Short-Term Memory in Hong Kong: Is it different?

FLORENCE YUET YU SZE (Email: iesyy@usthk.ust.hk),
RAVINDRA S. GOONETILLEKE (Email: ravindra@usthk.ust.hk),
and
HELOISA M. SHIH (Email: iehhshih@usthk.ust.hk)
Department of Industrial Engineering and Engineering Management,
Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

Abstract
The objective of this paper is to elicit the visual memory span for the Hong Kong population. An experiment with four conditions was designed, performed and analyzed with 60 Hong Kong Chinese subjects. Time and accuracy measures were the dependent variables. Distinct patterns are seen in the factor analysis with varimax rotation indicating that the conventionally used measure of percent correct recall may be insufficient. The accuracy measures are very similar across conditions. A full number presentation had better performance compared to a single digit chunk and unpaced presentations were better when compared to paced presentations. Overall, the results show that the memory span of Hong Kong Chinese is 8.5 to 9.9 (depending on type of visual presentation) and higher than that of native English speakers as reported in the literature.

1. Introduction

Miller (1956) has shown that the immediate memory span is a constant value and it is determined by the number of "chunks", averaging about seven chunks and varying between five and nine. Hunter (1962) complained that a rate of one digit per second is too slow but a rate of five per second allowed him to repeat 15 digits in both forward and backward orders. However, Broadbent (1975) elaborates on this issue, saying that when people are given a list to recall, the number of items they can recall is 3 to 4 reliably and 7 to 9 with 50% probability. The memory span for letters may be increased depending on the letters: 6 when the letters are selected at random, about 9 when they are consonant-vowel-consonant syllables, and may go as high as 50 or more when the letters make up words in a meaningful sentence (Baddeley, 1990). Herrnstein and Murray (1994) in their controversial book, the Bell Curve, think that those in Hong Kong have higher IQ's compared to whites and hence it may be possible that the memory span of the Hong Kong population be greater than that specified in the literature. In studies related to the Chinese language, Zhang and Simon (1985) proposed that memory span is really determined by rehearsal rate. Ayres (1986) found memory span to be directly proportional to reading speed for speakers of four different languages. Similarly, based on a word length study, Baddeley (1975) indicated that memory span corresponds to the number of words a subject can read in approximately 2 sec. Hence it may be hypothesized that Cantonese speakers have higher memory span as opposed to English speakers. The average reading speed for a Cantonese digit is 265ms (Hoosain, 1984) while Ellis and Hennelly (1980) have found an average reading speed of a digit in English to be 321ms and in Welsh to be 385ms with bilingual subjects. Using Baddeley's findings, the above values translate to a memory span of (2000/265)= 7.5 for a Cantonese speaker, and (2000/321) = 6.2 for a English speaker, and (2000/385) = 5.2 for a Welsh speaker. In addition to the available literature, it is hypothesized that the intonation built into the Cantonese language can significantly enhance the memory span of Hong Kong Chinese. The experiment reported here evaluates the memory span of Hong Kong Chinese fluent in Cantonese using a visual memory span test with different forms of number presentation.

2. Methodology

Subjects
A total of 60 subjects (31 males and 29 females) participated in the study. Each subject was paid HK$ 15 and performed all 4 conditions. Their mean age was 28.3 years with a standard deviation of 10.84 years. The age range was 18 to 72 years.

