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Foreword

This ETSI Technical Report (ETR) has been produced by the Human Factors (HF) Technical Committee of the European Telecommunications Standards Institute (ETSI).

ETRs are informative documents resulting from ETSI studies which are not appropriate for European Telecommunication Standard (ETS) or Interim European Telecommunication Standard (I-ETS) status. An ETR may be used to publish material which is either of an informative nature, relating to the use or the application of ETSs or I-ETSs, or which is immature and not yet suitable for formal adoption as an ETS or an I-ETS.

Introduction

The Technical Committee for Human Factors has prepared this ETSI Technical Report to report publicly its work on the assessment and definition of a harmonized minimum man-machine interface for the access and control of public network based supplementary services. It is intended to complement ETS 300 738 [30].

This ETR constitutes part 2 of a multi-part ETR ("Assessment and definition of a harmonized minimum man-machine interface (MMI) for accessing and controlling public network based supplementary services"), whose parts have the following titles:

Part 1: "General approach and summary of findings";

Part 2: "Literature review - Memory and related issues for dialling supplementary services using number codes";

Part 3: "Experimental comparison of two MMIs - Simulated UPT access and prototype ISDN supplementary services";

Part 4: "Experimental comparison of the effect of categorized and non-categorized formats within user instructions";

Part 5: "Experimental comparison of the CEPT and GSM codes schemes";

Part 6: "Survey of existing PSTN, ISDN and mobile networks, and a user survey of supplementary service use within Centrex and PBX environments";

Part 7: "Experimental evaluation of draft ETS 300 738".

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1 Scope

This multi-part ETSI Technical Report (ETR) presents the results of the research work conducted to develop a European Telecommunication Standard (ETS) defining a harmonized minimum man-machine interface (MMI) for the access and control of public network based telecommunications services, and in particular supplementary services.

This part 2 of the ETR presents a review of the existing literature on memory and related issues concerning accessing and controlling supplementary services with numeric codes.

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3 Definitions, symbols and abbreviations

For the purposes of this part of the ETR, the definitions, symbols and abbreviations given in part 1 [72] of the ETR apply.

4 Generalizing from memory research

From knowledge of memory derived from experimental psychology, one can formulate a number of expectations about how people will cope with different command structures and situations involving the use of number codes and the * and # symbols available on telephones. However, most memory research is based on laboratory learning situations that differ from the way that people may be expected to learn telephone supplementary service commands. This extends even to experiments designed specifically to investigate learning and memory of such codes.

For example, Jones, 1990 [45] had subjects learn 2-digit code commands. Although the command language was for instructing a robot to do household tasks, the language and experiment were specifically aimed at studying the design of codes for PBX commands. Subjects were instructed to learn as many of 47 command codes as they could in 10 minutes.

It seems likely that this is very different from the way users of supplementary services learn the codes. Presumably, real users will start by looking up codes as they use them. Learning the codes may be incidental or it may be that people learn them intentionally in small groups or one at a time, starting with the most useful; or because the rememberer notices some aspect that makes a number easy to remember. Certainly it seems unlikely that people sit down and try to learn as many as possible in a set amount of time.

This does not necessarily mean that the results from experiments such as Jones's cannot be applied generally to other situations. There are several ways to proceed from such results. One can study what happens in situations where people do learn in this way, looking at the literature on incidental learning etc.; set up longitudinal experiments; or, perhaps best, study what happens when a new telephone system with such services is installed in an organization. The organization might even allow comparison of different groups that vary in the instructions they are given, or in some other way. One can also try to understand the existing results based on theoretical understanding of memory. This may allow some prediction about whether results will generalize to particular situations. This is the approach taken in much of this report.

Some learning and memory phenomena are fairly robust and are encountered in many different types of task. One of these is the distributed practice effect: the superiority of spreading out practice rather than massing it. This is found in mice learning mazes and humans learning typing skills. It is found over relatively long periods: an hour's practice per day is better than two hours for half the number of days. It is also found over relatively short periods, so that repetitions of a to-be-remembered word in a list of such words produce better recall if the repetitions are far apart than if they are close together (Melton, 1970 [55]).

