 1.5 seconds. With respect to old graphic designers and old normal adults, only a match for high-imagery lists was obtained. Old graphic designers' level of correct recall with the 1.5 s rate was about the same as old normal adults' performance with the 4.5 s rate. Six one-way analyses of variance with correct responses as the dependent variable were computed to examine whether groups differed in recall level. No significant differences in correct recall were found (all $ps > .1$).[36] Reliability coefficients (Cronbach's α) for correct responses and confusion errors are displayed in Table 11. Given the small sample size ($N = 6$ within groups) and the small number of items (i. e., four trials per scale), reliabilities were considered satisfactory.

[36]In all six cases, the test for homogeneity of variances (Bartlett-Box F) was not significant (all $ps > .07$).

Three separate Group (2) x List (2) analyses of variance were computed to investigate whether groups differed in the number of confusion errors and/or in the magnitude of the similarity effect (see also Figures 9, 10, and 11). As summarized in Table 12, the three analyses led to similar results. A significant effect of list confirmed the finding that high-similarity lists were associated with a greater number of confusion errors than low-similarity lists. At the same time, groups differed neither in the number of confusion errors nor in the magnitude of the list effect.

Summary

In the present section, it was explored whether the three groups differed in the discriminability of visual images. Discriminability was conceived as a secondary aspect

Table 11
Discriminability Analyses: Reliability Coefficients (Cronbach's Alpha) of Composite Scores

Composite	Total sample N = 18	Old normal N = 6	Old expert N = 6	Young adults
HI LS 4.5	.97 (.89)	.92 (.79)	.83 (.45)	
HI HS 4.5	.96 (.82)	.84 (.55)	.85 (.79)	
HI LS 1.5	.96 (.78)		.82 (.83)	.86 (.83)
HI HS 1.5	.91 (.83)		.73 (.81)	.79 (.87)
LI LS 7.5	.96 (.87)		.75 (.77)	
LI HS 7.5	.97 (.77)		.93 (.62)	
LI LS 1.5	.93 (.65)			.83 (.45)
LI HS 1.5	.92 (.72)			.74 (.68)

Note. Composites are described as a combination of imagery level (HI = high, LI = low), within-list similarity (LS = low, HS = high), and presentation rate (seconds per word). Values without parentheses refer to correct responses. Values in parentheses refer to confusion errors.

Table 12
Group Differences in Confusion Errors at Equal Levels of Correct Recall: Summary of Analyses (F-Values)

Old normals	Old experts	Young adults	List	Group	Group-by-list
— —	HI 4.5	HI 1.5	33.81[a]	0.24	2.78
— —	LI 7.5	LI 1.5	19.89[a]	2.91	0.02
HI 4.5	HI 1.5	— —	22.39[a]	0.00	0.07

Note. For all analyses, $df = 1,10$. Composites are indicated as a combination of imagery-level (HI = high, LI = low) and presentation rate (e.g., 4.5 = 4.5 seconds per word). At each imagery level, performance with the low-similarity list was tested against performance with the high-imagery list. In all three analyses, Box's M test for homogeneity of variance-covariance matrices was not significant (all $ps > .1$).

[a] $p < .01$.

Figure 9
Confusion Errors with High-Imagery Lists in Old Experts and Young Adults

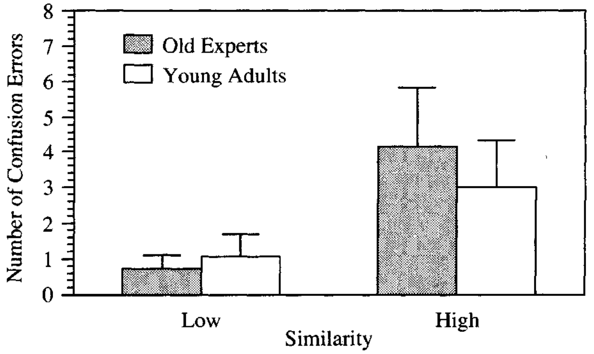


Figure 10
Confusion Errors with Low-Imagery Lists in Old Experts and Young Adults

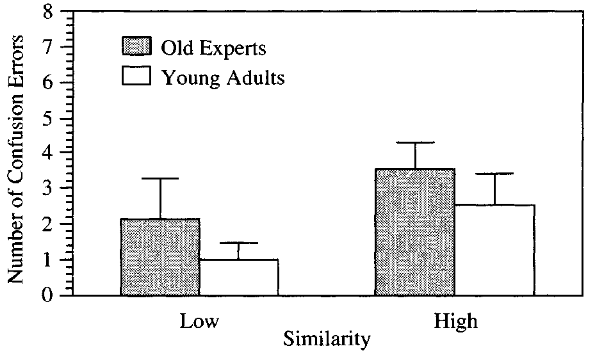
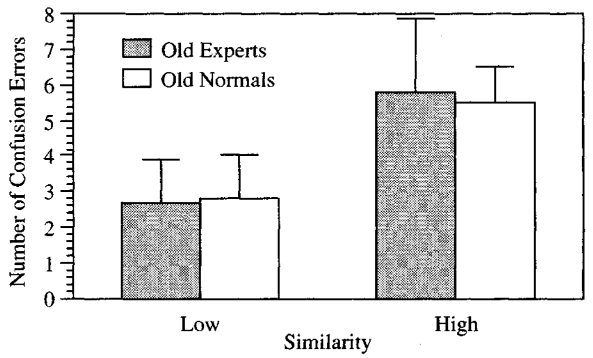


Figure 11
Confusion Errors with High-Imagery Lists in Old Experts and Old Normal Adults



Note. Vertical lines indicate the upper boundary of the 90% confidence interval of the mean. Comparison groups did not differ in the average level of correct recall (see also Table 11).

of memory functioning with the *Method of Loci.* Therefore, the existence of group differences in confusion errors, which were employed as an indicator of lack in discriminability, was investigated at equal levels of correct recall. To obtain evidence in the form of group-by-treatment interactions, the degree of discriminability was experimentally manipulated by providing lists with similar and dissimilar nouns.

The experimental manipulation worked in the expected direction: Lists with similar nouns led to a higher number of confusion errors than lists with dissimilar nouns. This finding supports the view that discriminability is an important aspect of memory functioning with the *Method of Loci.* However, the magnitude of the list effect did not differ significantly between adjacent groups. In addition, old graphic designers did not commit a significantly smaller number of confusion errors than old normal adults, and they did not commit a significantly greater number of confusion errors than young adults. Thus, neither the expected group-by-list interaction (Prediction 7a) nor the expected difference in level (Prediction 7b) was observed. The results were inconsistent with the hypothesis that old graphic designers, due to their professional expertise, would form more discriminable images than old normal adults. They were also inconsistent with the hypothesis of an age-related decrement in discriminability.

At this point, two comments are in order. The first concerns other studies which found evidence in favor of age-related differences in discriminability (e.g., Craik & Byrd, 1982; Hess & Higgins, 1983; Rankin & Kausler, 1979). Such results may have been due to the fact that young and old subjects were not equated on a primary response characteristic such as correct recall. Instead, differences in the primary variable itself were interpreted in terms of discriminability, distinctiveness, or interference. If this data-analytic procedure had been employed in the present study, group differences in discriminability would have been observed.

The second comment concerns the discriminability of visual images in old graphic designers. The present data do not support the hypothesis that old graphic designers generate more discriminable visual images than old normal adults. This finding appears to be inconsistent with the performance of old graphic designers on the "Parallel Lines" subtest of the Torrance visual creativity test. In this test, old graphic designers obtained especially high scores on two dimensions, originality and elaboration (see also Table 5, p. 67). Given that drawings with high ratings on these dimensions excel in discriminability, one is faced with the situation that old graphic designers produced drawings of high discriminability, but visual images of average discriminability. Of course, the two tasks varied on many dimensions so that no firm conclusions can be drawn regarding the source of this dissociation. However, it seems that interindividual differences in specific aspects of drawings are not directly connected to interindividual differences in corresponding dimensions of visual imagery.[37]

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[37] At the end of the experiment (Session 27), subjects in all groups were asked to provide drawings related to the visual images that they had generated in the context of the *Method of Loci* (for details, see p. 75 of the Method section). As an extension of the present work, it is planned to rate these drawings on several dimensions, such as use of color, dimensionality, etc. This procedure may allow for a more direct investigation of the relationship between visual images and drawings.

Recall Performance with Two-Digit Numbers (Prediction 8)

The hypothesis that old graphic designers would reach higher levels of mnemonic skill than old normal adults was based on the assumption that the generation of visual images is an important, if not critical element of skill in memory performance with the *Method of Loci,* and that old graphic designers, due to their professional expertise and/or task-related specific abilities, are better able to generate interactive visual images at encoding. The administration of a list with 20 two-digit numbers during the Test Phase served as a specific test of the hypothesis that the advantage of old graphic designers is restricted to the visual image generation component. It was assumed that subjects in all groups would not be able to recode two-digit numbers into visual images (cf. Bellezza, 1981; Kliegl, Smith, Heckhausen, & Baltes, 1986, 1987). In this situation, the Digit List was expected to function as a working memory measure unrelated to visual image generation (and largely unaffected by mnemonic training). Therefore, it was predicted that old graphic designers and old normal subjects would not differ in the cued serial recall of two-digit numbers.