Conditions
Four conditions were coded using the Visual Basic language and run on a Pentium personal computer to study the memory span of Hong Kong Chinese. The objective of the task was to remember a number displayed on the screen, and to input it at the end of the presentation. For the sake of clarity, it should be emphasized that digits comprise a number in one presentation. In each of the 4 conditions, a total of 18 numbers (9 variations * 2 repetitions) with each number having 5 to 13 digits (9 variations) were presented, one at a time. The order of the digits and the number of digits in each presentation was random. Condition 1 had digits appearing one at a time. The duration each digit remained on the screen was controlled by the subject. A subject could take as long as he/she wanted prior to requesting the next digit (single digit, unpaced). In condition 2, a whole number with 5 to 13 digits appeared on the screen and the subject was expected to remember the number as fast as possible. Subjects were allowed to take as long as they needed (whole number, unpaced). Conditions 3 and 4 were paced in the sense that the rate at which the numbers or digits appeared was controlled by the computer. The digits in a number appeared one at a time in condition 3. Each digit was shown for 0.7 seconds. The subject had no control over the time at which the number disappeared (single digit, paced). Condition 4 had all digits appearing at the same time. A subject was expected to remember the whole number given a limited time of 5 seconds (whole number, paced). It should be noted that the difference between conditions 1 and 3 is the pacing aspect similar to the difference between condition 2 and 4. However, the difference across the two groups is a whole number or single digit presentation.

Procedure
The order of presentation of the 4 conditions was completely randomized to minimize any order effects. Each subject was told that the objective of the experiment was to determine human performance in a number remembering task. All four conditions took approximately 15-30 minutes. Prior to each condition, each subject did two practice trials. The subjects were supposed to remember the numbers and then type them in to the computer when they were requested to do so.

Performance Measures
Six basic performance measures were used:

1. Time (T)
2. Accuracy Measure 1 (M1). This measure was defined as the number of digits correct up to the first wrong digit. For example, if the number was 7 4 5 2 1 4 5 6 3 4 and the number typed in by the subject was 7 4 5 2 0 3 4 6 3 4, then this measure is equal to 4 because the number of correct digits are only 7 4 5 2. The next digit which should have been 1 is entered as 0.
3. Accuracy Measure 2 (M2) was defined as the number of correct digits at the correct locations in the sequence. For the above example, 7 4 5 2 are correct and at their correct locations. The last three digits, 6 3 4 are also correct and at the correct location and hence measure 2 is equal to 7.
4. Accuracy Measure 3 (M3) was defined as the total number of digits matching the original number regardless of order. For the above example, 7 4 5 2 4 6 3 and 4 are matching digits and hence measure 3 is equal to 8.
5. Accuracy Measure 4 (M4) was defined as the number of correct digits starting from the end and counting backwards. For the above example, the last three digits 6 3 4 match the displayed number when counting backwards and hence measure 4 is equal to 3.
6. Accuracy Measure 5 (M5) was 100% if the entered number matches the displayed number, else M5=0. In other words, it is an indication the percent correct. All literature generally use only M5.

Transformed measures were used to evaluate each measure per digit so that the numbers could in some way be "normalized". Thus 5 more measures were defined. They were Time per digit (TD), M1 per digit (M1D), M2 per digit (M2D), M3 per digit (M3D), and M4 per digit (M4D), where

TD = T/ number of digits in one presentation
M1D = M1/ number of digits in one presentation
M2D = M2/ number of digits in one presentation
M3D = M3/ number of digits in one presentation
M4D = M4/ number of digits in one presentation

Note that when M1D =M5= 100%, it reflects perfect recall and hence M2D, M3D and M4D will also equal 100%. Generally, M1D, M2D, M3D and M4D will be greater than or equal to M5.

3. Results and Analysis

Figure 1, 2, 3, 4, and 5 show the variation of measures M1D, M2D, M3D, M4D, and M5 versus number of digits for each condition. Figure 6 shows the time per digit for each condition.

One interesting finding is the similarity in the shape of the curves of accuracy versus number of digits for each measure across all conditions (Figures 1 to 5). It appears that the limiting case of condition 3 (paced) is condition 1 (unpaced) and the limiting case of condition 4 (paced) is condition 2 (unpaced). This conclusion seems valid considering the fact that the difference between condition 1 and 3 and condition 2 and 4 is only the pacing factor.