However, many results are not so robust; for example, Barnard and Grudin, 1988 [8] report apparently contradictory experiments in designing sets of command names where the different results turn out to be explicable in terms of not being able to generalize between two superficially similar situations that differ in some subtle but important way. A theoretical understanding of what is going on can help determine when generalization is likely to be appropriate.

NOTE: One must also be cautious about assuming that memory skills themselves will generalize from one task to another. For example, a student practised over 20 months and increased his digit span from about 7 to 80 digits; however, the effect of the practice did not even generalize to memory span for consonants, which remained at only about 6 when digit span had already increased substantially (Ericsson, Chase and Falcon, 1980 [27]).

5 Methods of learning

This clause deals with learning the codes, in other words, committing them to long-term memory for dialling without reference to an external reminder. In some cases it is necessary to conduct relevant experiments using numbers as the material to be remembered, but most of the studies on such memory have been based on other material, typically individual non-digit words. In these cases it is necessary to try, perhaps from theoretical constructs, to reason as to what the relevance of the studies is for remembering numbers. Also, memorizing numbers used for counting or measurements seems to be different from memorizing arbitrary number codes.

5.1 Passive listening

Simply having users listen passively to the code numbers is unlikely to result in their learning the numbers, even if the numbers are repeated regularly over long periods. Bekerian and Baddeley, 1980 [9] investigated the effect of the BBC's campaign to advertise the new wavelengths for their existing radio services. According to the claimed hours of listening, their subjects must have heard over 1 000 broadcasts of the new numbers, but accurate recall ranged from 12 % to 22 %, depending on the radio service. Over 70 % of responses were "don't know". This was despite the fact that the message was not entirely ignored as most of the subjects were well aware that the change was going to happen. It seems that different types of information require different methods of assimilation.

Extrapolating from these results to learning codes for telephone supplementary services, one would expect that constant repetition is unlikely to be successful in learning the codes themselves. On the other hand, simple explanations of the services available should lead to at least some learning, and this is something that users need to know before they can be expected to learn the corresponding codes. However, whether all the services should be introduced to new users at the same time needs further consideration (see following subclauses).

5.2 Repeated reading and verbatim recall

If repeated listening to the codes is of little help in learning them, maybe users reading the codes themselves would be of more value. However, again the evidence is that merely reading them may be of little help in learning them. The evidence is that it partly depends on whether an attempt is made to learn the material and to what aspects attention is paid (e.g. phonological or semantic). Verbatim recall is fairly rarely required and use of language seems to have evolved to leave an understanding of, and memory for, the meaning of what has been said or read rather than the words in which it is expressed or their order. Number codes have to be recalled verbatim. For example, a certain individual copies his credit card number once a month, reading it and then writing it verbatim on the back of a cheque, and he additionally reads it out over the phone from time to time, yet he can only reliably recall the first digit.

Stanford, 1917 & 1982 [66] reported on his ability to recall prayers that he had read daily at least 5 000 times in the previous 25 years, usually at 24-hour intervals, often for many weeks in succession. He only made one error (omitting "and" in the Lord's prayer which he had actively learned as a child and none in a benediction he had committed to memory intentionally. With the remaining four prayers, which he had read just as often but had not deliberately learned, he needed continuous prompting in order to recite and made "many outright blunders - usually the substitution of words of similar import". In other words he remembered the meaning but not the actual words used to express it.

5.2.1 Type of coding and verbatim recall

A well known series of studies of verbal memory in the 1960s led to the view that short-term memory is coded according to the *sound* of the words remembered, and long-term memory according to their *meaning* (Conrad, 1964 [17]; Conrad and Hull, 1964 [20]; Baddeley, 1966a [1], 1966b [2]; Sachs, 1967 [63], Kitsch and Buschke, 1969 [47]). Strings of code digits and the symbols * and # are relatively devoid of meaning in the way normal words and language have meaning, and one might therefore expect long-term learning of them not to be natural or easy.

One of the few situations that demand verbatim recall is in acting. Most acting requires that performances are recited more or less verbatim. It is particularly so for plays such as those of Shakespeare, where the words themselves are important, or films and TV plays, where timing of shots and instructions to camera operators are important. Also other actors need verbatim cues to start them off. Actors report that they have to make a deliberate effort to learn their lines and large individual differences have been claimed in the time and effort involved in getting "off book".