The statistical analysis was based on the average of the four trials with the Digit List. Old normal adults, old graphic designers, and young adults recalled 3.2 ($SD = .9$), 3.5 ($SD = .7$), and 6.8 ($SD = 2.6$) two-digit numbers in correct serial position, respectively. A one-way analysis of variance indicated that old graphic designers did not differ from old normal subjects [$F(1,10) = .54$; $p > .4$].[38] The results were consistent with the prediction that the two groups of old subjects would not differ in recall level when the visual image generation component of the task is disabled.

It is possible that the absence of group differences was not caused by the type of material but by the presentation rate of 1.5 s per word. Differences in cued serial recall between old graphic designers and old normal adults may generally be absent at this presentation rate. To examine this possibility, a Group (2) x List (3) analysis of variance with repeated measures on the list factor was computed. The three lists were the two high-imagery 20-item noun lists presented at the 1.5 s rate and the Digit List (see Figure 12). A contrast was defined for list, testing the average recall performance with the two high-imagery lists against the Digit List. A significant group-by-list interaction was found [$F(1,10) = 10.27$; $p < .01$].[39] The difference between the two high-imagery lists and the Digit List was more pronounced in old graphic designers than in old normal adults. With the two high-imagery lists, old graphic designers recalled more words than old normal adults [$t(10) = -2.90$; $p < .05$]. Old normal adults showed about the same level of recall on all three lists. This suggests that the absence of group differences between old graphic designers and old normal adults with the Digit List was not only due to the rate at which the list was presented.

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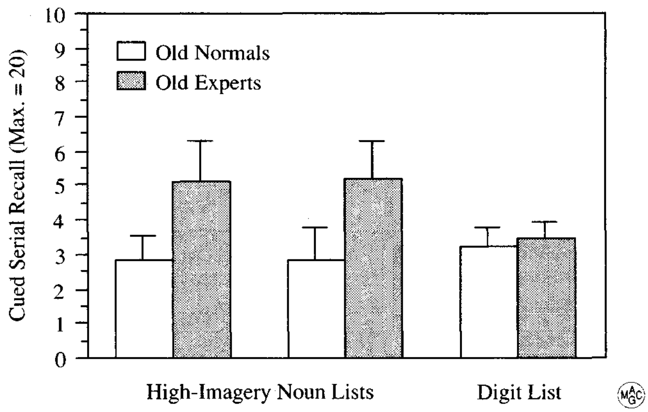
[38]Young adults were not included in this analysis. The test for homogeneity of variances was not significant (Bartlett-Box $F = 0.18$; $p > .1$).

[39]Box's M test for homogeneity of variance-covariance matrices was not significant [$F(6,724) = 0.49$; $p > .1$].

Figure 12
Cued Serial Recall in Old Experts and Old Normal Adults at the 1.5 s Presentation Rate



Note. Vertical lines indicate the upper boundary of the 90% confidence interval of the mean.

Predictors of Mnemonic Skill

The third group of predictions addressed the extent to which psychometric markers of cognitive abilities and chronological age predict group differences in cued serial word recall with the *Method of Loci.* Three measures—Card Rotation, Surface Development, and the Vividness of Visual Imagery Questionnaire (VVIQ)—were included as potential predictors of interindividual differences in mnemonic skill. Card Rotation and Surface Development served as marker tests of spatial visualization.[40] According to Carroll (1974), both tests require the transformation of a spatial configuration in short-term visual memory. Surface Development is more complex than Card Rotation because it requires the additional component of performing an entire series of transformation to arrive at the correct solution. The VVIQ is a self-rating questionnaire of imagery vividness which was included for exploratory reasons. No specific predictions regarding its relationship to objective measures were made.[41]

Description of Measures

Card Rotation

The subject is shown a card with a drawing of a more or less irregular shape at the left side of the test form (cf. Ekstrom, French, & Harman, 1976, p. 150). Eight other drawings of the same card are to its right. These drawings are either merely rotated or turned over to the other side (i. e., reflected). Subjects have to indicate whether or not the card has been turned over. Subjects are given ten minutes to work on ten drawings. The

[40]Card Rotation and Surface Development load on two different first-order factors, Spatial Orientation and Spatial Visualization (cf. Ekstrom, French, & Harman, 1976). Cattell (1971) described Spatial Visualization as a second-order factor with a strong relationship to fluid intelligence. Both Card Rotation and Surface Development would load on this second-order factor.

[41]Tests were administered in Sessions 1 and 2 (see also the Method section). Table 7 (p. 70) indicates the reliability of all tests and their source.

test score is based on the number of correct answers minus the number of wrong answers, and subjects are asked to work as quickly as they can without loss of accuracy.

Surface Development
In this test, drawings of solid forms are presented that could be made with paper or sheet metal (cf. Ekstrom, French, & Harman, 1976, p. 174). With each drawing, there is a diagram showing how a piece of paper might be cut and folded so as to make the solid form. Dotted lines show where the paper is folded. One part of the diagram is marked to correspond to a marked surface of the drawing. Subjects have to indicate which of the lettered edges in the drawing correspond to the numbered edges or dotted lines in the diagram. The test has a total of 30 items, five in each of the six drawings, and the test lasts for six minutes. Again, scoring is based on the number of correct answers minus the number of wrong answers.[42]

VVIQ
The VVIQ (Vividness of Visual Imagery Questionnaire) is a 16-item scale in which subjects are asked to form visual images of various scenes. Each image is rated on a 7-point scale, ranging from "perfectly clear" (rating of 1) to "no image at all" (rating of 7). Thus, low scores denote high self-ratings of imagery vividness.

Overview of Group Differences and Correlations

Table 13 reports means, standard deviations, and group differences (*T*-tests) for the three measures described above and for a composite of Card Rotation and Surface Development which was employed in the hierarchical regression analyses reported below.[43] Correlations among all psychometric measures of the present study, cued serial recall with the *Method of Loci* at different points in time, and chronological age are reported in Table 14. Correlations are listed separately for the total sample ($N = 18$) and for the subsample of old adults ($N = 12$). Within the subsample of old adults, age was negatively related to mnemonic performance and positively related to the VVIQ [$r(12) = .76$; $p < .01$]. Low scores on the VVIQ denote high self-ratings of imagery vividness. Therefore, the positive correlation with age means that older adults gave lower self-ratings of imagery vividness. The two findings cannot be explained by group differences between old graphic designers and old normal adults because the two groups did not differ in chronological age.

In this context, one should note that the two samples of older adults covered a rather wide age range (i.e., 64–81 years). Recent reports from longitudinal studies have evidence in favor of an acceleration of age-related decline in cognitive functioning around the age of 70 (Schaie, 1983). The present findings would be consistent with the hypothesis that this effect is especially pronounced when individuals are tested to investigate the upper range of their cognitive potential.

These considerations do not explain the rather high correlation between the VVIQ and chronological age within the present sample of older adults. Given that little is known about changes in self-ratings of visual imagery in old age, and given that the relationship between self-ratings of imagery and objective measures of performance is unclear (Ernest, 1977), no interpretation of this finding is attempted here.

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[42]In the case of the two spatial reasoning tests, German versions of the instructions were adapted with minor modifications from Scholl (1976).

[43]Information about means, standard deviations, and associated *T*-tests for Digit Symbol Substitution, Digit Span, and Vocabulary are displayed in Table 6 (p. 69). Results of the "Parallel Lines" visual creativity test are reported in Table 5, p. 67.

Table 13
Means (SD) and *T*-Tests for Card Rotation, Surface Development, VVIQ, Digit Symbol Substitution, and the "Parallel Lines" Subtest of the Torrance

	Old normals	Old experts	Young adults	Old experts vs. old normals	Old experts vs. young adults
Card Rotation	25.2 (8.2)	50.2 (13.4)	60.0 (25.1)	+3.77 $p < .01$	−1.48 ns
Surface Development	.3 (2.1)	9.2 (10.9)	21.0 (7.3)	+2.00 $0.25 < p < .1$	−2.68 $p < .025$
Spatial visualization composite					
VVIQ	1.6 (.5)	1.6 (.4)	1.9 (.5)	−0.11 ns	−1.16 ns

Note. Numbers regarding the two contrasts refer to *T*-values ($df = 15$; trends with $.025 < p < .1$ are reported; *ns* = not significant). Card Rotation and Surface Development were adapted from Ekstrom, French, and Harman (1976). The spatial visualization composite is based on the average of the *T*-transformed scores (i. e., $x = 50$, $SD = 10$) of Card Rotation and Surface Development. The variable is included here because it was employed in hierarchical regression analyses reported below (i. e., Prediction 10). The VVIQ (Vividness of Visual Imagery Questionnaire) is a self-rating scale of imagery vividness and was translated from Marks (1973). With the VVIQ, low scores denote high self-ratings of imagery vividness.