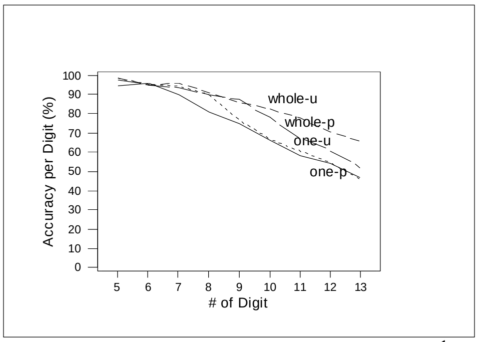

Figure 1 Accuracy Measure M1D[1]

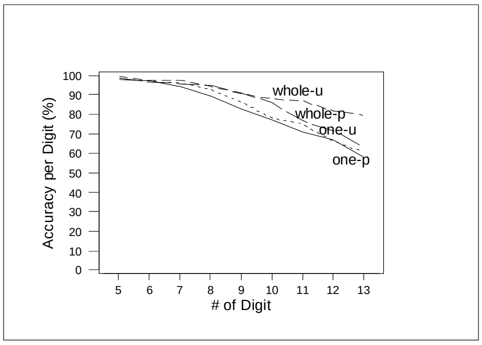

Figure 2 Accuracy Measure M2D[1]

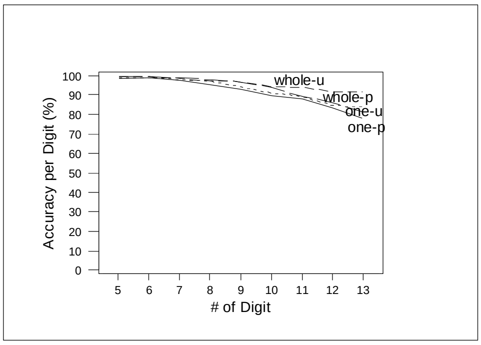

Figure 3 Accuracy Measure M3D[1]

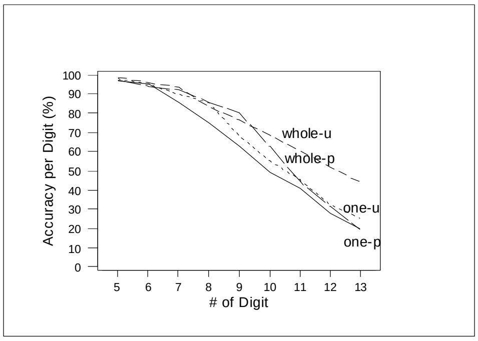

Figure 4 Accuracy Measure M4D[1]

[1] Condition 1 (single digit, unpaced) is denoted as "one-u", Condition 2 (whole number, unpaced) is denoted as "whole-u", Condition 3 (single digit, paced) is denoted as "one-p", Condition 4 (whole number, paced) is denoted as "whole-p"

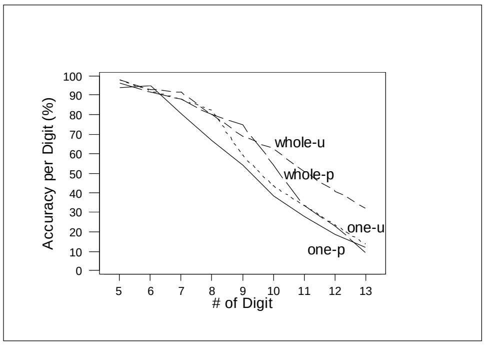

Figure 5 Accuracy Measure M5

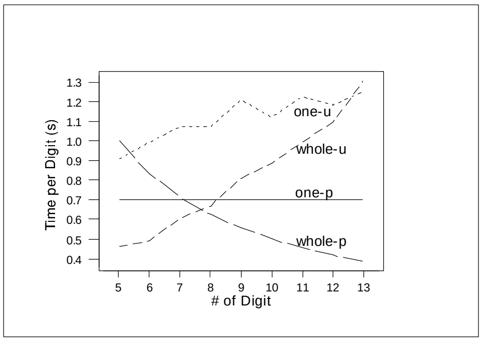

Figure 6 Time Per Digit

Analysis of Variance (ANOVA)