So from both Sanford's prayers and from actors it seems that although the meaning of text can easily be remembered from reading, perfect verbatim recall is not usually attained even by repeated reading unless an effort is made to remember it. It seems that additional mental processing of the surface structure of the words, or the building of links between the words at the semantic level is needed.

5.2.2 Counter evidence

However, before leaving this topic, it is worth quoting some counter evidence. Mechanic, 1964 [54] had subjects pronounce nonsense syllables with either incidental learning or intentional learning instructions. In one condition, subjects just pronounced each syllable once during its presentation while in another they repeated them as many times as possible for the rate of presentation. With the incidental learning instructions, repetition of the syllables did improve performance in a subsequent recall test. A more frequent finding is that if mere repetition has an effect on memory, it is only of significance when tested by recognition and not at all (Woodward, Bjork and Jongeward, 1973 [71]) or only marginally (Glenberg, Smith and Green, 1977 [34]) when tested by recall.

An example that contrasts with the failure to remember a credit card number cited above is that the same individual does remember that 77 is the number to dial at a certain hotel to arrange a wake-up alarm call. He had spent six nights there during three visits in two months. He was not aware of having made any effort to learn it. There are some special features worth noting:

- the code is much shorter than his credit card number;
- a run of identical digits is easier to remember (The individual would most certainly remember his credit card number if it were all 7s!);
- he only used one service and code number at the hotel (see section on interference);
- there was little chance of interference from other service numbers as he has no services available by dialling codes from his residential or business phones.

Lastly, although Professor Sanford needed prompting every few words and made many substitutions of words of similar "import", he still recalled the rest. He may have even recalled more words than the sum of those he got wrong and those on which he needed prompting. So he had learned something, though he may have generated much of this from the meaning. He may not have been merely reciting the prayers without thinking about them, and such mental processing does lead to learning even when it is incidental and there is no intention to learn the material.

Craik and Lockhart's [21] distinction between maintenance rehearsal and elaborative rehearsal can be related to this. Maintenance rehearsal only recycles the material at a superficial level in a phonological code for recall a short time later. Elaborative rehearsal increases the level of processing so that the coding is changed; although this allows the deeper level, typically semantic, information to be retained for long-term recall, while the phonological code is lost and has to be regenerated.

5.3 Incidental learning and levels/amount of processing

Memorizing material while using it, but without the intention to memorize it, is a well established phenomenon known as incidental learning. In the classical demonstration, Mandler, 1967 [53] reported a number of experiments in which subjects were given a pack of cards each bearing a word. Those told to sort the words into categories, putting together words that had something in common (and no indication of a later memory test), later recalled as many of the words as those told only to memorize the words, and as those told to do both. Subjects told only to arrange the cards into seven columns recalled fewer words.

So although intention to learn will help in some circumstances, it seems not to be needed in others. It can be related to the notion that long-term retention is a result of processing, and that deeper processing results in longer lasting memories; this was first put forward in an influential paper by Craik and Lockhart, 1972 [21]. Thus, if the material is difficult to process at deeper more meaningful levels, merely reading it is unlikely to result in much memorizing. On the other hand, sorting words into different categories, as in Mandler's experiment [53], requires thinking about the words in order to decide on categories and then assigning individual words to them. This processing resulted in as good a recall performance as whatever processing the memory-only-instructions subjects used spontaneously.

Craik and Tulving, 1975 [22] looked at incidental learning occurring in three different situations. Without any indication that there was to be a memory test, subjects were presented with words, and in three separate experiments, had to make different types of decision about each word:

1) whether they were written in lower or upper-case letters;
2) whether they rhymed with another word that was also presented;
3) whether they fitted in as the missing word in a sentence that was presented.

After the presentation of many words, a memory test showed that they were much better recognized as having been presented if their presentation had been in condition 3 (involving semantic processing) than in condition 2, and in condition 2 than in condition 1 (in which neither semantic nor acoustic processing was required). Three versions of condition 3, using sentences of different complexity were compared in another experiment reported by Craik and Tulving [22], the greater complexity of the sentences producing greater incidental learning as measured by cued recognition and slightly greater as measured by recall. The more complex sentences were seen as requiring more processing or more elaborate processing, although all three conditions required the processing to be at the semantic level.

