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BEFORE THE FEDERAL COMMUNICATIONS COMMISSION

In the Matter of:

Implementation of the Local Competition Provisions in the Telecommunications Act of 1996	**CC Docket No. 96-98**
Interconnection Between Local Exchange Carriers and Commercial Mobile Radio Service Providers	**CC Docket No. 95-185**
Area Code Relief Plan for Dallas and Houston, Ordered by the Public Utility Commission of TX	**NSD File No. 95-8**
Administration of the North American Numbering Plan	**CC Docket No. 92-237**
Proposed 708 Relief Plan and 630 Numbering Plan Area Code by Ameritech-Illinois	**IAD File No. 94-102**

**SUPPLEMENT TO
AN ANSWER AND PETITION IN SUPPORT OF THE PETITION
BY THE WASHINGTON POST COMPANY
TO CLARIFY THE COMMISSION'S SECOND REPORT AND ORDER
(FCC 96-333 of August 8, 1996, CC Docket 96-98) AND OTHER ORDERING
INVOLVING THE NUMBERING PLAN(S)**

Communications Venture Services, Inc. hereby files this supplement to support the Washington Post Company's petition for clarification by the Commission to recognize that national assigned 555 telephone numbers be dialable as inherent 7-digit numbers.

This supplement provides the Commission with credible scientific research results to support ubiquitous 7-digit dialing (attached as Exhibits), and provides further evidence of industry consensus regarding 555 numbers as an Access service.

Seven digit dialing for 555 numbers is technically easier to implement than 10-digit dialing[1], and there is a public need for 7-digit dialed access and exchange services, particularly for older callers and persons with impaired short term memory (i.e. depression, Alzheimer's, etc.).[2] Studies cited are attached and incorporated.

Background: The 555 National Exchange:

555 exchange National numbers[3] were designed to have ubiquitous[4] 7 digit dialing throughout the USA, Canada, and Caribbean, where dialing plans can permit any 555 number (i.e. 555-1212) to be so dialed, with termination in any network, anywhere, including private, cellular, and satellite network(s).

Typically, the originating dial tone provider translates the dialed 555 number into a routable NPA-NXX-xxxx for access handoff to an interexchange carrier *selected by the 555 Number Assignee*, for termination at the location

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1 See: submission of Bob Hirsch, AT & T representative (now INC Co-Chair), entitled "Digit Analysis & Translation", to the "555 Access Arrangements Workshop" on or about November 13, 1995, ref: Sec. 2.1 & 2.2.. See also: Footnote 8 herein.

2 **"Age Differences in Everyday Memory: Laboratory Analogues of Telephone Number Recall,"** Robin West & Thomas H. Crook, Psychology & Aging, 1990, Vol. 5, No. 4, 520-529. See also: **"Structure of Everyday Memory in Adults With Age-Associated Memory Impairment,"** Adrian Tomer, Glenn Larrabee & Thomas Crook, Psychology & Aging, 1994, Vol. 9, No. 4, 606-615; **"Everyday Memory Performance Across Life Span: Effects of Age and Noncognitive Individual Differences,"** Psychology & Aging, 1992, Vol. 7, No. 1, 72-82; **"Evaluation of Drugs in Alzheimer's Disease and Age-Associated Memory Impairment,"** T.H. Crook, B.A. Johnson, & G.J. Larrabee, in "Methodology of the Evaluation of Psychotropic Drugs", Editors: O. Benkert, W. Maier, & K. Rickels (Psychopharmacology Series 8), Copyright Springer-Verlag Berlin Heidelberg 1990.. (Available from Thomas Crook, III, PhD, Psychologix, 7125 E. Lincoln Dr., Scottsdale, AZ 85253, (602) 948-4784; or Memory Assessment Clinics, Bethesda, Md. (301) 657-0030). (Referred by Betty Davis, American Association of Retired Persons (AARP), Wash., D.C. (202) 434-2264).

3 Except 555-0100 thru 555-0199, which are reserved for the entertainment media (films, radio).

4 **ICCF 96-0411-014, par. 1.1**, April 11, 1996 ("555 Technical Service Interconnection Arrangements", produced by the "555 Access Arrangements Workshop").

designated by the 555 Assignee. **However, translation(s) could (also) be made at the intermediate [5] (i.e. IXC),** or terminating (i.e. LEC) network(s).

Industry consensus on 555 is now complete after several years of discussions on assignment and activation (technical interconnection arrangements). The Industry has now finally approved the interconnection arrangements.[6]

Activation

LEC activation[7] and interexchange translation and transport planning for the 555 exchange is now beginning. 555 numbers are inherently "portable" since the number assignee has that number in all geographic area codes in the NANP Area (formerly World Zone 1, USA, Canada, Caribbean). Therefore, portability is a "moot" point with 555 numbers, and thus there is no reason they cannot be dialed as 7 digits (switches already give "special" treatment to 555 numbers, and the 555 NPA (area code) will never be used as an area code, thus 555 is a perfect trigger for translations).

In fact, AT & T reported to the ICCF Workshop that 10-digit 555 dialing would be more difficult to implement than 7-digit dialing (submission of Bob Hirsch, AT & T representative (now INC Co-Chair, entitled "Digit Analysis & Translation", to the "555 Access Arrangements Workshop" on or about November 13, 1995, ref: Sec. 2.1 & 2.2).[8]

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5 Fortunately, the 555 code is not available for assignment as an NPA (area code) (per "NPA Allocation Plan and Assignment Guidelines," INC 96-0308-011, par. 4.2.3., 3/8/96). Thus, any switch receiving 555 as an NPA may treat it as a trigger to perform specific routing or translations (i.e. should a 555 number be dialed as 1+555 or 0+555); alternatively the LEC/RBOC can be instructed by the number assignee to hand off specific 555 numbers to the Point-of-Presence (POP) of a selected carrier, or translate the 555 number to a routable 10-digit number or international number or private network address.

6 See: Industry Carriers Compatibility Forum (ICCF) document **"555 Technical Service Interconnection Arrangements"**, ICCF 96-0411-014, adopted 4/11/96 from report of **the "555 Access Arrangements Workshop"**, and interpretative letter from Madeline Bogdan, ICCF Moderator, dated June 12, 1995 to the undersigned and the 555 Association (Subject: 555 Access Arrangements Workshop"). (Also see: Industry Numbering Committee (INC) Document No. 94-0429-002 entitled "555 NXX Assignment Guidelines"). In addition, the Information Industry Liaison Committee (IILC) Task Group has adopted 7-digit 555 dialing for both access and exchange services (IILC Issue #046, dated August, 1996). **The FCC has stated that Industry consensus should not be disturbed. (Southern New England Telephone Expedited Petition for Emergency Interim Relief, Preliminary Injunction and Stay , 1995 FCC 6687, Rel DA 95-2141, 10/6/95).**

7 Activation is required in at least 30% of the available area codes (NPA's) or States. We have taken and restate here for ourselves and our clients, the position that "available" means both exchange and access services provided at reasonable rates and with non-discriminatory interconnection access (c.f. some RBOC's have their own 555 assignments).

8 Quoted in part: "If calls are dialed using seven digits, the three digit analysis currently performed in end offices would be sufficient to recognize the 555 call and initiate the necessary call processing or route the call to the tandem switch. It therefore appears that technical service interconnection arrangements for seven digit dialed 555 calls could be made available more easily than arrangements with

Therefore, we support wholeheartedly the Commission's clarification, and any further Ordering provisions necessary, for ubiquitous 7-digit dialing of the 555 exchange throughout the NANP area (555 can be a typical Feature Group D access service, similar to the 950 Feature Group B access service).

Summary

There is industry consensus and a public interest need for "ubiquitous deployment" of 7-digit 555 access and exchange service nationwide.[9] The Commission has given the presumption to Industry Consensus (Southern New England Telephone Expedited Petition for Emergency Interim Relief, Preliminary Injunction and Stay , 1995 FCC 6687, Rel DA 95-2141, 10/6/95).

The public interest, particularly where the elderly and memory impaired individuals are concerned, and the interest of national information service, enhanced service, reservation centers, and competitive directory assistance providers, should convince the Commission that it did not intend that 555 numbers be required to be dialed 10-digits. In addition, it has been shown that 10-digit dialing is not only technically unnecessary, but more difficult than 7-digit dialing. Since national 555 numbers are inherently portable, "portability" is not an issue.