A battery of statistical analysis were performed using the SAS package. The ANOVA (Table 1) indicated significant ($p < 0.05$) effects for condition, number of digits and the interaction between condition and number of digits for all dependent variables. Due to the significant interaction, it is not possible to conclude on the main effects. Hence simple effects analyses were performed for each number from 5 to 13. Table 2 shows that the accuracy measures are not significantly ($p < 0.05$) different for all four conditions when the number has 5 to 7 digits. Above 7 digits (i.e., 8 onwards) the type of presentation will significantly ($p < 0.05$) influence the accuracy measures with the highest accuracy being in condition 2 and condition 3 having the lowest accuracy as indicated by a *post-hoc* Student Newman Keuls (SNK) test.

Table 1. ANOVA - F Values and probability in parenthesis.

Source (df)	**TD**	**M1D**	**M2D**	**M3D**	**M4D**	**M5**
cond. (3)	338 (.0001)	38.02 (.0001)	47.89 (.0001)	45.29 (.0001)	28.58 (.0001)	25.63 (.0001)
Digit (8)	8.2 (.0001)	184.4 (.0001)	194.04 (.0001)	184.35 (.0001)	189.94 (.0001)	280.57 (.0001)
cond * digit (24)	32.73 (.0001)	2.84 (.0001)	4.57 (.0001)	5.84 (.0001)	2.98 (.0001)	2.55 (.0001)
Trial (1)	0.09 (0.76)	0.54 (.46)	0.14 (0.71)	0.03 (0.85)	0.01 (0.92)	0.22 (0.64)
cond * trial (3)	2.1 (0.098)	0.29 (.83)	0.14 (0.94)	0.31 (0.82)	0.39 (0.76)	0.35 (0.79)
Digit * trial (8)	0.59 (.79)	0.35 (0.95)	0.26 (0.98)	0.33 (0.95)	0.95 (0.47)	1.32 (0.23)
Cond * digit * trial (24)	0.40 (0.996)	0.75 (0.81)	0.68 (0.88)	0.88 (0.63)	0.59 (0.94)	0.95 (0.53)

Factor Analysis

The results of the factor analysis with varimax rotation are shown in Table 3, 4, 5 and 6. The factors show that depending on the condition, each of the transformed variables measure a “different” aspect of performance. Factor 1 for all conditions appear to be dominated by M4D and M5 and hence may be viewed as a “recency” or “correctness” effect. Since the experiment was visual, it is reasonable that the % correct be related to the latter part of a number (or the recency). In other words if the latter part is correctly remembered, it is safe to assume that the whole number is correct. M3D for all conditions seem to dominate a separate factor (“free recall”). For the unpaced conditions, M1D (“primacy”) and M2D (“sequence”) form separate factors, while they appear to be part of the same factor for the paced conditions. The result for the paced condition seems reasonable in that primacy and sequence are really “one” since any errors at the beginning may not allow a subject to get any other digits correct elsewhere in the same sequence.

Table 2. ANOVA for all four conditions and each digit.

Digit	TD	M1D	M2D	M3D	M4D	M5
5	146.01 (0.0001)	2.43 (0.07)	0.80 (0.50)	0.79 (0.50)	0.53 (0.66)	1.53 (0.21)
6	80.93 (0.0001)	0.05 (0.98)	0.09 (0.97)	0.76 (0.52)	0.21 (0.89)	0.38 (0.77)
7	56.32 (0.0001)	2.19 (0.09)	1.80 (0.15)	2.05 (0.11)	2.16 (0.09)	2.28 (0.08)
8	50.11 (0.0001)	3.87 (0.01)	2.80 (0.04)	2.60 (0.05)	2.72 (0.04)	3.63 (0.01)
9	75.00 (0.0001)	5.55 (0.001)	4.32 (0.005)	6.31 (0.0003)	4.56 (0.0037)	4.74 (0.0029)
10	53.95 (0.0001)	8.03 (0.0001)	7.15 (0.0001)	5.38 (0.0012)	4.74 (0.0029)	5.82 (0.0007)
11	61.35 (0.0001)	9.02 (0.0001)	11.43 (0.0001)	6.50 (0.0003)	5.12 (0.0029)	5.44 (0.0007)
12	67.27 (0.0001)	7.00 (0.0001)	10.30 (0.0001)	10.27 (0.0001)	8.94 (0.0001)	6.32 (0.0003)
13	66.13 (0.0001)	10.64 (0.0001)	19.63 (0.0001)	22.95 (0.0001)	13.07 (0.0001)	9.66 (0.0001)