There are many other experiments showing better long-term memory performance after deeper or richer processing and the effect is very robust.

5.4 Memorizing numbers

In the current context, the interest is in the implications for remembering number codes for supplementary services, although no memory experiments in this area using numbers as the material have been found, perhaps for the obvious reason that the range of processing levels and richness seem to be severely restricted.

5.4.1 Natural numbers vs code numbers

With the normal use of numbers in counting and measuring there is a certain amount of processing that could be done. For example, extending Craik and Tulving's semantic condition (condition 3), it makes sense to ask which of two numbers fits better into the following sentences:

-	5 or 6	He was quite short, not more than .... feet tall.
-	2 or 3	The .... of them got married.
-	1 or 2	She clapped her .... hands together.
-	3 or 50	They were shocked to have to pay .... pence for a loaf.
-	100 or 120	There are .... centimetres in a metre.

The thought of three people getting married is bizarre but quite easily entertained and imagined, and even in normal life one can think of a 5-foot man as rather short and perhaps visualize a short person. On the other hand when figures are just codes and the precise number is arbitrary in its connection with what it represents, it is much more difficult to process or think about in any way, let alone a meaningful one. The number has little or no semantic content in this context and memory coding used is likely to be superficial rather than deeper/semantic. Which code 23, 76, or 231 goes with a particular service is in principle arbitrary, and it is difficult to produce images or connections such as those for the more natural use of numbers above. One is left with associations to other numbers or constructing artificial associations.

5.4.2 Learning arbitrary numbers

People do learn telephone numbers (and PINs, but not, it has been noted, at least in some cases, credit card numbers) that they use regularly, but probably make some effort to do so and in the absence of other elaborations, they make links to other numbers they know, or they notice internal structures or relationships among the digits.

For example: An individual moved house and he had to learn a new telephone number. The new area code was easy enough as he had learnt it when he lived in the same city. He noticed that the next numbers, 453, were the same numbers as a London exchange he used a lot, 435, but in a different order. He still had to look up the order till he noticed that 453 is the left to right ordering on a push-button telephone. He can now dial the number from memory but cannot recall these three numbers in order without referring to this ordering mnemonic, though he may soon be able to recall the number without difficulty.

People notice runs of the same digit or of regularly increasing or decreasing digits as in 246 or 987. All such strategies give a context in which to think about or process the numbers, and, as has been noted above, thinking about or mentally processing is often related to memorizing material.

These strategies seem to work, at least to some extent, when the need is to learn relatively long numbers, one at a time or maybe a few at a time. People rarely try to learn 10 or even 5 new telephone numbers in one go. If they did, they might get muddled up between the strategies used for different numbers. In such a case they need to use strategies to link the number to the person or organization whose number it is, as in paired-associate learning. This is probably more similar to the problem of supplementary service codes. When the services become available, they tend do so in large numbers. Users suddenly have a lot of fairly short codes to remember. If, say, there were 20 commands to learn and the numbers 01 to 20 were used for them, it would be no use remembering that there was a number with a run of two 1s as this is obvious if one knows that there are 11 or more services. What is needed is a way of linking the code number to the service, perhaps by artificial mnemonics, for example, call forwarding *TO* another number starts with 2. (This example is obviously less useful for non-English-speakers!).

5.5 Learning the * and # symbols

If each command including the * and # symbols were learned as individual strings, meaningless except as an association to the particular command/service, the difficulties discussed above of learning such material would probably apply. The effect of mixing relatively familiar symbols (numbers), used in other contexts, with the special symbols, mainly or entirely used in this context, would be a complicating unknown. In any case, this does not seem to be a sensible way to proceed.

If the * and # symbols are learned, not as part of an unstructured list of symbols and numbers, but by some sort of meaningful or syntactical rule, these parts of the commands may be more easily recalled or rather *generated* from the rule. Learning a short set of rules should also be more economical than learning the * and # symbols individually for each command. Mnemonics should help here too, such as pointing out to English-speaking users that the star symbol * is used to STARt a service. A difficulty is using the symbols for different syntactic purposes.