November 2, 1996

COMMMUNICATIONS VENTURE SERVICES, INC. AND OUR CLIENTS:

RICHARD C. BARTEL, PRESIDENT

Attachments Incorporated:
Exhibits

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ten digit dialed 555 calls if those calls were to be dialed with a FNPA." (Robert Hirsch, AT & T, now INC co-chair).

9 ICCF 96-0411-014, par. 1.1, 4/11/96. In addition, the Information Industry Liaison Committee (IILC) Task Group has adopted 7-digit 555 dialing for both access and exchange services (IILC Issue #046, dated August, 1996).

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Age Differences in Everyday Memory: Laboratory Analogues of Telephone Number Recall

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Three experiments were conducted to examine age differences in memory for telephone numbers by adults ranging from 18 to 85 years of age. In the first 2 studies, using visual simultaneous presentation, age declines in immediate recall were evident on 10-digit numbers, but not on 3-digit numbers. With 7-digit numbers, the youngest group performed significantly better than the oldest (70–85 years) group. In the second study, more marked age declines occurred when subjects had to redial a number after a busy signal. The third experiment replicated the observed aging pattern with auditory sequential presentation. Also, chunked presentation of local telephone numbers resulted in high performance for old and young in sequential recall. The findings were discussed in relation to task processing demands and practical issues related to telephone number recall.

In recent years, there has been a call for studies of everyday memory in the elderly because unfamiliar laboratory tests may fail to show true age-related performance patterns (Sinnott, 1984). For example, investigators have begun to examine prospective memory (West, 1988), grocery list recall (Read, 1987), spatial memory in familiar environs (Kirasic & Allen, 1985), and memory for a phone dial (Foos, 1989). Initial attempts to study everyday skills have shown that older adults' performance on familiar tasks, comparable to everyday experience, is often better than on laboratory tests (West, 1986). With that in mind, this research expands the study of everyday tasks into a new domain, telephone number recall. This task was selected because it has high face validity as a reflection of everyday cognition and because it is related to the digit-span task, for which there are considerable age-related data. A laboratory analogue format was used because it has the advantage of retaining some degree of control over encoding and retrieval conditions while retaining some degree of generalization to real-world experience (Mook, 1989).

Almost no research has been conducted with telephone number recall tasks. The closest laboratory task is the digit-span task. Mixed evidence exists for age decline on the digit-span task. Some investigators emphasized that age deficits are present (e.g., Mueller, Rankin, & Carlomusto, 1979; Taub, 1975), and others concluded that there are no reliable age differences on the standard span task (e.g., Gilbert & Levee, 1971; Inglis & Caird, 1963; Parkinson, Lindholm, & Urell, 1980). One possible reason for the discrepant conclusions may be found in Botwinick and Storandt's (1974) report. They consistently found *significant* age differences in performance on the digit-span task, but these accounted for less than 10% of the variance in performance. Gilbert (1941) also reported that older adults of higher intelligence outperformed the younger group on the digit-span task. If age is not the strongest determinant of performance, variations may occur from study to study, depending on encoding and retrieval conditions and sample characteristics.

Inconsistent age patterns on studies of the digit-span task have led to arguments concerning the extent to which the task taps working memory capacity. The absence of age differences on the standard digit-span task has been taken as one indication that primary memory capacity is not affected by age (Craik, 1977; Welford, 1980). Other investigators have focused on the data showing deficits and have argued that memory spans decrease with age as a function of decline in working memory capacity (Light & Anderson, 1985). From this perspective, working memory is defined as the simultaneous storage and manipulation of items in memory, and it varies along a continuum. A standard digit-span task probably does not require such manipulation for the below-span items, which do not require a significant working memory demand (Craik & Rabinowitz, 1984). There are data to suggest that standard digit-span tasks are only weakly correlated with other indicants of working memory (e.g., Wingfield, Stine, Lahar, & Aberdeen, 1988). As the number of digits increases to the level of one's span and longer, however, duplication of the series during recall requires manipulation as well as storage because the subject has to maintain the serial order of the initial digits as later digits are being presented (cf. Light & Anderson, 1985; Parkinson, Lindholm, & Inman, 1982; Talland, 1968). From this perspective, working memory load will be higher as the number of digits increases and as more transformations of the information are required during storage. In line with this interpretation, methodologies that do not require correctly ordered recall can eliminate age differences in digit-span task performance found with standard scoring methods (cf. Crook, Ferris, McCarthy, & Rae, 1980; Friedman, 1974), and age differences increase with higher demands for serial accuracy (Talland, 1968). Thus, we

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expected to find age differences increasing as a function of processing demands in this study.

Standard digit-span tasks rarely challenge subjects to go beyond their span. Instead, such tasks are used to identify the length of an individual's span (Talland, 1968) and involve a different form of testing than recall of digit series. It is clear that supraspan tasks (requiring the serial recall of 8–15 digits) are more difficult for older adults and usually result in more dramatic age deficits (e.g., Drachman & Leavitt, 1972; Taub, 1973). There is no disagreement that such tasks go beyond primary memory capacity (Parkinson et al., 1982), require more strategic manipulation of items (Waugh & Barr, 1980), and thus are more likely to reflect working memory (Craik & Rabinowitz, 1984). Average spans, across age, are generally between 5 and 6 digits. Thus, memory for telephone numbers, requiring the recall of 7 digits, is right at the border between span and supraspan for many individuals. Generalizing from standard digit-span tasks would suggest that older adults could recall most telephone numbers easily because their spans, per se, are often similar to those of younger adults (e.g., Bromley, 1958). In contrast, generalizing from studies using supraspan tasks would suggest that older adults would have memory difficulties, especially on long-distance numbers (Craik, 1968). Alternatively, telephone number recall may not show age declines because it is a familiar, everyday activity; on such a task, older adults may have learned ways to compensate for their memory deficits (Bäckman, 1989). This laboratory analogue study may shed some light on which of these conclusions is appropriate for telephone number recall in the elderly.

In addition, understanding age-related changes in telephone number recall is important because memory for phone numbers has high face validity for older adults. If it is an age-sensitive test, its face validity makes it a useful experimental test for examining variables that influence age-related changes in memory. Only one earlier study presented number series as area codes or telephone numbers for recall. Normal elderly adults, young adults, and memory-impaired elderly (Crook et al., 1980) were shown series of 3, 7, or 10 digits, presented visually (and subjects read the items aloud) in a chunked presentation (3-4 or 3-3-4). Age differences varied with type of retrieval. When subjects were asked to fill in 1 missing digit in a series, younger adults were comparable with normal elderly adults on all items but performed significantly better than the impaired elderly on the 10-digit items. The same effects occurred when retrieval involved verbal repetition of the digits in order, except that the young adults and normal elderly performed better than the memory-impaired elderly on 7-digit numbers. When retrieval involved telephone dialing, the young adults consistently outperformed both older groups.

The laboratory analogue studies presented herein examined the age-related impact of varying retrieval and encoding conditions on telephone number recall. In the first study, the inclusion of a large number of subjects ($N = 715$) across a wide age range (18–85 years) permitted the examination of age trends to identify the age at which telephone number recall becomes difficult. A wide age range and long digit series were included in only one earlier study (Talland, 1968). In Experiment 1, we also attempted to replicate the results of an earlier investigation (Crook et al., 1980): The items administered for immediate recall consisted of 3, 7, or 10 digits, identified as area codes, local telephone numbers, or long-distance telephone numbers, respectively. In this study, however, we examined age deficits in telephone number recall under conditions in which strategic chunking was not provided.

Experiment 1

Method

Subjects. Community-dwelling subjects were recruited by newspaper advertisement in the Washington, DC, area to participate in memory testing. The participants were divided into age groups of 18–39 (youngest), 40–49 (40s), 50–59 (50s), 60–69 (young-old), and 70–85 (oldest) for study, to identify the age decade at which decline occurs. Statistics for the sample characteristics are given in Table 1, including scores on the Wechsler Adult Intelligence Scale (WAIS) Vocabulary test (Wechsler, 1955). Prospective participants were screened for adequate current health status with a personal history questionnaire, focusing on physical, psychiatric, and neurologic history, and completed a depression scale (Yesavage et al., 1983). There were no significant age-group differences in years of education, but there were significant differences in the WAIS Vocabulary scores, $F(4, 660) = 3.8$, $p < .005$, $\omega^2 = .02$, showing an increase with age (40 subjects did not complete the vocabulary scale). Persons taking anticholinergic medicines or those with diseases or chronic health problems that might affect memory performance (e.g., stroke, depression, and head injury) were excluded. The sample included no more than a handful of students. These subjects represent healthy community-dwelling volunteers of all ages.