Table 3. Factor analysis for Condition 1 (single digit, unpaced). Shown are factor loadings > 0.49

Measure	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
TD				0.998	
M1D			0.785		
M2D					0.656
M3D		0.853			
M4D	0.864				
M5	0.819				
Proportion of Variance explained	**32.95%**	**20.09%**	**19.20%**	**16.80%**	**10.42%**
Cumulative	**32.95%**	**53.04%**	**72.24%**	**89.04%**	**99.46%**

Table 4. Factor analysis for condition 2 (whole number, unpaced). Shown are factor loadings > 0.49

Measure	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
TD				0.994	
M1D		0.824			
M2D					0.679
M3D			0.871		
M4D	0.854				
M5	0.785				
Proportion of Variance explained	**30.81%**	**20.63%**	**20.08%**	**17.05%**	**11.10%**
Cumulative	**30.81%**	**51.44%**	**71.52%**	**88.57%**	**99.67%**

Table 5. Factor analysis for Condition 3 (single digit, paced). Shown are factor loadings > 0.49

Measure	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
TD					
M1D		0.833			
M2D		0.513		0.604	
M3D			0.841		
M4D	0.875				
M5	0.824				
Proportion of Variance explained	**39.44%**	**26.41%**	**23.64%**	**9.78%**	**0.74%**
Cumulative	**39.44%**	**65.85%**	**89.49%**	**99.27%**	**100.00%**

Table 6. Factor analysis for Condition 4 (whole number, paced). Shown are factor loadings > 0.49

Measure	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
TD				0.943	
M1D		0.816			
M2D		0.499			0.626
M3D			0.86		
M4D	0.821				
M5	0.768				
Proportion of Variance explained	**29.28%**	**21.70%**	**19.88%**	**19.25%**	**9.46%**
Cumulative	**29.28%**	**50.98%**	**70.86%**	**90.11%**	**99.57%**

Memory Span

The memory span was calculated in two different ways for each condition. The first method is as indicated in the literature (Jacobs, 1887; Zhang and Simon, 1985). In this method, only sequences that had at least one correct in a total of two trials is used. If both trials are incorrect, all larger number sequences are ignored in the calculations. This biases the results somewhat since no credit is given to the subject if both trials of a smaller number of digits is incorrect. The second method proposed here gives credit to all correct recall. In other words, memory span = K + 0.5(N) where K=4 and N= number of presentations having correct recall. The results of both methods are shown in Table 7. It is clearly seen that the memory span is different depending on the type of presentation with the highest in condition 2 (whole number, unpaced). Note that in all 4 conditions, the actual memory span may be higher, since there were a total of 3, 23, 4, and 4 subjects having correct recall with 13 digit numbers in conditions 1, 2, 3, and 4 respectively. The memory span of these subjects were marked as 13 when in fact it may be higher.

