The coming PIN code epidemic: A survey study of memory of numeric security codes

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Abstract

Most people must remember various numeric passwords, security codes and PIN numbers for banking, credit cards, debit cards, online accounts, mobile phones, door locks, luggage locks, etc. One pilot study (*N*=13) developed a list of eleven strategies for remembering numeric codes, and another (*N*=15) optimized the research questionnaire which asked respondents about a) the number of security codes they had, b) the number of self-created codes, c) mnemonic strategies used, d) problems and effort remembering codes, and e) gender, age, and education. Respondents (*N*=388) had a median of 4 security codes and typically used 2 different memory strategies, the most common of which were based on repetition and on keypad pattern. Difficulties remembering codes were unrelated to gender or education but were positively correlated with age and with number of strategies used. Self-creation of codes slightly reduced difficulties remembering numeric codes.

Keywords: *Memory; Mnemonics; Online banking; Passwords; PIN; Security codes*

Introduction

In an era of increasing use of electronic security systems for debit cards, credit cards, online banking, online trading, mobile phones, door locks, etc., difficulties remembering numeric security codes will certainly be increasing. Remembering one random numeric sequence can be a challenging task; remembering many such sequences can cause memory interference effects which are further complicated when numeric codes are changed. The problem is so predictable that some individuals and institutions pay fees for code retrieval services that store the user's security codes and can be accessed via an online connection (Shah, 2008).

Some journalists have written about the problems people have remembering PIN codes. For example, Stewart (2002) explained why secure passwords of long sequences of random numbers and letters are difficult to remember, and recommended transposing them into nonsense sentences than can then be written down. Moon (2005) noted that the UK charity “Help the Aged” has estimated that “there are about 750,000 victims of low-level dementia who will struggle to use chip and PIN.” Another online report entitled “Computer chip implant for those who incessantly forget their passwords” (Techshout.com, 2006) began by noting that forgetting computer passwords was “a very common problem that most of us face very often.”

Boolean search of PsychINFO, ISI Web of Science, and Google Scholar found relatively little research literature on memory for numeric security codes. As Yan, Blackwell, Anderson and Grant wrote in 2004 (p. 30), “The literature on password selection and memorability is surprisingly sparse,” and that is mostly about alphanumeric passwords (e.g., Besnard & Arief, 2004; Carstens, McCauley-Bell, Malone & De Mara, 2004; Pond, Podd, Bunnell & Henderson, 2000; Zviran & Haga, 1993). This search for literature on digit sequence security codes found only the study by Hill, Campbell, Foxley and Lindsay (1997) who examined if the elderly had improved recall for 6-digit lock combinations by using the number-consonant mnemonic. This entails pairing numbers with consonants based on phonetics (e.g., 4 = R; 7 = S) or on graphemics (e.g., 1 = L; 2 = N), then converting the consonant sequence to a memorable word sequence. For example, 2417 = NRLS = NeaR LoSs. Elderly subjects instructed in the number-consonant mnemonic had better recall than a control group at 7-day follow-up.

The purpose of this study was to explore the difficulties people experience in remembering numeric security codes. Alphabetic passwords were not considered. Also examined were the number of competing codes, assigned vs. created codes, the variety of memory strategies, as well as the influence of age, education and gender.

Method

Pilot studies

Thirteen informal pilot interviews explored what kinds of troubles people have with numeric security codes and what kinds of strategies are commonly used to remember numeric codes. Everyone admitted to problems and effort remembering security codes. The interviews resulted in a list of 11 mnemonic strategies.

The information from these interviews was used to create a tentative one-page research questionnaire. Five categories of questions were: 1) how many numeric security codes the respondent has in the categories of a) bank- and credit cards, (b) mobile phones, c) electronic doors, and d) baggage locks, bike locks and padlocks; 2) how many of these codes had been self-created; 3) five questions about how frequent were problems remembering numeric codes; 4) which of the 11 mnemonic strategies had the respondent used; 5) what were the respondent's gender, age and years of education after age 18.

The tentative questionnaire was administered to 15 respondents who were also asked if they thought any part of the questionnaire were unclear, and which question they regarded as most difficult. As a result, the five questions about frequency of difficulties remembering numeric security codes were changed to a two-item scale asking about 1) problems remembering numeric security codes, and 2) effort made to remember numeric security codes. These were to be answered on an likert scale ranging from "none" (value 1) to "severe" (value 7).

Sample

The online version of the survey was announced through *Facebook* (a free-access social networking website with, more than 500 million active users) (Press Room, 2010), and through *VGDebatt* which is an online forum run by the popular Oslo newspaper *Verdens Gang*. A one-page paper version was distributed to university students. Because the questionnaire was distributed via online forums, the total number of people invited to participate is unknown; therefore, the response rate is unknown.

The final sample consisted of 388 participants, 357 of whom answered the online versions. Of the total respondents, 230 were men (59%) and 157 women (41%). Age was reported in decade intervals. There were no respondents over age 70. Using interval midpoints, mean age was 29 (SD = 11.1). The number of years of education after age 18, ranged from 0 to 15, with a mean of 3.31 years (SD = 2.36).