Materials and procedures. All to-be-remembered information was presented on a laser-disk computer, with a touch-sensitive monitor. The telephone-dialing task was administered as part of a 90-min battery of everyday memory analogue tests (Crook & Larrabee, 1988). The telephone task was presented early in the battery, after the completion of self-report questionnaires. Participants were asked to read aloud an entire digit series as it was presented (simultaneously) on a computer monitor. This reflects a visual (plus auditory) presentation. After the series was read, the screen cleared, and there was an immediate recall test in which subjects dialed a standard push-button phone interfaced with the computer. Subjects were presented with 3, 7, or 10 digits in this self-paced manner; there were 12 digit series, 4 of each length (the length of the series on any given trial was determined randomly). Specific digits were selected randomly, with the exception that Washington area codes and exchanges were excluded.

Results and Discussion

Ordered recall. Responses were scored in an ordered recall format: Each digit in the recall sequence was compared with a corresponding digit from the encoded sequence (in order), and one point was given for each match that occurred. That is, a recalled digit had to be in the correct output order for credit to be given. For example, if the digit series was 652-0914, a response of 653-0914 would represent a score of 6, and 653-9014 would receive a score of 4. The dependent measure was the average number of correct digits on the four trials for each series length.

The scores for series of 3, 7, and 10 digits were examined in a multivariate analysis of variance that revealed age-group differences, $F(12, 2130) = 10.3$, $p < .001$. Univariate follow-up tests showed no significant differences on the 3-digit series ($p > .10$); all groups performed at ceiling. Significant age-group differ-

Table 1
Sample Characteristics

Variable	Age group (years) 18–39	40–49	50–59	60–69	70–85
	Experiment 1				
n	92	79	217	220	107
Age (years)					
M	30.5	44.8	54.4	64.6	73.0
SD	5.2	2.8	2.8	2.8	2.8
Education					
M	15.8	16.0	16.0	15.6	15.7
SD	2.4	2.6	2.8	2.8	2.9
Gender					
Male	41	22	76	84	45
Female	51	55	141	136	62
WAIS Vocabulary					
M	57.9	60.2	62.3	62.2	62.5
SD	10.8	10.6	9.5	9.7	10.9
	Experiment 2				
n	244	74	197	212	105
Age (years)					
M	24.5	44.5	54.9	63.9	73.7
SD	7.3	2.6	3.0	2.8	3.9
Education					
M	14.4	15.9	16.3	15.8	15.3
SD	2.0	2.9	2.7	2.8	3.0
Gender					
Male	118	27	74	102	49
Female	126	47	123	110	56
WAIS Vocabulary					
M	58.8	62.9	64.3	64.0	66.0
SD	9.8	4.6	9.6	9.2	8.3

Experiment 3	Age group (years) 18–30	60–80
n	116	116
Age (years)		
M	18.7	68.1
SD	2.3	5.3
Education		
M	12.8	14.5
SD	1.1	3.0
Gender		
Male	32	39
Female	84	77
WAIS–R Information		
M	18.5	22.3
SD	4.7	4.3

Note. WAIS = Wechsler Adult Intelligence Scale; WAIS-R = revised version of WAIS.

ences occurred on the 7-digit series, $F(4, 710) = 3.9$, $p < .005$, $\omega^2 = .15$, and the 10-digit series, $F(4, 710) = 11.4$, $p < .0001$, $\omega^2 = .25$.

Age differences varied as a function of series length. Post hoc comparisons (Scheffé test, $p < .05$) indicated that the only significant difference on the 7-digit series was between the youngest and the oldest groups. The correlation between age and ordered recall was −.16 ($p < .01$) for the 7-digit series and −.28 ($p < .001$) for the 10-digit series. On the 10-digit series, the youngest group and those in their 40s performed better than the young-old and the oldest group (see Table 2). Also, the group in their 50s performed better than the oldest group.

These results replicate the findings of Crook et al. (1980), who found that digit recall involving telephone dialing showed a performance decline with age between 40 years and 60–85 years. Consistent with our data, those differences were evident on both the 7-digit and 10-digit series. On the basis of these results, it is likely that the oldest subjects among the elderly normal group in the earlier study were most likely to have difficulty with the 7-digit series. It should be noted that these results are not confounded by student status (Riley & Meyo, 1988; Zivian & Darjes, 1983) because there were virtually no students in the experiment. All age groups were recruited in the same manner with the same sampling procedure.

Interpretation of the absence of age differences (until age 70) on local telephone numbers is difficult because of ceiling effects in these data. With the youngest group, 70% had an average score of 7. Approximately 60% of groups in their 40s and 50s performed at ceiling, and 50% among the young-old, and 41% performed at ceiling among the oldest participants. An examination of differences in these proportions with the use of Fisher's procedure (Guilford, 1965) indicated that the youngest group contained a significantly higher proportion of perfect scorers than did groups in their 60s or 70s (both $ps < .001$). That is, the younger adults were more likely to dial a number correctly on their first try.

The typical way to correct for ceiling effects, by adding items, is not appropriate with this ecological task, given that 8- and 9-digit phone numbers are not used in this country. Therefore, nonparametric tests were also conducted to determine whether the distributions of subjects from varying age groups were similar on the 7-digit numbers. The Kolmogorov-Smirnov procedure was used because it is sensitive to any differences

Table 2
Experiment 1: Correct Recall on the Telephone Dialing Test

Age group (years)	Series length (digits) 3	7	10
18–38			
M	2.98^{a}	6.74^{a}	7.66^{a}
SD	0.13	0.51	1.51
40–49			
M	2.95^{a}	6.74^{a,b}	7.46^{a}
SD	0.21	0.42	1.57
50–59			
M	2.95^{a}	6.63^{a,b}	7.15^{a,b}
SD	0.17	0.62	1.58
60–69			
M	2.94^{a}	6.55^{a,b}	6.73^{b,c}
SD	0.19	0.65	1.63
70–85			
M	2.93^{a}	6.47^{b}	6.42^{c}
SD	0.21	0.71	1.65

Note. Within each column, entries that are not significantly different share a superscript.

between the two distributions and tests whether the two sets of data derive from the same population (Siegel & Castellan, 1988). Each age group was compared with all other age groups. Because of the number of comparisons (10) involved, $p < .005$ was used as the required level for significance. These results, in general, verified the earlier conclusions. The only significant differences were between the youngest group and the two older groups. There were no significant differences in the middle years (all $ps > .25$).

The pattern on the 10-digit series showed earlier age deficits than did the 7-digit series in the initial analysis. On the 10-digit series, and in the nonparametric analysis of the 7-digit data, age-related declines were evident after age 60, and performance stability was present up to age 60; that is, the young and middle-aged adult groups did not show statistical differences in scores. It is evident that recall of phone numbers will show age declines in the older years.

It would be tempting to conclude from these findings that few problems with telephone numbers should occur for adults under age 60 in everyday life. One problem with that conclusion is that the Experiment 1 test did not present any recall difficulties or delays like those that might occur in an everyday environment. Interruptions during telephone dialing are a common occurrence and may have many sources: Someone knocks on the door as the dialer begins to dial, or the dialer begins to consider what he or she wants to say, but the line is busy and he or she has to redial. Age-related patterns of performance could vary with interruptions. To investigate this in Experiment 2, a brief interruption occurred in the form of a busy signal, and the subject had to redial the number. The effect of this manipulation was measured by comparing correct recall before and after the signal. It was expected that middle-aged and older adults would be particularly disadvantaged by the presence of a distracting signal.

Experiment 2

Method

Subjects. Subjects were recruited and screened in the same way as in Experiment 1, and their demographic characteristics were similar (Table 1). There were no significant differences in education as a function of age group, but WAIS Vocabulary scores improved with age, $F(4, 675) = 12.4$, $p < .0001$, $\omega^2 = .06$ (for the 680 subjects who completed the vocabulary test).

Materials and procedures. The administration of the telephone dialing test was the same as in Experiment 1, with the exception of a busy signal on some trials. Also, no 3-digit series were presented. Six 7-digit series and six 10-digit series were given. Subjects could not always anticipate that the line would be busy. Busy signals were present on four of the six trials. Before testing began, the subject was instructed to "hang up and dial again" if a busy signal occurred.

Results and Discussion

Ordered recall. Average correct recall before (first dialing) and after (second dialing) the busy signal were calculated as dependent measures for the four trials on which the signal occurred, with separate measures for the 7-digit and 10-digit series. Ordered recall scores were calculated as in Experiment 1.