Spatial Visualization and Mnemonic Skill (Prediction 9)

Prediction 9 referred to the validity of spatial visualization tests in predicting cued serial recall with the *Method of Loci.* Surface Development and Card Rotation functioned as marker tests of spatial visualization. As such, they were assumed to measure individual differences in the generation of visual images. According to the literature reviewed above (pp. 44–49), memory functioning with the *Method of Loci* is positively related to the use of interactive visual imagery. Therefore, tests of spatial visualization were expected to predict interindividual differences in serial recall with the *Method of Loci.*

To examine this issue, the two tests of spatial visualization, Card Rotation and Surface Development, were *T*-transformed and combined into a single measure. Figure 13 illustrates the relationship between the spatial visualization composite and cued serial recall with the *Method of Loci.* The two measures were highly correlated in the total sample [$r(18) = .83$; $p < .01$]. The relationship between the two measures remained significant after partialing out chronological age [$r(15) = .64$; $p < .01$]. Given that spatial visualization tests and cued serial recall with the *Method of Loci* differ greatly at the surface level, the magnitude of the relationship is remarkable. It supports the hypothesis that success in both types of tasks is critically dependent upon the generation and transformation of visual images.[44]

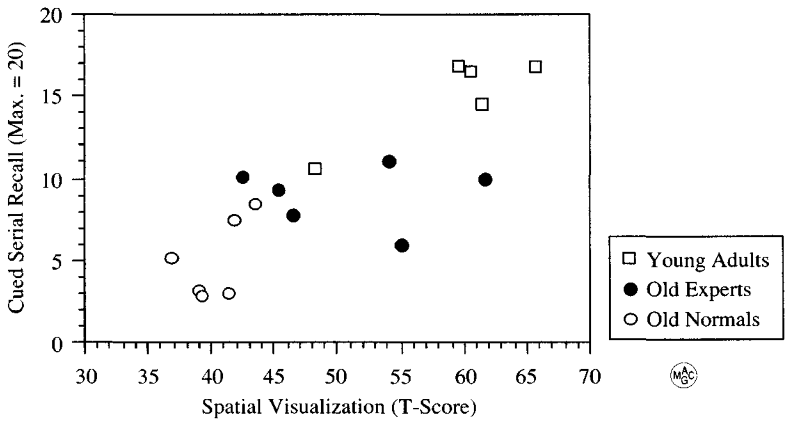
[44]As can be seen in Figure 13, the relationship between spatial visualization and mnemonic skill was much less pronounced in old graphic designers than in the two other groups. No interpretation of this difference is attempted here.

Table 14
Correlations Between Psychometric Markers and Mnemonic Skill for the Total Sample and the Subsample of Older Adults

	Psychometric markers							Mnemonic skill							Age
	CR	SD	PL	VVIQ	DSS	DSP	VOC	Session 6	12	13		14–25		26	
								Pres. rate 4.5	4.5	1.5	7.5	4.5	1.5	1.5	
Total sample N = 18															
Psychometric markers															
Card Rotation															*–.57*
Surface Development	*.77*														*–.72*
Parallel Lines	*.45*	.22													.07
VVIQ	.00	.06	–.31												–.19
Digit Symbol	*.46*	*.48*	–.11	.01											*–.64*
Digit Span	.31	*.55*	–.07	.30	.33										–.33
Vocabulary	.06	–.04	–.06	.01	*.47*	.00									–.13
Mnemonic skill															
6 4.5	*.72*	*.82*	.27	.01	*.56*	.30	.03								*–.86*
12 4.5	*.78*	*.78*	.35	.02	*.56*	.31	–.01	*.97*							*–.82*
13 1.5	*.64*	*.79*	.08	.11	*.52*	.39	–.05	*.87*	*.87*						*–.88*
14 - 25 7.5	*.78*	*.79*	.37	.00	*.57*	.33	.02	*.96*	*.99*	*.88*					*–.82*
14 - 25 4.5	*.74*	*.82*	.25	.01	*.58*	.38	.02	*.97*	*.98*	*.94*	*.99*				*–.87*
14 - 25 1.5	*.66*	*.77*	.14	.09	*.59*	.33	.04	*.87*	*.88*	*.97*	*.89*	*.93*			*–.89*
26 1.5	*.67*	*.77*	.17	.06	*.59*	.31	–.01	*.94*	*.94*	*.96*	*.93*	*.96*	*.97*		*–.88*
Old adults N = 12															
Psychometric Markers															
Card Rotation															.01
Surface Development	*.62*														–.29
Parallel Lines	*.65*	.36													–.37
VVIQ	–.06	–.13	–.23												*.76*
Digit Symbol	.04	.20	–.12	–.28											–.27
Digit Span	.12	.37	–.16	.23	.45										.24
Vocabulary	–.07	–.14	–.17	–.17	*.52*	–.08									–.18
Mnemonic Skill															
6 4.5	*.56*	*.61*	*.69*	*–.50*	.23	–.03	–.01								*–.64*
12 4.5	*.65*	.50	*.77*	–.39	.19	.01	–.12	*.92*							–.49
13 1.5	.27	.41	.47	–.44	.09	.06	–.21	*.79*	*.82*						*–.67*
14 - 25 7.5	*.63*	.47	*.76*	–.41	.26	–.01	–.06	*.92*	*.98*	*.82*					*–.57*
14 - 25 4.5	*.56*	*.51*	*.67*	–.47	.31	.03	–.04	*.94*	*.97*	*.88*	*.98*				*–.62*
14 - 25 1.5	.38	.27	*.70*	*–.54*	.26	–.11	.07	*.81*	*.86*	*.80*	*.89*	*.90*			*–.70*
26 1.5	.45	.43	*.67*	*–.54*	.19	–.01	–.07	*.90*	*.95*	*.91*	*.92*	*.95*	*.91*		*–.64*

Note. Significant correlations ($p < .05$) are set in italics. With the VVIQ, low scores denote high self-ratings of imagery vividness.

Figure 13
Correlation Between Spatial Visualization
and Mnemonic Skill



The Unique Contribution of Chronological Age (Prediction 10)

According to Prediction 10, novel (formerly latent) variance uniquely related to age would emerge in the course of mnemonic training. Age-related variance not explained by marker tests of mental speed, spatial visualization, and visual creativity was expected to increase in the course of training. The prediction was based on two assumptions: First, that interindividual differences in mnemonic skill are increasingly determined by differences in developmental reserve capacity (maximum learning potential); second, that developmental reserve capacity decreases with age.

Data Analysis

A series of multiple hierarchical regression analyses was computed to analyze the data.[45] Three variables—the spatial visualization composite, the "Parallel Lines" visual creativity test of the Torrance, and Digit Symbol Substitution—were entered in a first step, and age group was entered in a second step. Table 15 displays semipartial correlations (i.e., β-coefficients) between the three psychometric markers and cued serial recall for different phases of the experiment. The table also indicates changes in multiple correlation coefficients (R^2) due to age group at different time points of the experiment.[46]

Throughout the entire period of 21 sessions with the *Method of Loci,* age group always accounted for more than 11% of the interindividual differences in cued serial recall after controlling for differences in Digit Symbol Substitution, Spatial Visualiza-

[45]The specification of a latent growth curve which models the hypothesized increase in the effect of chronological age would have provided a better test of Prediction 10 (cf. McArdle & Epstein, 1988). Small sample size precluded the use of this data-analytic procedure (cf. Boomsma, 1982; Marsh, Balla, & McDonald, 1988).

Table 15
Results of Seven Hierarchical Multiple Regression Analyses of Cued Serial Recall on Cognitive Abilities Assessed Prior to Training

Session	6	12	13	14–25	14–25	14–25	26
Presentation rate (s/word)	4.5	4.5	1.5	7.5	4.5	1.5	1.5
Spatial Visualization	*.69*	*.65*	*.76*	*.64*	*.70*	*.65*	*.65*
"Parallel Lines"	.04	.14	–.18	.17	.02	–.06	–.03
DSS	.23	.25	.13	.27	.24	.26	.26
R^2	*.70* (.64)	*.73* (.67)	*.63* (.55)	*.75* (.69)	*.73* (.67)	*.64* (.56)	*.64* (.57)
R^2-change due to age group	*.11*	*.12*	*.15*	*.11*	*.12*	*.18*	*.16*

Note. Values are standardized regression coefficients (i. e., semi-partial correlations). Italicized coefficients were significant at the 5% level. Adjusted R^2-values are reported in parentheses. Spatial visualization was a composite of Card Rotation and Surface Development (Ekstrom, French, & Harman, 1976). The "Parallel Lines" visual creativity test was taken from the Torrance Tests of Creative Thinking: Thinking Creatively with Pictures, Form A (Torrance, 1966a, 1966b). The Digit Symbol Substitution test (DSS) was taken from Wechsler (1964).

tion, and the "Parallel Lines" subtest of the Torrance. Given that these three psychometric markers already explained between 64% and 75% of the variance, the amount of variance uniquely related to age group was remarkably high.

An inspection of Table 15 reveals that the magnitude of R^2-changes due to age group varied with presentation rate: Changes at the 1.5 s rate were larger than changes at the 7.5 s and 4.5 s rates. This was probably due to the finding reported earlier that more difficult task conditions (such as those with faster presentation rates) minimized group differences between old graphic designers and old normal adults and maximized differences between old graphic designers and young adults (see also pp. 82–84). In the context of Prediction 10, cued serial recall at the 4.5 s rate is particularly informative because this rate was presented at the beginning and close to the end of the training program. Contrary to expectations, the amount of variance uniquely related to age did not increase significantly over time (Session 6: 11%; Session 12: 12%; Sessions 14–25: 12%).