Results

Types of numeric security codes

The median number of numeric security codes was 4 (M = 4.72; SD = 2.96). At the low end, 6 people (1.5%) had only 1 numeric code; whereas, 17 people (4.4%) had 10 or more. The highest number reported was 30, and of these 25 were for door locks, possibly indicating the respondent was a security guard. As shown in Table 1, the most common codes were for bank cards and credit cards, followed by mobile phones. Electronic door locks and mechanical combination locks were less common. There were no gender differences (t = .58; df = 385; p > .05) nor age differences (F = .17; df = 5/382; p > .05) in the number of security codes reported.

Table 1
Number of numeric security codes used by participants

	Median	Range	Mean	SD
Bankcards & credit cards	2	0–10	2.12	1.35
Mobile phones	1	0–5	1.21	0.70
Electronic doors & garages	0	0–25	0.73	1.75
Baggage locks, bike locks & padlocks	0	0–5	0.65	0.93
Total numeric security codes	4	1–30	4.72	2.96
Percentage of codes self-created	40	0–100	43	32

The median number of codes that were self-created was 2 (Mn = 1.89; SD = 1.58). On average, 43% of codes were self-created, with a range of 0% to 100%. There were no gender difference (t = -.65; df = 384; p > .05) nor age differences (F = 1.17; df = 5/381; p > .05) in the percentage of codes that were self-created.

Pin code difficulties

Table 2 shows descriptive statistics for the variables measured in this study along the bottom two rows. The variable labeled as "Difficulties" is the average of scalar responses to two measures about 1) problems remembering numeric security codes, and 2) effort to remember numeric security codes. Combining these was warranted because they were strongly correlated with one another (r = .57; N = 387; p < .001). The mean for the Difficulties measure was M = 2.35 (SD = 1.11), which is well below the scale midpoint of 4.00, indicating that this sample as a group reported little difficulty with numeric codes. However, 17 respondents (4.4%) had Difficulties scores of 5.00 or higher, with 2 people having Difficulties scores of 6.00. Scores of 5.00 and higher had z-scores greater than 2.00. If two standard deviations are considered a criterion of abnormality, then 4.4% of this sample had abnormally high Difficulties with their numeric security codes.

Difficulties were unrelated to the total number of codes the person had (r = .07; N = 386; p > .05) and were slightly lower for higher percentage of codes being self-created (r = -.12; N = 386; p < .05). There

Table 2
Intercorrelations above the diagonal, with beta values for predictors of Difficulties in italic below the diagonal and descriptive statistics along the bottom two rows

Study (N = 388)	Difficulties	Gender[1]	Age	Education	Total codes	Percentage self-created	Total strategies
Difficulties	-----	.09	.28*	.09	.07	-.12	.41*
Gender[1]	*.03*	-----	.10	.07	-.03	.03	.12
Age	*.25**		-----	.31*	.00	.00	.12
Education	*-.02*			-----	.17*	.04	.12
Total Codes	*-.01*				-----	-.14*	.15*
Percentage Self-Created	*-.13**					-----	.03
Total Strategies	*.39**						-----
Mean	2.35	0.41	29.14	3.31	4.72	43	2.65
Standard Deviation	1.11	0.49	11.08	2.36	2.96	32	1.62

Note: [1]Gender: 0=M, 1=F; *p<.01

were no gender differences in Difficulties (t = -1.76; N = 384; p > .05), but there were significant age differences (F = 6.96; df = 5/381; p < .001). Difficulties scores increased with every successive age decade, from teenagers to those in their 20s, 30s, 40s, 50s and 60s, respectively: 1.93, 2.21, 2.39, 2.80, 2.84 and 3.65. Tukey's HSD test for unequal N showed the oldest group had Difficulties scores significantly (p < .05) higher than those of the three youngest groups. Of the eight people with Difficulties scores higher than 5.00, five of them were in their 50s or 60s.

Mnemonic strategies

A tabulation of mnemonic strategies for remembering numeric security codes is shown in Table 3. Of the total respondents, 26% reported using only one strategy, 23% reported using two strategies, and 20% reported three strategies. One respondent reported having used 10 of the 11 listed strategies. The number of mnemonic strategies used was positively correlated with Difficulties (r = .41; N = 387; p < .001).

The most common strategy, reported by 71% of respondents, was to learn numeric security codes by repetition. This strategy was unrelated to Age or to Difficulties remembering. The next most common mnemonic strategy, reported by 54%, was to remember the pattern the code makes when entered on the keypad. The strategy of using security codes from other contexts was reported by 40%, and choosing a code with a personal meaning was reported by 38%.

Strategies of writing down security codes were not popular, but they were used more by older people. As shown on the right in Table 2, all significant correlations of strategies and Age were for strategies that entail writing down the code. In fact, the three
Table 3
strategies with highest correlations with Age also had high positive correlations with Difficulties.