These data were examined with series (7- or 10-digit series) as a multivariate variable, with age group as a between-subjects variable and signal (before or after busy signal) as a within-subject variable. There were significant effects for age group, $F(8, 1654) = 17.5$, $p < .0001$; Age Group × Signal interaction, $F(8, 1654) = 10.9$, $p < .0001$; and signal, $F(2, 826) = 1{,}176.7$, $p < .0001$. Univariate tests examining the effects of age and signal on the two tests confirmed that the impact of these variables was comparable for 7- and 10-digit series. On the 7-digit series, significant differences based on signal, $F(1, 827) = 487.1$, $p < .0001$, $\omega^2 = .15$, and age, $F(4, 827) = 14.1$, $p < .001$, $\omega^2 = .03$, were superseded by their interaction, $F(4, 827) = 15.8$, $p < .001$, $\omega^2 = .02$.

Post hoc analyses (Scheffé test, $p < .05$) indicated that signal effects were significant for all groups. Age differences were not apparent before the signal except that all other groups performed better than the oldest group. There was a significant difference after the signal among all age groups, and post hoc tests revealed decade-by-decade decline in telephone number recall under these conditions. Because of potential ceiling effects on recall before the busy signal, nonparametric tests were also conducted. These tests, using the Kolmogorov-Smirnov analysis as described earlier, also showed no age differences before the signal. After the signal, all groups except for the young-old performed better than the oldest group (all $ps < .005$). In addition, the youngest group performed better than the young-old ($p < .005$). These results confirmed that age differences in recall were present after and not before the signal.

In contrast with Experiment 1, there was no age effect on the 7-digit series in this experiment (that is, before the signal). In Experiment 1, age differences on the 7-digit series accounted for 15% of the variance. In this experiment, however, they were not significant. The reason for this difference is not clear; the two samples were recruited in the same way, and test administration was similar. Perhaps foreknowledge about a potential busy signal increased the vigilance or concentration of the oldest subjects, permitting them to perform somewhat better in Experiment 2.

On the 10-digit series, the Age × Signal interaction was comparable with that observed with the 7-digit series, $F(4, 827) = 9.1$, $p < .0001$, $\omega^2 = .01$, and the main effects were stronger for age, $F(4, 827) = 34.1$, $p < .0001$, $\omega^2 = .08$, and for signal, $F(1, 827) = 2{,}092.6$, $p < .0001$, $\omega^2 = .29$. According to post hoc tests, the interaction was due to larger age differences after the signal than before it. Before the signal, the three young to middle-aged groups performed better than the young-old and oldest groups. After the signal, all age groups differed, except that the youngest group performed no better than the 40s group and the 40s group performed no better than the 50s group. The signal effect was significant across all groups (see Table 3).

As before, interpretation of the 7-digit series is complicated by the presence of ceiling effects before the signal. In this case, however, the Age × Signal interaction of interest was present on the 10-digit series as well, suggesting that the interaction was not due solely to ceiling effects. Also, nonparametric tests confirmed the nature of the interaction. These results indicate that increased processing demands (in this case, by including a distraction) change the aging pattern, resulting in more consistent decline.

Table 3
Experiment 2: Correct Recall Before and After a Busy Signal

Age group (years)	Before: 7 digits	Before: 10 digits	After: 7 digits	After: 10 digits
18–39				
M	6.7[a]	7.7[b]	6.2[c]	5.6[d]
SD	0.6	1.5	4.0	2.0
40–49				
M	6.7[a]	7.7[b]	6.0[c,e]	5.1[d,f]
SD	0.4	1.5	1.0	2.0
50–59				
M	6.7[a]	7.5[b]	5.9[c,e]	4.8[f]
SD	0.4	1.6	1.1	1.9
60–69				
M	6.6[a]	7.0[g]	5.6[e,h]	4.1
SD	0.5	1.6	1.4	1.9
70–85				
M	6.5[a]	6.2[g]	5.1[h]	3.2
SD	0.7	1.6	1.5	1.8

Note. Entries that are significantly different share a superscript.

There are several possible interpretations of the larger age differences after the busy signal. Additional time passed between presentation and recall after the busy signal, and recall had to be performed twice. Although these factors may have influenced the presence of larger age differences, we favor an attentional explanation. The signal probably acted as a distracter, taking attention away from the immediate processing of items in memory. There is clear evidence that older adults are more susceptible to such attentional distractions (Plude & Hoyer, 1985). The significant impact of the signal is striking, given that subjects might have anticipated or prepared for the busy signal under the conditions of this experiment. Under ecological conditions, preparation would not typically occur. What is most interesting is that the distracting signal significantly changed the relationship of the young and middle-aged groups, revealing an age deficit at a much younger age than found in Experiment 1. In fact, with a distraction present, age declines were apparent at each successive decade.

These results indicate that age differences will probably occur with long-distance phone numbers that include area codes, but they may be less apparent for local calls. The initial investigation of 7-digit numbers was replicated by the findings of the second study. No age changes were present before age 60 in any of the results using standard presentation. Thus, immediate recall of local telephone numbers is not an age-sensitive test. Under ecological conditions, when many of the exchanges are well known, and there is little item-to-item interference, age change might be expected to occur even later. In contrast, recall of long-distance numbers is an age-sensitive test that could be used in applied or experimental settings. On the basis of these large-sample data, healthy adult volunteers should not show declines in telephone number recall before the 60s when tested without a distraction.

One additional investigation was carried out to confirm these findings and to identify varying conditions that might alter skill levels on this task. The two investigations we have described involved visual simultaneous presentation of a phone number that subjects read from a computer screen. This is analogous to looking up a number in the telephone book and then reading it aloud. Subjects processed the number both visually and auditorily. It is possible that this form of presentation is less problematic for older adults than auditory sequential presentation (analogous to hearing a telephone number given by the operator). The next investigation used auditory sequential presentation of telephone numbers to replicate and extend the first two studies.

Some investigators have found that modality differences are important in older adults' recall performance, with greater age-related decline reported for the visual modality (Bromley, 1958; McGhie, Chapman, & Lawson, 1965). Others have not found an Age × Modality effect (Botwinick & Storandt, 1974; Talland, 1968; Taub, 1975) or have reported more problems for older adults with the auditory modality (Craik, 1968; Gilbert, 1941). With a digit-span task, Waugh and Barr (1980) compared visual and auditory presentation (both sequential) of 9-digit series. Both groups recalled more auditory digits. Older and younger subjects benefited from grouping or chunking in the auditory mode, but older adults did not benefit from chunking in the visual mode. The authors concluded that subjects primarily used a verbal code to recall numbers. With visual presentation, they had to translate the visual information into a verbal code. Waugh and Barr argued that this translation process was slower for older adults, and thus they were unable to benefit from grouping in the visual mode. Craik (1968) also reported increased difficulty for older adults in integrating verbal material into strategically chunked items in immediate recall.

This literature suggests that modality and chunking may affect age differences. Thus, it is important to replicate the earlier findings, using auditory sequential presentation and chunking. This was done in the third experiment, in which a human voice instead of a computer screen presented the digit series. Four conditions were compared in this final study, with pairs of conditions designed to address specific questions. First, number series presented as telephone numbers without chunking were compared with numbers having chunked presentation. We hypothesized that chunked presentation would improve scores, especially for older adults. Two other conditions could be compared to determine the impact of verbal recall as opposed to actual telephone dialing. An earlier study indicated that verbal recall might be less difficult for older adults (Crook et al., 1980); thus, the expectation was an interaction of age and recall requirements. Finally, this study compared the recall of numbers presented as *digit series* with the recall of *telephone numbers* to determine whether the familiar task label per se would affect performance.

Experiment 3

Method

Subjects. Given the results obtained earlier, this investigation included only one younger and one older subject group. The subjects were 116 younger students and 116 older adults (see Table 1 for sample characteristics), with 29 individuals randomly assigned to each condition. Older individuals were recruited by newspaper advertisement in a small southeastern community and were excluded for health-related problems as in the first two investigations. The older adults had significantly more education, $F(1, 230) = 32.2$, $p < .0001$, $\omega^2 = .12$, and higher WAIS–R (Wechsler, 1981) Information scores than the younger group, $F(1, 230) = 6.0$, $p < .01$, $\omega^2 = .02$.