The situation was somewhat different in the case of cued serial recall at the 1.5 s rate (Session 13: 15%; Sessions 14–25: 18 %; Session 26: 16%). To test the significance of the difference between Session 13 and Sessions 14 to 25, a regression analysis was computed, with recall performance in Sessions 14 to 25 serving as the dependent variable.

[46]Age group, rather than chronological age itself, was employed in the present set of analyses to provide a more direct link to group differences in mnemonic skill reported above. Analyses with chronological age as a predictor led to virtually identical results. Age group was coded as a dummy variable (0: old adults, 1: young adults). For all regression analyses, the effect of expertise status (0: young adults and old normal adults, 1: old graphic designers) was entered in a third step. No significant changes in R^2 were expected because the "Parallel Lines" subtest of the Torrance was assumed to function as a marker variable of professional expertise. Expertise status led to a significant increase in explained variance in Session 12 (R^2-change: .06; $p < .05$); in all other cases, no significant R^2-changes were observed.

The set of psychometric predictors and mnemonic performance in Session 13 was entered in a first step, and age group was entered in a second step. The increase in the amount of explained variance after entering age group was not significant (R^2-change $= .01; p > .1$).

Interpretation

It was expected that the amount of variance in mnemonic skill uniquely related to chronological age would increase as individuals approach their functional limits. A series of hierarchical regression analyses were computed to test this prediction. The amount of age-related variance was significant throughout the training program, but no significant increase in age-related variance was observed. Thus, the data were not consistent with Prediction 10.

The relative stability of age-related differences in mnemonic performance over time can be interpreted in two different ways. First, it is possible that the expected change in measurement context was not captured within the limited amount of mnemonic experience provided in the present experiment. Second, it is possible that mnemonic performance immediately after instruction was already a good predictor of age-related differences near maximum levels of functioning. The magnitude of the age difference in mnemonic skill is more consistent with the second view.[47]

In concluding this section, a cautionary note is in order. It is possible that other measures of cognitive ability administered prior to training would have explained at least a portion of the unique contribution of age group. Measures of learnability (cf. Guthke, 1982) or a measure of paired-associate learning without imagery instructions should be noted in this context.

Visual Creativity and Recall Level in Old Experts and Old Normal Adults (Prediction 11)

Prediction 11 concerned the source of the difference in cued serial recall between old graphic designers and old normal adults. The two groups were expected not to differ in cued serial recall with the *Method of Loci* after statistically controlling for differences on the "Parallel Lines" visual creativity test. The "Parallel Lines" test was regarded as a valid measure of professional expertise in graphic design. Therefore, it was predicted that differences in cued serial recall between the two groups of old adults would be explainable in terms of individual differences on this test.

To test this prediction, an analysis of covariance was computed, with Group (2) as a between-subjects factor and the score on the "Parallel Lines" subtest as a covariate.

[47]In a recent age-comparative training study with the *Method of Loci*, age differences were magnified immediately after instruction in the mnemonic device, especially on tests at slow presentation rates (i.e., 10 s and below; cf. Kliegl, Smith, & Baltes, 1989b). In this study, a similar series of regression analyses was reported. The amount of variance uniquely due to age group was smaller, but increased from 3% immediately after instruction in the *Method of Loci* to 10% at posttest. In contrast to the present data, the contribution of a marker test of spatial visualization (Card Rotation) dropped to a nonsignificant level as participants moved through the intervention program.

The dependent variable was the same as for Predictions 2 and 3 (i.e., the average level of cued serial recall on the 48 trials with 20-item noun lists from Sessions 14–25). The covariate explained a significant amount of variance [$F(1,9) = 11.42$; $p < .01$]. The remaining difference in cued serial between the two groups was not significant [$F(1,9) = 1.22$; $p < .1$].[48] This result was consistent with the prediction. Given that old graphic designers exhibited higher scores on both measures, a dependency between the two measures was expected for statistical reasons. Nevertheless, the complete elimination of group differences in cued serial recall between the two groups after statistically controlling for differences in visual creativity gives further support to the hypothesis that the advantage of old graphic designers over old normal adults is confined to the visual image generation component of the *Method of Loci.*

Summary of Results

The present study investigated the effects of professional expertise and task-relevant cognitive ability on the range of cognitive plasticity in old age. Professional experience was conceived as an important developmental agent in adult life which provides large amounts of practice in specific aspects of cognitive functioning. Thus, it was hypothesized that cognitive plasticity in old age is greater in older persons whose professional life history included task-relevant activity than in older persons without such specific life experiences.

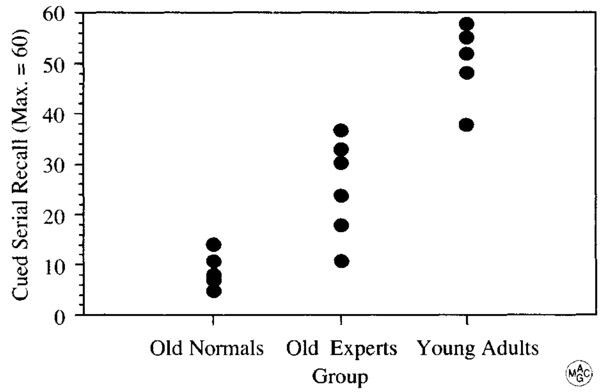
This hypothesis was investigated in the domain of imagery-based memory functioning. A group of old expert graphic designers, a group of old normal adults of comparable intelligence, and a group of young adults were instructed and trained in the *Method of Loci* (Bower, 1970a). Based on the literature on memory functioning with the *Method of Loci,* the generation of visual images was assumed to play a major, if not critical, role in producing interindividual differences in the level of serial recall.

In comparison to most other work devoted to the theme of aging-experience relationships, the distinguishing feature of the present study was the attempt to investigate the moderation of age differences through experience near maximum limits of functioning. For this purpose, individuals participated in a 21-session training program with the *Method of Loci.* Professional expertise in graphic design was predicted to attenuate, rather than eliminate, age-related differences in recall performance.

The results of the experiment were consistent with this expectation. Throughout the entire experiment, old graphic designers reached higher levels of mnemonic skill than old normal adults (Prediction 2), but performed considerably below the level of young adults (Prediction 3). As a further illustration of this finding, Figure 14 displays the best performance of each subject with the 60-item noun list presented at the slower of

[48]In a separate analysis, the interaction between group and the covariate was tested for significance. The interaction term was not significant [$F(1,8) = 0.19$; $p > .6$]. Thus, the assumption of parallel regression slopes was not rejected by the data.

Figure 14
Top Performances with the 60-Item Noun List at the 7.5 s Rate: Individual Data



the two presentation rates (i.e., at a rate of 7.5 s per word). The best old graphic designer recalled 37 words in correct serial position and the best young adult recalled 58 words. The amount of overlap between the two groups was minimal. At the same time, the recall performance of old graphic designers was clearly superior to the performance of old normal adults.

The significance of these findings for the issue of age differences near limits of cognitive functioning was reduced by the fact that individuals did not approximate their functional limits prior to the beginning of the Test Phase (i.e., Prediction 4 was not confirmed by the data). However, given the magnitude of observed group differences, the absence of significant group-by-time interactions in favor of the old, and the stability of interindividual differences in cued serial recall, the argument was made that the present data reflect group differences in developmental reserve capacity and are probably highly predictive of group differences near limits of functioning. In other words, although it is likely that individuals in all groups would have continued to improve their level of mnemonic skill if the intervention had been continued, it appears unlikely that these possible future gains in recall performance would have led to important changes in the pattern of group differences.

Results pertaining to the first category of predictions (group differences in cued serial recall) can be summarized in three points. First, the existence of training gains in all groups was consistent with the proposition that cognitive plasticity or the potential to profit from new experience is not lost among healthy older adults. At the same time, the data are consistent with the proposition that the upper range of cognitive plasticity is reduced as a consequence of normal aging. Third, the data suggest that task-relevant professional experience attenuates, rather than eliminates, the consequences of this age-related reduction in developmental reserve capacity.

At the processual level of analysis, the data were consistent with Predictions 5, 6, and 8, but inconsistent, or at least inconclusive, with respect to Predictions 7a and 7b. As expected, the magnitude of group differences varied as a function of task difficulty

(Prediction 5), and lower levels of serial recall were associated with an increase in primacy effects (Prediction 6). The association between an increase in primacy and a decrease in serial recall was interpreted in terms of a shift in processing from the *Method of Loci* to verbal rehearsal and/or retention of the first few visual images in working memory. Taken together, the results of the analyses related to Predictions 5 and 6 were consistent with the hypothesis that group differences in cued serial recall were maximized whenever most individuals in one group still employed the *Method of Loci,* whereas most subjects in the other group switched to other, less effective forms of encoding.

Predictions 7a and 7b referred to group differences in the discriminability of visual images. It was expected that old graphic designers would form more discriminable visual images than old normal adults and less discriminable visual images than young adults. Confusion errors were regarded as indicators of lacking discriminability. Results differed depending upon whether groups were equated with respect to the primary variable (i.e., correct recall) by means of the presentation rate manipulation. When no attempt was made to control for differences in correct recall, pronounced group differences in the expected direction were obtained. At equal levels of correct recall, however, neither the two groups of old subjects nor old graphic designers and young adults differed in the number of confusion errors, and no group differences in the effect of within-list similarity were observed.