Table 7. Memory Span for each condition

	Jacobs (1887) Method		**New Method**	
Conditions	**Memory Span**	**Standard Deviation**	**Memory Span**	**Standard Deviation**
Single Digit, unpaced (Condition 1)	8.94	1.42	9.34	1.39
Whole Number, unpaced (Condition 2)	9.88	1.75	10.18	1.46
Single Digit, paced (Condition 3)	8.48	1.62	8.87	1.64
Whole Number, paced (Condition 4)	9.16	1.48	9.51	1.19

4. Conclusions

Overall, unpaced presentation is better than paced in terms of accuracy above 7 digits. As seen in Figure 6, unpaced conditions require more time as the number of digits increase. This is not surprising since more time would be needed for rehearsal thereby increasing the probability of correct recall (Rundus, 1971). Whole number presentation is better than one digit at a time as it will allow the subjects to see more than one digit at a time with a whole presentation (Fukuda, 1992).

The type of presentation seems to not matter when the number of digits is less than 8. However, the type of presentation will influence the accuracy with 8 or more digits. Worst accuracy in condition 3 is not surprising since the time per digit of 0.7 seconds may be insufficient for a single chunk to be made a larger chunk.

The memory span for native English-speaking Americans is 7.2 (Stigler et al, 1986) when digits were presented one at a time for 1 second each. In this experiment, a similar condition shows a memory span of 8.48 (from Jacobs method) even though the number was displayed for only 0.7 seconds (condition 3). One possible reason for the increased memory span may be attributed to the Cantonese language where the pronunciation of each number is shorter than in English (Hoosain, 1984) thereby allowing a greater rehearsal time. According to Baddeley (1975), the memory span is equivalent to the number of words which can be read out in approximately 2000ms. However, we find that when numbers are to be remembered in Cantonese, that time corresponds to approximately 2250 – 2600 ms based on the average reading speed published by Hoosain (1984). Thus, more words can be remembered (rehearsed) when their pronunciation requires a smaller amount of time.

Finally, it must be said that measures other than percent correct also need to me considered in memory studies since they measure different “dimensions”.

5. References:

Ayres T. J (1986). Digit Span, Reading Rate, and Linguistic Relatively. *Journal of Experimental Psychology, 38*A, 739-751.

Baddeley, A. D (1975). Word Length and the Structure of Short-Term Memory. *Journal of Verbal Learning and Verbal Behavior, 14*, 575-589.

Baddeley, A. D (1990). *Human Memory*. Canada: Allyn and Bacon.

Broadbent, D. E. (1975). The magical number seven after fifteen years. In A. Kennedy and A. Wilkes (Eds.) *Studies in Long-term Memory*. New York: John Wiley.

Ellis N. C and Hennelly R. A (1980). A bilingual word-length effect: Implications for intelligence testing and the relative ease of mental calculation in Welsh and English. *British Journal of Psychology, 71*, 43-51.

Fukuda, T. (1992). Visual capability to receive character information Part I: How many characters can we recognize at a glance? *Ergonomics*, *35*, 617-627.

Herrnstein, R. J. and Murray, C. (1994). *The Bell Curve*. New York: Free Press.

Hoosain, R. (1984). Experiments on digit spans in the Chinese and English languages. In: H.S.R. Kao & R. Hoosain (Eds.), *Psychological studies of the Chinese language*. Hong Kong: The Chinese Language Society of Hong Kong.

Hunter, I. M. L. (1962). An exceptional talent for calculative thinking. *British Journal of Psychology, 53*, 243-258.

Jacobs, J. (1887). Experiments on ‘prehension’. *Mind*, 12, 75-79.

Miller, G. A. (1956). The magical number seven plus or minus two: Some limits on our capacity for processing information, *Psychological Review*, *63*, 81-97.

Rundus, D (1971). Analysis of rehearsal processes in free-recall. *Journal of Experimental Psychology*, *89*, 63-77.

Stigler, J. W., Lee, S. Y., and Stevenson, H. W. (1986). Digit memory in Chinese and English: Evidence for a temporally limited store. *Cognition, 23*, 1-20.

Zhang, G., and Simon, H. A. (1985). STM capacity for Chinese word and idioms: Chunking and acoustical loop hypotheses. *Memory and Cognition*, *13*, 193-201.