Materials and procedures. Participants were asked to recall four 7-digit and four 10-digit numbers under four conditions determined by random assignment. Each number was followed by immediate verbal recall, then the next number was presented, and so forth. The digits in the series were randomly assigned, with the exception that no 2 consecutive digits were identical. Also, all 10-digit numbers were constructed with the second digit as a 0 or 1 to match area-code characteristics in the American telephone system. Local area codes and exchanges were excluded. In all conditions, a practice task was given to ensure that the directions were understood before proceeding.

The telephone memory task was administered as part of a 30-min battery of four laboratory analogue tests of everyday memory. All tests were preceded by a memory self-report questionnaire. The presentation order within the battery was controlled by four randomly derived sequences. There were no performance differences as a function of order, so all data were combined for presentation.

Four different conditions were examined: (a) In the N (numbers) condition, subjects were asked to recall "some sets of numbers" and were told, "Some of the number sets are longer than others. After I give you each set of numbers, you are to repeat them back to me." The presentation procedures followed the rules of digit-span administration on the WAIS–R (Wechsler, 1981), with a presentation rate of 1 digit per second and no chunking of digits. (b) The T condition varied from the N condition only in that the content was described as telephone numbers. Subjects were asked to recall "some phone numbers. Some of the numbers will be local, and some will be long distance." Administration and testing were identical to procedures in Condition N, as were the actual digits used. (c) In Condition TC (telephone–chunked), the telephone numbers were chunked during presentation: The first 3 digits were read, there was a pause, and the next 4 digits were given, chunked into two sets of 2 digits. In a 10-digit series, the area code was also read as one chunk. The total time that elapsed from first to last digit was maintained at 6 s, as in Conditions N and T (or 9 s on a 10-digit number), by pacing the digits closer together within each chunk, then pausing between chunks. (d) In the final condition (TCD, telephone–chunked–dialed), subjects were asked to dial each number on a telephone after it was presented and to verbally recall the number as it was dialed. Item presentation in Condition TCD was the same as that for TC.

Age differences were expected to vary as a function of memory demand. Although the greater familiarity of a telephone number recall task could lead to higher performance in Condition T than in Condition N overall, the memory demands of T and N were comparable, and therefore age differences should be comparable on the two tasks. The two conditions with chunked presentation (TC and TCD) had reduced encoding demands (relative to Conditions N and T) because strategic chunking was supplied by the experimenter. At the same time, the TCD condition had a dual retrieval requirement (verbal recall and telephone dialing). Thus, with the expectation that older adults perform better when the fewest spontaneous operations are required, age differences should be smallest under chunked presentation with verbal retrieval (TC).

For further validation of our findings, three different scoring methods were used to check for measure convergence. For all three methods, scores were recorded separately for 7-digit and 10-digit numbers. The first method was an ordered recall measure as used in Experiments 1 and 2. The second was a sequential recall measure used in earlier research by Drachman and Zaks (1967) as a way to reduce the influence of chance on the scores. The first and last digits were given a point or points, if in the correct position, as were correct digits adjacent to the first or last digit. In addition, any correctly ordered sequence of 3 or more digits was scored as correct. The third scoring system was the most stringent. Here, we tallied the number of totally correct series—every digit in its place (comparable with WAIS–R Digit Span scoring). Although this correct recall measure had a restricted range (scores varied from 0 to 4), it was a useful reflection of real-world difficulties; in practical situations, if even 1 digit is incorrect the number has to be redialed.

Results and Discussion

Multivariate analyses of variance were conducted for each scoring method. In each analysis, scores for 7- and 10-digit numbers were the dependent measures, with age and condition as between-subjects variables. All reported results were significant at $p < .05$ for primary analyses, and Scheffé post hoc tests ($p < .05$) were used where appropriate.

Ordered recall. Multivariate tests were significant for age, $F(2, 223) = 31.2$, $p < .0001$; condition, $F(6, 446) = 11.9$, $p < .0001$; and Age × Condition, $F(6, 446) = 4.7$, $p < .0001$. The univariate follow-up tests indicated that age, $F(1, 224) = 30.0$, $p < .0001$, $\omega^2 = .09$; condition, $F(3, 224) = 18.0$, $p < .0001$, $\omega^2 = .16$; and their interaction, $F(3, 224) = 6.0$, $p < .05$, $\omega^2 = .05$, were significant for the 7-digit numbers. However, only age effects, $F(1, 224) = 54.2$, $p < .0001$, $\omega^2 = .16$, and condition effects, $F(3, 224) = 16.6$, $p < .0001$, $\omega^2 = .14$, were significant for the 10-digit numbers.

Post hoc tests showed that older adults performed significantly worse than younger adults on the 10-digit items, and overall performance on the 10-digit items was greater in Conditions TC and TCD than in Condition N and greater in Condition TC than in Condition T. The results of post hoc comparisons indicated that the identification of numbers as long-distance telephone numbers had no effect on performance because Condition T performance was not significantly higher than performance in Condition N. The results suggested that chunking affected performance because of the difference between Conditions TC and T. Conditions TCD and TC were comparable, indicating that the requirement to dial the telephone did not make recall of the 10-digit numbers any more difficult. These condition effects operated in the same way for old and young.

With 7-digit numbers, post hoc tests indicated that age differences varied as a function of condition. Older adults performed significantly worse than the young ($p < .01$) only in Conditions N and T, where items were presented without chunking. Also, all conditions led to comparable scores for the young on the 7-digit numbers, whereas the older adults performed significantly better in Conditions TC and TCD than in Conditions N and T (see Table 4). These results indicate that the familiar label *telephone numbers* did not result in a significant improvement in verbal recall performance because Conditions N and T were comparable for both age groups.

To check for the impact of proactive interference across the series of numbers presented, analyses of the ordered recall data were repeated with trials as a separate variable. In this case, each trial was one item that was presented to the subject. These results demonstrated that performance declined as a function of item, with lower scores on the later digit series than on the

Table 4
Experiment 3: Ordered Recall and Sequential Recall Scores in Four Conditions

	Ordered recall				Sequential recall			
Age group	N	T	TC	TCD	N	T	TC	TCD
7-digit numbers								
Younger	6.2	6.6	6.7	6.7	6.2	6.5	6.7	6.7
Older	4.8	5.4	6.6	6.4	5.1	5.5	6.6	6.4
M	5.5	6.0	6.6	6.6	5.6	4.9	6.6	6.5
10-digit numbers								
Younger	4.6	5.9	7.3	6.9	5.0	5.5	6.8	6.2
Older	3.4	3.7	5.5	4.4	4.2	4.0	5.2	4.4
M	4.0	4.8	6.4	5.6	4.6	4.8	6.0	5.3

Note. Conditions were as follows: N = number series; T = numbers designated as telephone numbers; TC = telephone numbers chunked; TCD = telephone numbers chunked and dialed.

initial ones, probably a result of proactive interference. This decline was significant for the 7-digit series, $F(3, 228) = 10.1$, $p < .0001$, and the 10-digit series, $F(2, 230) = 15.7$, $p < .0001$. However, there were no interactions of this interference effect with age or condition (all *p*s > .10). Thus, the age differences observed were present on all trials (i.e., all items) and did not significantly increase over trials as a function of proactive interference. Accordingly, analyses with trials were not included on subsequent measures.

Our results suggested that when the task demands were higher (on the 10-digit series), the older adults were unable to take advantage of the chunked auditory presentation in TC to perform as well as the young. Older adults matched the high performance of younger adults only with sequential recall of a local telephone number presented auditorily with chunking (Condition TC). In other words, the chunked condition was not sufficiently difficult with a local number to show the age differences that were seen in other conditions.

Sequential recall. The second dependent measure did not require perfect sequential ordering but gave individuals credit for series of digits that matched part of the encoded number. Although it has been argued that ordered recall scores capitalize on chance (Drachman & Zaks, 1967), this change in scoring methodology had no impact on our findings. Multivariate analysis showed a significant effect for age, $F(2, 223) = 21.1$, $p < .0001$; condition, $F(6, 446) = 7.5$, $p < .0001$; and Age × Condition, $F(6, 446) = 3.05$, $p < .01$. Univariate follow-up tests of the hypotheses showed the same pattern as found with ordered recall, with all effects significant for the 7-digit items, for the Age × Condition interaction, $F(3, 224) = 4.0$, $p < .01$, $\omega^2 = .03$; age, $F(1, 224) = 25.8$, $p < .0001$, $\omega^2 = .08$; and condition, $F(3, 224) = 13.1$, $p < .0001$, $\omega^2 = .12$. All effects were significant except for the Age × Condition interaction on the 10-digit numbers: age, $F(1, 224) = 31.7$, $p < .0001$, $\omega^2 = .11$; condition, $F(3, 224) = 6.0$, $p < .001$, $\omega^2 = .05$. Post hoc tests also showed the same patterns across age, condition, and item type as those reported earlier for ordered recall (see Figure 1).