Based on these findings, it may be concluded that group differences in discriminability were not an important source of group differences in cued serial recall. Rather, it appears that the major difference between groups concerned their ability to generate visual images in the first place. In Bellezza's (1981) terminology, constructability, rather than discriminability, appeared to be the major source of group differences in cued serial recall.

As predicted, old graphic designers and old normal adults did not differ in the cued serial recall of two-digit numbers (Prediction 8). This was consistent with the expectation that differences in recall performance between the two groups would be absent when the generation of interactive visual images was rendered impossible by presenting to-be-remembered items that cannot be visualized at landmark cues. In this context, it should be noted that Prediction 11 from the third category of predictions also received empirical support: Differences in mnemonic skill between old graphic designers and old normal adults were no longer significant after statistically controlling for group differences in the "Parallel Lines" visual creativity test. Together with the absence of differences between old graphic designers and old normal adults on measures of mental speed (Digit Symbol Substitution), crystallized intelligence (Vocabulary), and short-term memory (Digit Span), the two findings strongly suggest that the superiority of old graphic designers over old normal adults was confined to those aspects of cognitive functioning which have been trained in the context of professional experience.

The last group of predictions (i.e., Predictions 9, 10, and 11) concerned the predictability of interindividual differences in mnemonic skill through baseline measures of cognitive ability and chronological age. According to Prediction 9, spatial visualization ability, that is, the ability to generate and transform visual images of twodimensional (Card Rotation) and three-dimensional (Surface Development) objects, would predict interindividual differences in mnemonic skill. In line with this expectation, a significant correlation between an index of mnemonic skill and an index of spatial visualization was obtained [$r(18) = .83$; age-partialed correlation: $r(15) = .64$; both $ps < .01$]. Thus, it appears that spatial visualization ability was an important determinant of interindividual differences in mnemonic performance.

Prediction 10 addressed the unique contribution of chronological age to interindividual differences in mnemonic skill (i.e., the amount of variance not explained by other variables). Age group was expected to become an increasingly better predictor of mnemonic skill in the course of the training program. Such an appearance of "novel" (formerly latent) age-related variance would have been consistent with the theoretical proposition that the role of chronological age increases as individuals approach, and possibly reach, the limits of their capabilities.

The data were not consistent with this prediction. Within presentation rates, age group accounted for a significant but rather relatively stable amount of interindividual variability in mnemonic skill. Two possible interpretations of this finding were offered. According to the first, the amount of mnemonic experience provided in the present experiment was too small to uncover interindividual differences as they would appear near limits of performance. According to the second, mnemonic performance immediately after instruction was already highly predictive of interindividual differences near maximum levels of functioning. A final decision between these two opposing views could not be made, but the magnitude of observed age differences gave some support to the second interpretation.

Results pertaining to Predictions 9, 10, and 11 can be summarized as follows. First, mnemonic skill was highly correlated with spatial visualization (Prediction 9). This finding was consistent with other research stressing the importance of visual processing with the *Method of Loci* (Bower, 1970a; DeBeni & Cornoldi, 1988; DiVesta & Sunshine, 1974; cf. Richardson, 1978). Second, differences in mnemonic skill between old graphic designers and old normal adults were fully explainable in terms of group differences in the "Parallel Lines" visual creativity test (Prediction 11). This test was used as a validation of the professional expertise of old graphic designers. Finally, age group accounted for a significant amount of variance not explained by other predictors of mnemonic skill. Contrary to Prediction 10, this amount did not increase significantly in the course of the experiment.

DISCUSSION

The Attenuation of Age Differences in Mnemonic Skill: Alternatives to an Interpretation in Terms of Expertise

The results of the study seem to demonstrate the beneficial effects of high levels of practice on related aspects of cognitive functioning in old age. However, other interpretations of the results could be possible. First, one may attribute the superiority of old graphic designers over old normal subjects in mnemonic skill to ability rather than expertise. This possibility, which was mentioned earlier in this text, is discussed in more detail below. Second, one may argue that imagery-extraneous variables, such as motivation and life-style, may also have contributed to the superior performance of old graphic designers.

The Confound Between Ability and Expertise

Most probably, old expert graphic designers shared some distinguishing characteristics (interest in arts, high visualization skills, etc.) before they entered the profession. Their decision to become graphic designers can be conceived as the consequence of environmental channeling and genetic predispositions (cf. Lerner & Kauffman, 1985). In addition, it is possible that not all members of the original work cohort were able to stay within the profession for more than 40 years; probably, some of them had to give up their careers as freelance artists at an earlier point in time. These two factors—selective entrance to the job and selective survival—support an ability-based interpretation of the superior performance of old graphic designers.

The term ability as used here refers to differences in performance that are not a consequence of differences in work experience but related to other factors, such as genetic predisposition, early socialization, and general experience. It should be noted that the expertise-ability confound is not restricted to mnemonic performance but also extends to group differences on tests of spatial reasoning. The two tests employed in the present study, Card Rotation and Surface Development, are traditionally used as measures of spatial visualization ability. At the same time, they involve cognitive operations that receive large amounts of practice in graphic design.

The optimal design for estimating the effect of professional expertise in graphic design on mnemonic performance would be to assign graphic students at random to different professional careers, such as graphic designing or civil service, and to repeatedly measure the performance of both groups on imagery-related tasks and other cognitive tasks throughout their lives. A selective increase of differences on imagery-related measures over the years would directly point to differentiating effects of professional experience. This proposal, which combines longitudinal and experimental perspectives, is not realistic but may serve as a point of reference for the evaluation of other, more realistic procedures.

Another procedure would require four instead of three different groups of subjects: old experts, old normal subjects, young novices (i.e., young graphic design students), and young normal subjects. If the difference in performance between the two groups of old adults were to be greater than the difference in performance between the two groups of young adults, the increased gap between old graphic designers and old normal adults would point to the positive effects of professional expertise. By itself, this procedure would not rule out selective survival as an alternative interpretation, because nothing is known about the future professional career of the young novice group. Thus, a conservative test of the expertise hypothesis would require the selection of young novices who are likely to become experts themselves. Moreover, the interpretation of a greater difference in recall performance between the two groups of old subjects in terms of an additional beneficial consequence of expertise would be based on the assumption that ability-related differences in performance remain stable during adulthood, and that work experience has a cumulative effect on cognitive functioning.

As an extension of the doctoral dissertation, six additional subjects have been recruited to arrive at a total of six young graphic design students and six normal young students. The six graphic design students are of good to excellent academic standing. It remains to be seen whether the two groups of young subjects differ less in their level of mnemonic performance than old graphic designers and old normal adults.[49]

The confound between expertise and ability weakens the cogency of the transfer-of-skill argumentation outlined above (*Transfer of Identical Elements,* pp. 30–35), because differences in ability could function as an equally viable basis for predicting an advantage of old graphic designers over old normal adults in mnemonic skill. At the same time, the confound does not compromise the major aim of the present study, the investigation of age-related differences in cognitive plasticity in the domain of imagery-based memory performance. It is most likely that the present sample of old expert graphic designers was biased in both respects: Old experts had probably attained high levels of practice in task-relevant cognitive activity (both cumulative and concurrent), and their task-related "latent" cognitive abilities were probably above average. Thus, the present data suggest that the combined effects of ability and expertise are not sufficient to eliminate the age-related differences in developmental reserve capacity in the domain of imagery-based memory performance.

Motivational Differences

Old graphic designers knew that they were asked to participate in the study because of their expert status, and they were told explicitly to relate the acquisition of the mnemonic technique to their work experience. As excellent professionals, they may have tried as hard as possible to perform well on a task which had some affinity to their work. Furthermore, it was not possible to prevent old graphic designers from knowing who else in their field participated in the study because they all knew each other personally before the experiment. Some of them had been competing with each other as freelance artists for decades. All of them felt that mnemonic training and graphic design both require the generation of "good" visual images and tended to interpret the experiment as a test of their own professional expertise. Thus, old graphic designers may have been extremely motivated to do well on the task for two interrelated reasons: They accepted the mnemonic training program as a test of professional excellence and were eager to outperform their expert colleagues.

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[49]In this context, Salthouse, Babcock, Skovronek, Mitchell, and Palmon (in press) introduced the distinction between *preserved differentiation* and *differential preservation.* Preserved differentiation means that the difference between expert professionals and normal individuals in old age is a mere continuation of (ability-based) differences which existed when the individuals were young. Differential preservation implies that the work experience of experts preserved cognitive abilities which declined in the normal group, with the result that differences in performance between normal individuals and experts become more pronounced with age. The data reported by the authors were consistent with the preserved differentiation view.

The high levels of motivation in old graphic designers would only constitute a problem if there were good reasons to believe that young adults and old normal adults were not highly motivated. It is the impression of the experimenter, however, that individuals in these two groups were as highly motivated as old graphic designers. Old normal adults experienced the entire experiment, and mnemonic training in particular, as a challenging new experience and as an opportunity to engage in "beneficial" mental exercise. Young adults greatly enjoyed their own creative potential and were constantly trying to find even more effective visual images.