Predicting difficulties

Multiple regression analyses were used to remove covariance effects in order to search for unique predictors of Difficulties remembering security codes. The predictors of Gender, Age, Education, Total Codes, Percentage Self-Created, and Total Strategies explained 25% of the variance in Difficulties, with unique predictive power coming from Total Strategies (β = .39; N = 385; p < .001), Age (β = .25; N = 385; p < .001), and Percentage Self-Created (β = -.13; N = 385; p < .01). Gender, Education, and Total Codes were not unique predictors of Difficulties.

The 11 mnemonic strategies as predictors explained 21% of the variance in Difficulties, but only two strategies had unique predictive power. The strategy of "write down and keep separate from card or lock" was a unique predictor of Difficulties (β = .22; N = 387; p < .01) as was the strategy of "write down a rearranged version of the code" (β = .17; N = 387; p < .01).

Discussion

Age effects

There was multiple evidence that age predicts Difficulties remembering numeric security codes: a) the first-order correlation of Age and Difficulties was positive; b) the regression beta value for Age predicting Difficulties was positive; c) the ANOVA for Difficulties across Age categories was significant, with every increasing age category having higher Difficulties scores, significantly so for those in their 60s compared

Mnemonic strategies for remembering numeric security codes, rank-ordered by frequency of use and showing correlations with Difficulties remembering and Age

Strategies used to remember numeric codes	Freq	%	Difficulties	Age
Learn the code by repetition	276	71	.09	-.01
Remember pattern the code makes when entered on keypad	210	54	.10	-.11
Use the security code from another context	155	40	.18*	.10
Chose a code with personal meaning (e.g., a date)	148	38	.19*	.08
Write down the code and keep separate from card or lock	71	18	.35*	.20*
Store code in mobile phone other than in a phone number	62	16	.20*	.02
Hide code in a phone number kept in mobile phone or written down	47	12	.22*	.02
Transform numbers to letters (e.g., 2 = a, b, c) and make mnemonic	24	6	.10	.03
Write down the code and keep close to card or lock	19	5	.17*	.13*
Write down a rearranged version of the code	9	2	.23*	.15*
Write down a transform of the code (e.g., add 2 to each digit)	9	2	.09	.10

* $p < .01$

to those in their teens, 20s, and 30s; d) most respondents with abnormally high Difficulties scores were in their 50s and 60s; e) the three mnemonic strategies that were most positively correlated with Age were also positively correlated with Difficulties.

It is not unexpected that older people have more difficulty remembering number sequences. Indeed, it would have been surprising if difficulties did not increase with age for the major reason that cognitive function decreases with age. There are further possibilities that older people have had a longer life of learning numeric sequences and may have more interference effects. That is, all of the telephone numbers, addresses, employee and tax numbers, bank accounts, padlock numbers, and security codes that a person has memorized over a life time, may interfere with memory for more recent numeric sequences. There is also the possibility that older people have less experience with, or more anxiety about, the new electronic technologies that are now demanding numeric security codes. Bank cards and credit cards with chips, mobile phones, and various online accounts using computers are all relatively recent technologies.

Mnemonic strategies

This study discovered that learning by repetition and learning by keypad pattern were the most common mnemonic strategies and also had no relationship to Difficulties, neither increasing them nor decreasing them. It is possible that the near-zero correlations of these two strategies with Difficulties arises from mutually cancelling-out positive correlational effects (i.e., difficulties leads to use of these strategies) and negative correlational effects (i.e., these strategies reduce difficulties). If future experimental studies can demonstrate that learning numeric sequences by repetition or by the keypad patterns *causes* fewer problems and less effort, then optimal pedagogic methods of teaching these strategies might be systematically examined.

This study also discovered that strategies of writing down security codes correlated positively with Difficulties. It is possible that persons experiencing difficulties remembering security codes cope with their difficulties by resorting to external memory. That is, difficulties may *cause* people to use external memory. It is also possible that external memory causes difficulties, namely, remembering where the security code has been recorded, or needing the code and not having access to the storage medium, or remembering what were the transformations, if any.

This study also discovered that the number of strategies used correlated positively with Difficulties. It is possible that numerous strategies cause interference effects (Wilson, Gallagher, Eichenbaum & Tanila, 2006). Or, perhaps people try numerous strategies because they are experiencing difficulties.

Applied research designs

Experimental studies of mnemonic strategies would entail random assignment of subjects to strategies, or to pedagogic methods to teach particular strategies, or to groups with different intensities of training. To be realistic for the applied contexts of security code recall, the follow-up assessments of accuracy or speed of recall, or self-reported difficulty of recall, should be carried out in subsequent sessions, weeks or months after the training. The number of security codes each individual already has in memory might be used as a covariate, to determine if, or to what degree, there are experience effects or interference effects.

In conclusion, it is certain that the modern wired world is going to have more, not less, use of security codes. It is certain that this will cause mnemonic problems. It is certain that much, much more human factor research needs to be done on the problems caused by numeric security codes.

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