Correct recall. This measure identified an answer as correct only if all digits were recalled in the correct order, a requirement for accuracy in practical circumstances. This represents a more demanding retrieval requirement than the other measures. Nevertheless, convergence occurred, with the multivariate analyses showing the same pattern as before. Significant effects occurred for age, $F(2, 223) = 15.4$, $p < .0001$; condition, $F(6, 446) = 5.2$, $p < .0001$; and their interaction, $F(6, 446) = 3.8$, $p < .001$. The univariate analyses revealed significant effects for age, $F(1, 224) = 18.0$, $p < .0001$, $\omega^2 = .06$; condition, $F(3, 224) = 9.3$, $p < .0001$, $\omega^2 = .09$; and their interaction, $F(3, 224) = 3.6$, $p < .05$, $\omega^2 = .03$, for 7-digit numbers. For 10-digit numbers, significant differences occurred for age, $F(1, 224) = 22.4$, $p < .0001$, $\omega^2 = .08$, and condition only, $F(3, 224) = 4.1$, $p < .01$, $\omega^2 = .04$.

Because of the restricted range of this variable (0–4), chi-square analyses were also conducted. These analyses were calculated separately for age effects and condition effects (there were too many empty cells to reliably test the Age × Condition matrix) with each specific score (0, 1, 2, etc.) as the dependent variable. These chi-square analyses confirmed that significant age differences occurred for the 7-digit numbers, $\chi^2(3, 228) = 19.2$, $p < .001$, and for the 10-digit numbers, $\chi^2(3, 228) = 28.3$, $p < .001$, and that significant condition differences occurred for the 7-digit numbers, $\chi^2(9, 222) = 37.0$, $p < .001$, and for the 10-digit numbers, $\chi^2(9, 222) = 23.6$, $p < .005$.

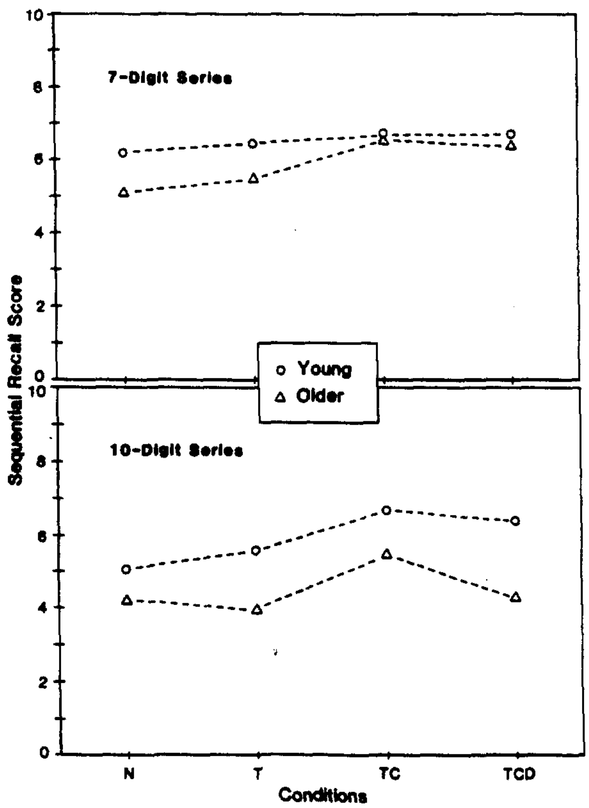

Figure 1. Age differences in sequential recall under all four conditions on the 7-digit and 10-digit series in Experiment 3. (Conditions were as follows: N = number series; T = numbers designated as telephone numbers; TC = telephone numbers chunked; TCD = telephone numbers chunked and dialed.)

On the 7-digit numbers, post hoc tests for the analysis of variance revealed that the young performed better than the old except in Condition TC (see the earlier discussion of ceiling effects). The younger adults performed similarly in all conditions except N (significantly lower scores than in Conditions T, TC, and TCD). It is interesting that with this measure, familiarity (referring to the items as telephone numbers) made a difference for both the young and old, resulting in higher performance on the more demanding recall measure. Older adults showed significant differences between all conditions, with the highest performance in Condition TC. On the 10-digit numbers, the young performed significantly better than the old, and Condition TC resulted in higher recall than did Condition N in post hoc tests. No other differences were significant.

These results suggest that the chunked presentation in Condition TC benefited both age groups, in contrast to results with standard digit-span presentation. There were no performance differences between N and TCD conditions. One interpretation of this outcome, which was not found with the other dependent measures, is that the dual retrieval requirement of TCD canceled the benefits of chunked presentation in TCD for both age groups. On average, dual retrieval in TCD led to one or two more digit errors than occurred in the TC condition—not a large enough change to affect the ordered recall or sequential recall scores. With the more demanding correct recall measure, however, one additional error made on two items would change an individual's score from 4 correct to 2 correct. The addition of a few errors prevents perfect recall, so that TCD performance was not higher than performance in Condition N in this case.

Caution is needed in interpreting the absence of age differences because there were ceiling effects in the 7-digit series. There is evidence to suggest that chunking was useful for the older adults and that the interaction was not due solely to ceiling effects. An isolated look at the data of older adults shows that chunking facilitated their performance; the older adults significantly raised their performance in Conditions TC and TCD relative to Conditions N and T in both ordered and sequential recall. In addition, age differences in the proportion of persons with 7 correct on all items varied dramatically across conditions. In Condition N, 30% of the young and 13% of the old performed at ceiling (a difference of 17%), and a comparable difference was observed in TCD. In Condition T, the age difference in proportions was 31%, whereas in Condition TC the difference was −2%, with the older adults having a somewhat larger percentage performing at ceiling than the young. An examination of the distributions of scores for the old and young in Condition TC also shows them to be nearly identical.

In addition, nonparametric analyses comparing the age groups in each condition using the Kolmogorov-Smirnov method confirmed the presence of an interaction between condition and age. With this procedure, the central tendency, dispersion, and skewness (Siegel & Castellan, 1988) of two distributions are compared to see whether the distributions come from the same population. The two age groups were significantly different in Conditions N and T on all measures ($ps < .01$, except $p < .05$ for Condition N ordered recall). However, there were no significant differences between the older and younger adults in Conditions TC and TCD on any measures ($ps > .25$). These additional data suggest that the observed interaction is not entirely due to a ceiling effect. The interaction may reflect variations in processing requirements because chunking was provided for the subjects and did not have to be generated spontaneously in Condition TC or TCD (see Craik, 1968; Waugh & Barr, 1980).

Three hypotheses were examined in Experiment 3. One was that the processing requirements of the task would determine the age pattern, rather than task familiarity, when Conditions N and T were compared. This was confirmed because in every case, younger adults performed better than older adults in Conditions N and T. Familiarity had a small impact on the scores, with its effect evident only on the correct recall measure on which old and young performed better in Condition T than in Condition N. Older adults did not differentially benefit from this familiarity; the young still performed better. Familiarity probably had no impact on age differences because the information-processing requirements across the two tasks were comparable. In many cases in which familiarity facilitated older adults' performance in other research, the familiarity effect was confounded with altered processing demands (West, 1986).

These results replicate and extend previous findings of age differences in recall of numbers presented without chunking (Conditions N and T) and confirm the benefits of auditory chunking (Waugh & Barr, 1980). The second hypothesis concerning an interaction of age and chunking was not clearly confirmed. Both age groups performed significantly better with Condition TC than with standard digit-span presentation (N or T) on most measures. Under a condition of auditory chunked presentation of 7-digit numbers, the score distributions for old and young were virtually identical, suggesting that older adults may have benefited from chunking in that particular case. However, on the more difficult 10-digit series, older adults did not benefit similarly from chunking.

The predictions concerning dual retrieval were confirmed only when the dual retrieval condition (TCD) was combined with a stricter performance criterion ("perfect" recall of the number). With the sequential recall and ordered recall measures, the younger and older adults generally performed as well in Condition TCD as in Condition TC. Thus, the requirement to dial did not create significant problems for the older adults, relative to other conditions, except when the stricter real-world criterion was used for scoring. The practical implications of this finding are discussed in the next section.

Measurement convergence occurred with comparable patterns of significant results across all three measures. Age accounted for the greatest variance in the ordered recall measure. The only inconsistency observed across measures was the impact of dual retrieval (Condition TCD) and the value of the telephone-number designation, which were most evident for the strictest measure, correct recall.