Life-Style Differences

Another possible explanation regards the cumulative effect of different life-styles (Thomae, 1981, 1983). In contrast to an explanation in terms of professional expertise, the life-style perspective would claim that generalized differences in attitudes and behaviors rather than domain-specific knowledge are responsible for the superior performance of old graphic designers.

Old normal adults had worked as employees for the major part of their professional life. Old graphic designers, on the other hand, had spent the major portion of their lives as freelance artists, and some were still active in their field of specialization. To make a living, they had established and maintained contacts with galleries, other artists, persons working in the culture department of the public administration, and to persons employed in the public-relations departments of major companies. The necessity to act purposefully in many different situations and to engage in conversations with many different kinds of people may have contributed to a general "openness to experience" (Costa & McCrae, 1980). This openness to experience may have exerted a positive influence on the way in which old graphic designers approached the entire experimental situation.

The best empirical counterargument to the life-style view is the pattern of group differences observed in the present study. Based on generalized differences in attitudes and behaviors, one would expect that old graphic designers would perform better than old normal adults across all tasks and tests. However, differences in performance between old graphic designers and old normal adults were most pronounced for measures of visual or spatial processes and absent for measures not related to visual imagery, such as Digit Span or Digit Symbol Substitution. It is difficult to envision how this pattern of group differences could result from differences in life-style.

Memory Functioning with the *Method of Loci:* Further Observations

The inspection of verbal protocols and drawings suggests that individuals differed greatly in the extent to which they recoded to-be-remembered nouns.[50] Some individuals, especially in the group of old normal adults, almost never departed from the most

[50]Recoding refers to "all the processes and operations that take place after the encoding of the original event and that bring about changes in the engram" (Tulving, 1983, p. 164). With the *Method of Loci,* this includes all operations of the mnemonist that take place after reading the to-be-remembered noun.

conventional meaning of a given item, whereas most individuals in the other two groups varied the meaning of the to-be-remembered word. This was probably done in order to enhance the imageability and/or discriminability of the memory trace.[51]

Two examples may suffice to illustrate the process of recoding in the context of the *Method of Loci.* Table 16 displays a verbal protocol of a young adult working with a low-imagery, high-similarity list at the 7.5 s rate. Apparently, recoding was an important process in the memorization of all landmark–noun combinations. To some extent, to-be-learned nouns were completely replaced by different words that could be visualized more easily. These substitutes were either phonetically similar to the original noun (e. g., *Sultanine* → *Resultat*), or they had some peculiar, idiosyncratic connection to the to-be-learned noun (e. g, *Haarwuchsmittel* → *Wirkung*).

Figure 15, which was drawn by an old expert graphic designer, is another example of recoding. In this case, the word "insight" *(Einsicht)* from the low-imagery, low-similarity list was presented at the National Gallery. The subject made the word more imageable by taking it literally (e. g., "in-sight"). This allowed him to generate a visual image which implicitly contained the meaning of the word, namely, a visitor to the National Gallery who sees a lighted candle placed behind a transparent picture frame.

According to Craik (1983), Bäckman (1985, 1986), and others, older adults are less likely to recode to-be-remembered information than young adults (cf. Hulicka & Grossman, 1967). With the *Method of Loci,* recoding probably requires a great amount of self-initiated processing because the conventional (i.e., most easily processed) meaning has to be inhibited to arrive at a more remote meaning. At the same time, the recoding of abstract, nonvisual concepts into memorable visual configurations and symbols is probably part of the expertise in graphic design (Schmitt, personal communication, August 1988). For instance, graphic designers frequently have to find a pictorial symbol that portrays the "message" of an advertisement.

To summarize, it is possible that differences in the recoding of information also contributed to differences in mnemonic skill between the groups. These considerations are post hoc and were not tested in the present investigation. Possibly, further analyses of verbal protocols and drawings could be instructive in this regard.

Outlook

As is true for most research, the particular set of observations made in the present study was only a subset of a larger set of potential observations that, hypothetically at least, might have been included but were not (cf. Baltes, Reese, & Nesselroade, 1977). In this final section, limitations of the study are summarized, and possible directions for future research are described.

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[51] A description of the procedure with which verbal protocols and drawings were obtained is provided in the Method section (p. 75). Verbal protocols and drawings are available upon request.

Table 16
Verbal Protocol of a Young Adult Working with the Low-Imagery, High-Similarity List: The Role of Recoding[1]

Funkturm Ergebnis, nicht das Ergebnis von Architekten so was zu bauen. Ingenieure bauen so was

ICC die nächste *Folge* von Raumschiff Enterprise, verschiedene Folgen vom Raumschiff Enterprise Enterprise

Lietzensee die *Wirkung,* der Lietzensee mit Haarwuchsmittel voll, sehen sie die Wirkung: überall Haare

Schloß Charlottenburg Anfang, der Anfang ist in der Mitte, und dann nach links und dann rechts

Deutsche Oper der *Effekt,* der Vorführeffekt, wenn die Sänger vorführen wollen, dann kommt kein Ton raus. Der Effekt daß man nicht singen kann

Schillertheater Uroma, Schiller, Harold and Maude, Schiller und so eine Oma[2]

Ernst-Reuter-Platz Bedingung, immer rechts, immer rechts rum, im Gegenuhrzeigersinn, ist die Bedingung

Siegessäule Michael *Ende*[3] vergoldet auf der Siegessäule

Schloß Bellevue das *Ziel* der Tour de France, jetzt Schloß Bellevue, Ziel

Kongreßhalle ist voll gefüllt mit Sultaninen, ausgestopft[4]

Reichstag, der homosexuelle Kongress, *Konsequenz*[5]

Brandenburger Tor Entwicklung, im Osten dauert es viel länger, gehen sie lieber in den Westen

Philharmonie Begin macht Musik, ägyptische Volksmusik[6]

Nationalgalerie der *Prozeß,* ein Bild ist geklaut worden, es gibt einen Prozeß

Staatsbibliothek Bücher über Chemie[7]

KaDeWe der Detektiv läßt es geschehen, daß alles geklaut worden ist[8]

Europa-Center Ausgang, na ja, unten, Ausgang zum ... oben, Ausgang des Liftes

Gedächtniskirche Ablauf, Wasserablauf, ins Taufbecken

Bahnhof Zoo gehen sie vor, ich will noch ein Ticket kaufen, *Vorgang,* vorgehen

Café Kranzler auf dem *Grund* der Tasse: Kaffeesatz

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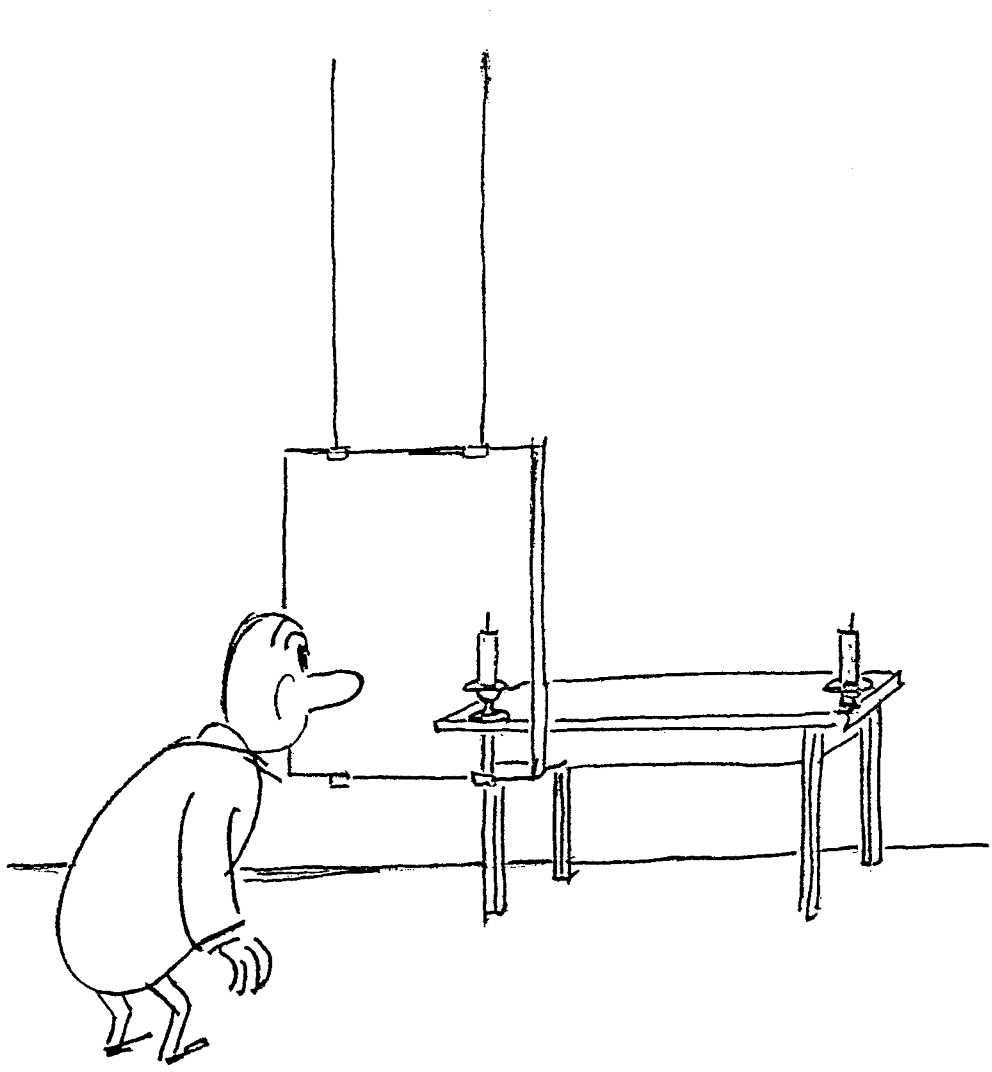
[1]The list was presented at a 7.5 s rate. The protocol refers to verbalizations during encoding.
[2]Uroma → Ursache.
[3]Michael Ende (contemporary writer) → Ende.
[4]Sultaninen → Resultat.
[5]"Die Konsequenz," a movie about a homosexual couple.
[6]Begin (Israeli politician) → Beginn.
[7]Chemie → Reaktion.
[8]geschehen (verb) → Geschehen (noun).

Figure 15
Illustration of Recoding Processes in Memory Functioning with the *Method of Loci:*
The Drawing of an Old Graphic Designer



Nationalgalerie Einsicht ... ja da muß ich ihnen sagen, da habe ich mir vorgestellt, daß da einer ein Bild aufhängt, mit einer Glasplatte, aber nichts dahinter, ja also nur eine Glasplatte ausgestellt ist, wo man reingucken kann. Merkwürdige Vorstellung.

Limitations of the Study

The present study has shown that professional expertise attenuates, rather than eliminates, age-related differences in cognitive plasticity in the domain of imagery-based memory performance. Due to limitations with regard to the sampling of subjects and analyzed data sets, the implications of this finding are limited in at least three different ways. One limitation, which was discussed above, concerns the confound between ability and expertise. It is not possible to decide on the basis of the present set of data whether the superiority of old graphic designers over old normal adults in mnemonic performance is due primarily to differences in latent abilities or to differences in professional expertise. A second limitation is related to the continued existence of gains in recall performance during the Test Phase of the training program. The existence of these gains made it necessary to introduce some caution to the interpretation of group differences in terms of developmental reserve capacity.

A third limitation concerns the choice of the expert group. Although the results of the study were consistent with the assumption that visual imagery is important both in graphic design and in memory functioning with the *Method of Loci,* the possibility cannot be excluded that a more pronounced reduction of age differences in mnemonic skill would have been observed with a different group of experts. For instance, it is possible that time constraints are more important in the context of mnemonic skill than in the context of expert performance in graphic design. Encoding time in memory functioning with the *Method of Loci* is generally limited, and the speed with which visual images are generated is probably an important determinant of interindividual differences in performance. Speed of image generation may play a less prominent role in attaining the status of an expert in graphic design.

In order to further investigate the generality of the present results for the domain of imagery-based memory performance, it would be interesting to conduct a training study with a group of old professional mnemonists. Expert mnemonists seem to use some form of visual imagery in their professional performance (Ericsson, 1985; Luria, 1968; Paivio, 1971). For this reason, it is likely that the degree of overlap between the demands of the profession and the demands of the target task would be high. Thus, the study of old expert mnemonists would represent a further conservative test of the hypothesis that cognitive plasticity in imagery-based memory functioning is reduced in old age.

Aging and Experience: The Role of Compensation

As was noted before, the mechanisms that mediate the relationship between professional expertise and cognitive aging were not analyzed in the present study. The modulation of age differences through professional experience may follow several different paths. For instance, specialized professional knowledge and the provision of continuous practice may prevent age-related decrements in cognitive functioning that would occur under normal circumstances. In addition, parts of the professional knowledge of aging experts may develop as a compensatory reaction to decrements in expertise-related cognitive operations. Some of these compensatory reactions may depend on the expert's prior awareness of impending aging loss, whereas others may take the form of adaptive regulations without awareness (cf. Baltes & Baltes, in press; Uttal & Perlmutter, 1989).

It is plausible to assume that the ability to develop compensatory knowledge and behavior is especially salient in the case of individuals who retain an expert level of professional performance while growing old. Therefore, the close examination of aging experts would probably lead to a better understanding of the relationship between aging, experience, and compensation. The analysis of observational data, practice schedules, interviews, and diaries, as well as the repeated administration of objective measures of performance would be informative in this regard.

Cognitive Plasticity and the Mechanics of Intelligence

Throughout this text, skilled memory performance with the *Method of Loci* was regarded as an exemplary task for the investigation of age differences in cognitive plasticity in the mechanics of intelligence. Clearly, the theoretical proposition that cognitive plasticity in old age is reduced through a decrement in the mechanics must also be tested in other domains of intellectual functioning that presumably impose high demands on the mechanics of intelligence. In this context, recent attempts in the domains of visual search (Rogers & Fisk, 1989), inductive reasoning (Mayr, 1989), and mental multiplication (Charness & Campbell, 1988) should be noted.

A main feature of the research strategy employed in the present study was to select a group of older individuals who, by virtue of their profession, were assumed to exhibit a greater amount of cognitive plasticity in a specific aspect of cognitive functioning than a group of old nonexperts of comparable intelligence. It is hoped that the application of similar strategies to other domains of cognitive functioning will help to explore the modifiability of age differences in cognitive plasticity through experience and ability.

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Appendix

A. Experimental Materials

Table A-1
Sequence of Berlin Landmarks

Funkturm
ICC
Lietzensee
Schloß Charlottenburg
Deutsche Oper
Schillertheater
Ernst-Reuter-Platz
Siegessäule
Schloß Bellevue
Kongreßhalle
Reichstag
Brandenburger Tor
Philharmonie
Nationalgalerie
Staatsbibliothek
KaDeWe
Europa-Center
Gedächtniskirche
Bahnhof Zoo
Café Kranzler

Note. Half of the subjects in each group were presented the list in reverse order.

Table A-2
Sessions 6 to 13 and Session 26: Lists of Nouns

List 1		List 2		List 3		List 4		List 5	
Apfel	(6.48)	Akkordeon	(6.04)	Bücherei	(6.16)	Arm	(6.64)	Bauch	(6.00)
Dampf	(6.36)	Bargeld	(6.48)	Chef	(6.12)	Bettler	(6.20)	Elefant	(6.60)
Ecke	(6.04)	Blut	(6.60)	Diamant	(6.44)	Brief	(6.28)	Explosion	(6.28)
Fahne	(6.60)	Doktor	(6.20)	Familie	(6.36)	Dudelsack	(6.28)	Felsblock	(6.52)
Gangster	(6.12)	Fabrik	(6.56)	Faß	(6.52)	Getränk	(6.00)	Flasche	(6.48)
Gefängnis	(6.40)	Gespenst	(6.00)	Feuer	(6.60)	Gitter	(6.24)	Fleisch	(6.44)
Junge	(6.20)	Großmutter	(6.44)	Halle	(6.28)	Kleidung	(6.28)	Freund	(6.00)
Kartoffel	(6.68)	Großstadt	(6.48)	Klavier	(6.32)	Kochtopf	(6.56)	Gabe	(6.72)
Kugel	(6.52)	Hammer	(6.76)	Mädchen	(6.24)	Kuß	(6.52)	Hotel	(6.56)
Körper	(6.00)	Harfe	(6.24)	Nonne	(6.32)	Küste	(6.36)	Kaffee	(6.44)
Leckerbissen	(6.08)	Haut	(6.16)	Pelz	(6.12)	Maler	(6.12)	Kinn	(6.32)
Mutter	(6.80)	Kind	(6.32)	Postkutsche	(6.48)	Metall	(6.12)	Reptil	(6.12)
Orchester	(6.20)	Markstück	(6.48)	Pudding	(6.20)	Mikroskop	(6.52)	Revolver	(6.68)
Pfirsich	(6.56)	Maschine	(6.12)	Schiff	(6.58)	Photographie	(6.08)	Richter	(6.24)
Puppe	(6.20)	Pfeffer	(6.44)	Schlinge	(6.08)	Pol	(6.04)	Scheinwerfer	(6.32)
Redner	(6.08)	Priester	(6.08)	Schüler	(6.04)	Polizist	(6.64)	Schmutz	(6.12)
Salat	(6.36)	Raupe	(6.56)	Säugling	(6.48)	Quadrat	(6.68)	Spirale	(6.12)
Sklave	(6.16)	Soße	(6.04)	Wiese	(6.68)	Schädel	(6.32)	Sänger	(6.04)
Tinte	(6.52)	Strand	(6.20)	Wolle	(6.00)	Stirn	(6.44)	Tier	(6.24)
Zitrone	(6.48)	Stuhl	(6.76)	Zigarre	(6.64)	Vulkan	(6.52)	Wald	(6.68)

Note. Numbers in parentheses denote imagery values based on the norms provided by Baschek, Bredenkamp, Öhrle, and Wippich (1977).