General Discussion

The results of this investigation yielded data of interest to researchers as well as information of practical value to older adults. Across the experiments reported in this article and the earlier study (Crook et al., 1980), there was high consistency. The three current studies revealed clear age differences in the recall of long-distance telephone numbers and age decline in recall of local numbers under some conditions. Not surprisingly, all age groups performed at ceiling on the recall of area codes. Decline was consistently evident by the seventh decade, even with local numbers. With long-distance numbers, decline was apparent by the 60s. There was little evidence for decline during the middle years except under distracting conditions, consistent with the data of Talland (1968). The evidence indicated that this particular task resulted in age trends quite comparable with those obtained on laboratory digit-span tasks and that, for the most part, the use of telephone numbers did not especially facilitate processing by older adults.

One minor discrepancy between these results and the earlier study is that Crook et al. (1980) found no age differences between elderly normal subjects and young subjects on 10-digit series that were recalled verbally, whereas all of the studies reported in this article showed an age decline in retrieval of 10-digit series when comparing groups under age 40 to groups over age 60. The present studies included no condition that was exactly comparable with the condition of the earlier study (Crook et al., 1980) involving visual (plus auditory) chunked presentation. The condition in that study involved bimodal input combined with chunking, which may account for the absence of age differences, even with the 10-digit series. In effect, Crook et al.'s subjects were provided with a bimodal visual and auditory chunked code and did not need to perform their own strategic chunking, a condition that should facilitate telephone number recall for older adults (Craik, 1968; Talland, 1968; Waugh & Barr, 1980).

The impact of aging was most clear on the 10-digit numbers. Even with an immediate recall test, adults over age 60 cannot perform as well as younger adults. Changing from telephone dialing to a less demanding sequential recall test did not eliminate age differences (Crook et al., 1980), nor did variations in modality (Taub, 1975). Auditory chunked presentation also did not eliminate age differences (Talland, 1968). In addition, using a familiar label for the task (identification of items as telephone numbers) did not appear to facilitate older adults or to compensate for deficits in recall (Crook et al., 1980). The large-sample data from Experiments 1 and 2 indicated that these deficits in recall of long-distance numbers may begin during the middle-aged years and intensify with aging. As aging proceeds, many adults may encounter increasing difficulty with immediate recall of new long-distance numbers.

The impact of aging on recall of local telephone numbers is less clear. The presence of ceiling effects led to the conclusion that recall of a 7-digit series is not an age-sensitive test appropriate for understanding age-related processing differences. However, this begs the practical question: Should middle-aged and older adults expect difficulty in immediate recall of local telephone numbers? Tentatively, the findings suggest that most middle-aged or young-old adults should not experience considerable difficulty under these conditions: when no distractions or interruptions occur, when presentation involves more than one modality (e.g., the number is heard and then seen as it is written down), and when the number is presented with chunking.

Retrieval requirements played a role in the age differences we observed. Data from Experiments 2 and 3 and the earlier study (Crook et al., 1980) indicated that older adults' scores are sensitive to varying dependent measures. The typical retrieval situation, requiring an entire number to be dialed correctly, was more likely to result in age declines than was sequential recall (Crook et al., 1980). When a busy signal required that a number be redialed, the resulting memory loss was greater for older individuals. In addition, in Experiment 3, the demanding correct recall measure was affected by the combination of dialing and verbal recall—older adults were unable to remember and dial as many local or long-distance numbers as were young people, even after chunked presentation. Comparable age-related retrieval deficits have been observed in other studies of immediate recall (Craik, 1968; Talland, 1968; Taub, 1977).

Although generalization to real-world situations is not direct, this laboratory analogue study has some practical implications. For most people, local telephone exchanges and familiar area codes are recalled as one chunk of information in memory. In addition, many different numbers were presented in this study. In circumstances in which only one phone number is presented, adults of all ages may perform better because of less interference. Therefore, ecological situations may be somewhat easier than the laboratory analogue we used. Thus, it would be fair to conclude from our data that immediate recall of local telephone numbers should not be substantially impaired before the late 60s or 70s. Until further research establishes that the same results will be observed with written presentation alone, older adults should be advised to transform numbers read from the telephone book. Numbers should be transformed immediately into an auditory code to provide for bimodal processing, and the number should also be chunked into segments to ease recall. In addition, older adults should be careful to avoid any kind of interruption between reading and dialing a number if they do not want to have to search the directory twice. Even though our subjects may have anticipated a busy signal, it still disrupted recall, so care is needed to avoid interruptions whenever possible. Recent changes in telephone-company procedures, such as using computerized presentation of numbers in standard digit-span format, are likely to disadvantage older adults. Instead, chunked auditory presentation is preferable to improve the probability that the number can be recalled correctly. Because dialing increased the retrieval demands and led to lower performance, older adults probably should rehearse a number verbally, to ensure that it is in memory, before attempting to dial.

The existing evidence concerning telephone number recall is clearly in line with recent conceptions about age-related declines in memory, with age differences increasing in direct relationship to processing demands. Thus, analogue tests of practical memory, such as the one used here, can confirm the trends evident in laboratory studies. Age differences have been larger as a function of (a) the need to spontaneously apply strategic encoding, as reflected by differences between chunked and unchunked presentation; (b) attentional distraction, as reflected by greater age declines with the presence of a busy signal at retrieval; (c) stricter retrieval requirements, as reflected by the detrimental combined effect of requiring totally correct recall and requiring verbal recall plus dialing; and (d) increased memory load, as reflected by larger age effects on long-distance telephone numbers that included area codes.

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Everyday Memory Performance Across the Life Span: Effects of Age and Noncognitive Individual Differences

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Gerontologists have long been concerned with the impact of individual-difference factors on memory. This study used a large sample (N = 2,495) of adult volunteers aged 18 to 90 years to determine if a set of individual-difference variables—vocabulary, education, depression, gender, marital status, and employment status—mediates the effects of aging on a wide range of laboratory-analogue tests of everyday memory. The data indicated that age was consistently the most significant predictor of memory performance, followed by vocabulary and gender. Vocabulary totally mediated age effects on a prose memory measure, and partial mediation of aging effects—primarily by vocabulary and gender—was observed on 5 other memory tests. These data suggest that when healthy samples of volunteers serve as research subjects, these individual differences can affect some memory test scores, but age remains the best overall predictor of memory performance.

Individual differences have long been a concern in the gerontology literature for several reasons. Individual differences in basic background characteristics that relate to skill-level variations—for example, vocabulary or education—may interact with aging to produce age-related differences in performance (Cavanaugh, 1983; Meyer & Rice, 1983). When skill-related factors vary as a function of cohort, they may be important predictors of age-related performance change, serving to enhance or reduce the impact of aging (Poon, Krauss, & Bowles, 1984). Cognitive change processes in aging can best be understood in association with individual-difference factors that covary with memory performance.

Theoretically, one very important issue is the degree to which individual differences mediate cognitive aging. This research focuses on this mediation issue to examine the explanatory power of age, as compared with the explanatory value of several individual-difference variables. If the impact of aging is totally mediated by other variables, then performance can be explained by individual differences, and the contribution of age to performance prediction is spurious. That is, the primary impact of aging could be through its association with other types of age-related psychological change (e.g., reduced cognitive demands associated with retirement or widowhood). Alternatively, age could retain its theoretical status as the most important performance predictor even when other factors are covaried (see Salthouse, Kausler, & Saults, 1988b).

Practical and empirical concerns also point to the importance of identifying those psychological characteristics that mediate memory performance. Clinicians and researchers can benefit from more precise information about factors that covary with age-related changes in cognitive performance. Clinicians need to consider individual differences in designing and standardizing cognitive tests. Also, if memory performance is predicted by individual-difference variables, it would be important, in empirical research, to incorporate the mediating variables into research designs so that cross-sample comparisons can be made on the relevant variables that affect performance (Hoyer, Raskind, & Abrahams, 1984; Salthouse, Kausler, & Saults, 1988a). Thus, the specific goal of this study is to quantify the role of some individual differences as they influence everyday memory performance.