Table A-3
Sessions 14 to 25: 20-Item Noun Lists

HI LS (High imagery, low similarity)		HI HS (High imagery, high similarity)		LI LS (Low imagery, low similarity)		LI HS (Low imagery, high similarity)	
Blumenstrauß	(6.64)	Becher	(6.44)	Anteil	(3.88)	Ablauf	
Butter	(6.60)	Becken		Auflage	(3.80)	Anfang	(3.28)
Dampfer	(6.48)	Behälter		Ausdruck	(3.40)	Ausgang	
Fleischer	(6.28)	Bottich		Betrag	(4.32)	Bedingung	(3.20)
Gold	(6.28)	Eimer		Beweis	(4.00)	Beginn	(4.04)
Hochschule	(6.00)	Faß	(6.52)	Einheit	(3.88)	Effekt	(3.42)
König	(6.08)	Flasche	(6.48)	Einsicht	(3.24)	Ende	
Kreis	(6.76)	Gefäß		Existenz	(4.04)	Entwicklung	(3.75)
Küche	(6.33)	Glas		Fall	(4.16)	Ergebnis	(3.88)
Kühlschrank	(6.52)	Kanister		Gedicht	(5.24)	Folge	(4.16)
Mönch	(6.17)	Kanne		Gegenteil	(3.52)	Geschehen	
Nagel	(6.52)	Kessel		Kenntnis	(3.52)	Grund	(3.88)
Orkan	(6.16)	Krug		Mangel	(4.24)	Konsequenz	
Palast	(6.32)	Napf		Objekt	(3.72)	Prozeß	
Pfeil	(6.44)	Schale		Patent	(4.00)	Reaktion	(4.04)
Schmied	(6.20)	Schüssel		Regel	(3.56)	Resultat	
Seegang	(6.00)	Tasse		Sprichwort	(4.04)	Ursache	
Uhr	(6.60)	Tonne		Stil	(3.92)	Vorgang	
Vieh	(6.28)	Topf		Verfassung	(4.08)	Wirkung	(4.00)
Wiege	(6.08)	Wanne		Wirklichkeit	(3.64)	Ziel	(5.20)

Note. Numbers in parentheses denote imagery values based on the norms provided by Baschek, Bredenkamp, Öhrle, and Wippich (1976). Norms were not available for all nouns.

Table A-4
Sessions 14 to 25: Digit List

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Table A-5
Sessions 14 to 25: 60-Item Noun List

Armband		Paket	
Ausweis		Pfennig	
Beutel		Photo	
Bleistift	(6.36)	Portemonnaie	
Brief	(6.28)	Postkarte	
Briefmarke		Pullover	
Brille		Päckchen	
Buch	(6.40)	Quittung	
Bürste		Radiergummi	
Etui		Reisepaß	
Fahrkarte		Ring	
Feuerzeug		Ringbuch	
Füller		Schal	
Groschen		Scheck	
Handschuhe		Schere	
Heft		Schirm	
Hut		Schlüssel	
Jacke		Schnalle	
Kamm		Schnur	
Kette		Stadtplan	
Kinoprogramm		Streichholz	
Kleingeld		Tasche	
Knopf		Tuch	
Koffer		Tüte	
Konzertkarte		Uhr	(6.60)
Lesezeichen		Umschlag	
Mantel		Weste	
Markstück	(6.48)	Zeitschrift	
Mütze		Zeitung	(6.04)
Notizblock		Zettel	

Note. Numbers in parentheses denote imagery values based on the norms provided by Baschek, Bredenkamp, Öhrle, and Wippich (1976). For most of the nouns, norms were not available.

Table A-6
Means (SD) per List for Imagery (I), Concreteness (C), Meaningfulness (m'), Frequency (Fr), and Word Length (Wl)

List	I	C	m'	Fr[a]	Wl[b]
1	6.34 (.23)	6.23 (.50)	4.41 (.58)	6.41 (2.3)	6.50 (2.0)
2	6.35 (.24)	6.12 (.76)	4.74 (.54)	6.41 (2.6)	6.50 (1.9)
3	6.33 (.21)	6.27 (.49)	4.72 (.62)	6.41 (2.5)	6.35 (1.9)
4	6.34 (.21)	6.19 (.44)	4.70 (.57)	6.53 (2.2)	6.45 (2.3)
5	6.35 (.24)	6.17 (.54)	4.66 (.56)	6.47 (2.1)	6.50 (2.0)
HI LS List	6.34 (.22)	6.22 (.52)	4.70 (.55)	6.23 (2.4)	6.44 (2.1)

Note. Lists 1 to 5 are reproduced in Table A-2; the HI LS (high-imagery, low-similarity) list is reproduced in Table A-3. Values for I, C, and m' are based on the norms provided by Baschek, Bredenkamp, Öhrle, and Wippich (1977). Word frequency ratings are based on Meier (1964).

[a]For 15 nouns (three in each list), frequency ratings were not available.
[b]Mean number of letters per word.

Appendix

B. Supplement Tables

Table B-1
Sessions 6 to 13 and Session 26: Means (SD) of Correct Responses Broken Down by Session and Group

Session	Presentation rate	Old normal adults	Old graphic designers	Young adults
6	4.5 s/word	4.4 (2.2)	10.6 (3.9)	17.3 (1.4)
7	self-paced	8.5 (5.1)	15.3 (2.0)	19.1 (0.9)
8	self-paced	9.2 (4.0)	16.4 (1.2)	19.0 (0.7)
9	7.5 s/word	7.1 (2.7)	13.8 (2.9)	18.5 (1.1)
10	7.5 s/word	6.5 (3.3)	14.2 (2.6)	18.5 (1.0)
11	4.5 s/word	6.1 (3.4)	12.3 (2.1)	17.7 (1.2)
12	4.5 s/word	6.3 (2.9)	13.0 (2.0)	18.4 (1.4)
13	1.5 s/word	3.1 (1.9)	5.2 (1.8)	13.3 (4.1)
26	1.5 s/word	4.8 (2.3)	8.3 (2.0)	15.5 (3.1)

Table B-2
Sessions 14 to 25: Means (SD) of Correct Responses and Confusion Errors with 20-Item Noun Lists Broken Down by Presentation Rate, List, and Group

	Old normal adults		Old graphic designers		Young adults	
	Correct	Confusions	Correct	Confusions	Correct	Confusions
7.5 s/word						
HI LS	8.9 (3.9)	2.3 (1.0)	16.3 (2.0)	0.5 (0.4)	19.4 (0.5)	0.1 (0.1)
HI HS	6.3 (3.2)	5.0 (1.6)	12.6 (3.0)	2.7 (1.6)	18.2 (1.7)	0.5 (0.8)
LI LS	5.8 (3.1)	3.2 (2.0)	11.0 (2.6)	2.2 (1.7)	18.0 (2.2)	0.3 (0.3)
LI HS	5.3 (2.5)	4.5 (1.7)	9.7 (3.1)	3.6 (1.1)	15.5 (4.0)	1.3 (0.8)
4.5 s/word						
HI LS	7.3 (4.3)	2.8 (1.8)	14.1 (2.5)	0.7 (0.5)	19.5 (0.4)	0.0 (0.0)
HI HS	5.7 (3.4)	5.5 (1.5)	10.0 (2.5)	4.2 (2.4)	17.0 (3.0)	0.8 (0.9)
LI LS	4.8 (2.7)	3.3 (1.7)	8.6 (2.6)	2.2 (0.7)	16.9 (3.2)	0.5 (0.4)
LI HS	4.4 (2.1)	4.5 (1.4)	8.6 (2.1)	3.2 (1.2)	15.3 (4.2)	1.1 (0.7)
1.5 s/word						
HI LS	2.8 (1.1)	3.9 (1.6)	5.1 (1.8)	2.7 (1.8)	13.5 (2.8)	1.1 (0.9)
HI HS	2.8 (1.4)	6.1 (2.6)	5.2 (1.6)	5.8 (3.1)	9.5 (3.3)	3.0 (1.9)
LI LS	3.1 (1.8)	3.5 (1.2)	3.7 (1.7)	3.1 (1.5)	10.9 (3.9)	1.0 (0.6)
LI HS	2.8 (1.5)	3.7 (1.4)	3.5 (1.3)	3.7 (2.3)	9.4 (2.9)	2.5 (1.3)

Note. Lists are classified according to presentation rate (seconds per word), imagery-level (HI = high, LI = low), and within-list similarity (LS = low, HS = high). Each entry is based on the average of four trials.

Table B-3
Means (SD) of Correct Responses and Confusion Errors with 60-Item Noun List Broken Down by Presentation Rate and Group

	Old normal adults		Old graphic designers		Young adults	
Presentation rate s/word	Correct	Confusions	Correct	Confusions	Correct	Confusions
7.5	8.0 (3.9)	6.4 (4.2)	21.8 (9.3)	6.3 (3.3)	41.9 (8.6)	1.9 (1.2)
2.5	4.2 (2.2)	6.9 (4.5)	9.6 (5.5)	9.8 (7.2)	23.7 (8.1)	4.5 (4.3)

Note. With the 60-item noun list, three nouns had to be recalled at the same landmark. Nouns recalled at the correct location were counted as correct regardless of order information within landmarks because instructions did not focus on the conservation of order information within landmarks.

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