One potentially important individual-difference factor is depression. There is mixed evidence concerning the impact of depression on cognitive performance. Although cognitive impairments in depressed patients are not always observed, serious depression can be linked with cognitive deficits, especially in older adults (Jorm, 1986; Niederehe, 1986). The cognitive changes that can occur with depression include encoding and retrieval difficulties, problems with attention and concentration, slowed information processing, and rapid forgetting (Weingartner, 1986); but what happens to the individual who has a few depressive symptoms but no indication of major depression? It is not clear how strong the link is between depression and cognition for older individuals who do not merit a diagnosis of depression (see Newmann, 1989). It is valuable to know if level of self-reported depression is an important individual-difference variable affecting memory scores when normal community-dwelling volunteers are assessed, that is, individ-

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Structure of Everyday Memory in Adults With Age-Associated Memory Impairment

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Everyday memory was tested in a group of adults manifesting Age-Associated Memory Impairment; a computerized battery of tests was constructed to simulate memory tasks of daily life. Confirmatory and other structural equation models were estimated for the entire sample of 273 Ss and for 3 age groups. A 4-factor model was found to fit the data well and was invariant across age and gender. After education had been controlled, only the General Recall factor was found to be consistently related to age in both men and women; the other 3 factors—Narrative Memory, Digit Recall, and Visual Memory—were related to age only in men. Confirmatory factor analyses of the everyday memory tests combined with several psychometric memory tests suggested that some of the latter (the Benton Visual Retention Test and Wechsler Memory Scale Hard Paired Associates) load on more than 1 factor of everyday memory, suggesting complex relationships between the 2 types of tests.

Age and gender differences in level of memory performance have been documented for a variety of memory tasks, including conventional laboratory tasks and everyday life memory tasks (e.g., West, 1986). Much less work has been conducted to determine the pattern or structure of memory abilities and whether this structure is constant across age and gender. Level differences are typically interpreted on the basis of an assumption of invariance of structure (cf. Hertzog, 1987); therefore, this assumption should be carefully examined. The possibility that the structure of memory varies with age or gender, or both, may suggest changes or differences in cognitive organization. The interpretation of findings in studies of cognitive aging, which have been based commonly on samples with a preponderance of female subjects (who often perform better than male subjects on verbal memory tasks; e.g., Larrabee, Trahan, Curtiss, & Levin, 1988), would also be affected by the presence of gender differences in the structure of memory.

Everyday memory, which is the focus of this article, can be defined as memory evidenced in everyday life tasks and measured either outside of the laboratory or, using simulated everyday life tasks, inside the laboratory. Recent exploratory factor-analytical work (e.g., Crook & Larrabee, 1988; Larrabee & Crook, 1989) has provided important information about the dimensions of everyday memory in normal adults, as well as in those manifesting developmental changes in memory characteristic of Age-Associated Memory Impairment (AAMI; Crook, Bartus, et al., 1986). This research has used a newly developed computerized battery (Crook, Johnson, & Larrabee, 1990; Crook, Salama, & Gobert, 1986) to test memory in a way that attempts to simulate realistically everyday tasks (e.g., learning a grocery list) while using well-controlled experimental paradigms (e.g., selective reminding). Exploratory methods have also been used to examine the relationship between tests in this computerized everyday memory battery and several standard neuropsychological tests (Larrabee & Crook, 1989).

Some investigations have addressed the issue of stability of structure with age using exploratory factor analyses of age-residualized versus raw scores (Crook & Larrabee, 1988; Delis, Freeland, Kramer, & Kaplan, 1988; Larrabee, Trahan, & Curtiss, 1992). Also, Larrabee et al. (1988) have used exploratory methods to address the issue of gender differences. These studies have provided evidence of the stability of memory structure across age and gender but have not used more powerful, model-driven confirmatory analyses.

This was precisely the purpose of the present investigation, which used a relatively large sample and the method just described of (presumably) ecologically valid tasks. The structural issue was addressed by constructing a model based on previous exploratory analyses and by using the structural equation modeling (SEM) approach (e.g., Hertzog, 1987) to test this model in a new sample. Equivalence of structure across gender and age was examined by imposing constraints of equality and by determining the fit of constrained models (in comparison with unconstrained models). The following paragraphs deal with the rationale for the construction of the confirmatory factor analysis model.

Principal-components analyses with varimax rotations produced a four-component solution in a similar but different AAMI sample (Larrabee & Crook, 1989). Several sets of everyday memory tests were used, including measures of reaction time. Reaction time measures were not included in the present model and analyses because they were considered to be conceptually different from other measures and because there were inconsistencies in the relationships between the reaction time measures and the other measures across two samples (Crook

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Evaluation of Drugs in Alzheimer's Disease and Age-Associated Memory Impairment

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A major issue in assessing the efficacy of drugs for late-life cognitive disorders is that of clinical relevance or "ecologic validity." It has been argued (Crook 1983; 1985a; Larrabee and Crook 1988; Leber 1986) that measures of treatment effects should bear a clear relationship to the behavioral problems for which treatment is undertaken. These behavioral problems may be assessed through rating scales completed by the clinician, the family of the patient, and sometimes the patient himself. Behavioral capacities may also be assessed directly through objective, psychometric performance tests. A major problem with most psychometric tests, however, is that they are abstract and bear little relationship to the behavioral problems for which drugs may be prescribed.

An effort was begun a decade ago to develop a battery of clinically relevant performance tests for assessing treatment effects in adult onset cognitive disorders. The first generation of tests was developed in collaboration with Drs. Steven Ferris, Charles Flicker, and other investigators (e.g., Ferris and Crook 1983; Crook 1985a; Ferris et al. 1986a). In 1985 we began an accelerated effort to develop a second generation of measures utilizing stage-of-the-art computer and laser-disk technology to closely simulate tasks of daily life on which performance is often impaired in adult-onset cognitive disorders.

Our objectives in test development were as follows:

1. To develop measures that relate closely to the behavioral problems for which treatment may be undertaken in adult-onset cognitive disorders.
2. To employ academically sound paradigms of human cognitive processes.
3. To develop measures sensitive to both normal age-related memory loss and cognitive symptoms seen early in the course of adult-onset cognitive disorders.
4. To develop measures that meet the highest standards of inter-rater and test-retest reliability.
5. To develop tests that are appropriate for different languages and cultures and, thus, appropriate for use in multinational drug trials.
6. To develop measures available in at least five alternate forms for repeated use in drug trials.

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7. To develop extensive normative data in different cultures and extensive data on the patterns of deficits seen in different neurologic disorders.
8. To develop measures sensitive to drug effects including measures based on paradigms of learning and memory found sensitive to drug effects in experimental animals.
9. To develop a battery measuring empirically as well as theoretically distinct parameters of cognitive function.
10. To develop an assessment system in which relevant behavioral capacities are assessed through self-ratings, family ratings, and clinician ratings, as well as through performance tests.

In an effort to meet these objectives, research aimed at test development and refinement, as well as drug testing, was undertaken and is now under way in multiple clinics, universities, and community settings in Belgium, Denmark, England, Finland, France, Italy, Sweden, and the United States. In this paper we describe several of the tests in the battery and present data from several studies conducted in the United States. For a more general discussion of theoretical issues related to the assessment of drug effects and other tests that may be used in treatment evaluation studies, we refer the reader to two other recent papers (i.e., Flicker 1988; Larrabee and Crook 1988). A review of other computerized tests is provided by Maulucci and Eckhouse (1988).

1 Computerized Laser-Disk Performance Tests

1.1 Hardware and Software

Although our battery of performance tests is computerized, we believe strongly in using electronic technology to simulate clinical reality. Thus, in no case are subjects required to interact with the computer during testing. We do not employ keyboards, joysticks, or other manipulanda with which subjects are differentially familiar in testing. Rather, a tester operates the computer and laser-disk equipment and the subject responds either verbally, by touching a large touch-sensitive monitor to register a response, or by operating familiar manipulanda (e.g., a telephone) interfaced with the computer.

The equipment that constitutes a computerized test station is the same worldwide. Hardware is as follows:

- An American Telephone and Telegraph (AT&T) 6300 computer with a 20 megabyte hard disk drive.
- Installed in the computer is an Image Capture Board (ICB) produced by AT&T for presentation of computer generated graphics.
- A Pioneer LDV 6010 laser-disk player.
- A laser-disk produced by our organization and mastered by 3M Corporation. For each language in which we test.
- A Sony 19', 1910, color monitor with a touchscreen installed by our organization.

Certificate of Service

I, Richard C. Bartel, hereby certify that a copy of this Supplement to our Answer and Petition was mailed or faxed to the Washington Post Company and Digital Ink, Inc., c/o Henry D. Levine & D.E. Boehling, Levine, Blaszak, Block, & Boothby, 1300 Conn. Ave., NW, #500, Washington, DC 20036, on this 2nd day of November, 1996.

Richard C. Bartel