For example, * may be used to start commands that set up or turn on facilities and also to separate command codes and data numbers the commands act on. In the same system # may be used both to terminate all commands and to initiate commands that turn off or cancel the setting up of a service.

Although such a scheme may be confusing, this particular one has been designed with some economy of learning, in that # in the quoted example tends to do with termination, switching off or cancelling, with the exception that it is used to *start* some commands. The use of * is used both to start initializing and setting up, except that it is also used as a separator and that # is used to start some commands. The picture gets more complicated when commands are included to cover enquiries about whether services are set up or in operation. However, there is a logic, which at least a proportion of users will understand. It should not be difficult, for example, to explain the need for a separator to most users, and they may then accept the arbitrary choice of a star as the separator. Again a mnemonic may help (e.g. - for English-speaking users - *separator* and *star* both start with s).

While one might expect healthy young adults of average or above average intelligence to have little difficulty with such a scheme, a possible study could be how well different types of people can understand and use it.

5.6 Learning the services

The services that the numbers refer to can presumably be made more meaningful than the numbers themselves, and, as has been shown, meaningfulness has the potential to help memorization. The appropriate way to proceed, therefore, seems to be to learn what the services are and then to learn the number codes associated with them. As noted above, the association should benefit from construction of mnemonics.

With 20 to 40 supplementary services suddenly available it is difficult to remember them all even if one understands them. An individual had some difficulty understanding all the services listed in the CEPT [14] and ETSI [30] documents and a week after reading them could recall only a minority of them. The lack of understanding in this case is certainly partly due to the way the explanations were given.

Before people will even consider using a service let alone making an effort to remember a service code they must:

- understand and remember what the service is;
- know the service is available;
- see the service as sufficiently useful to warrant looking up or learning the code.

An ad hoc survey was conducted of people working in organizations which have such services. It seems that the subjects only use a very few of the available services and this is probably because one or more of the three conditions above has or have not been fulfilled. Indeed they have only a vague idea about the existence of other services. Some services, such as passing on an answered call to a different extension, are facilities people readily understand, see a need for, and use.

There are available some surveys of the usage of advanced facilities in PBXs. Certainly, studying users of telephones connected to PBXs with supplementary services would be useful. Of users of systems that have been available for some time, one might ask:

- Do they understand the services and know which are available?
- Do they regard the services they know about as sufficiently useful to warrant looking up the codes or learning them?
- If so, do they learn the codes or look them up?
- If they learn the codes, how do they set about it? (Use mnemonics?)
- What effect do various types of training and look-up material have?
- How has their usage changed over time?
- Do individuals vary a lot in the range of available services they use?
- If so, what else distinguishes the people at the extremes? (Can lessons be learnt from those that use a lot of services to help other users make better use of them?)

It would also be interesting to study an institution where such a PBX was installed for the first time, for its own sake and for comparison with the above. It may be that at installation more information is more easily available; there may be training sessions and people are more open to finding out and learning about how to make use of the new system. Another possible group for study is that of new people joining an organization with existing supplementary services.

5.7 Other ways to aid learning

Ideas such as mnemonics to help learn the codes for particular services and to learn the use of symbols such as * have already been covered. There are other aspects and techniques that need to be considered.

5.7.1 Names for services and commands

One aspect is the verbal names given to the various services. Such names are not strictly needed, as logically the user could learn to associate the description of the service with the code needed for it. However, with over 30 services, the users need a verbal label for the different services, and/or the different commands, assuming more than one command is needed to implement a service.

Grudin and Barnard, 1985 [35] found that subjects who learned and used full command names for operations, later switching to abbreviations, made fewer errors in using the abbreviations than those learning and using the abbreviations from the start. There are differences in the current situation in that the numbers are not simply abbreviations and that users cannot use the full names on their own before learning the numbers. However, it is at least suggestive of the names being useful mediators between the code numbers and the full description of the service or command.

Even if users are using a prompt card, they need such verbal labels, because they will not want to read a full description each time they look up a code for a service they already know and understand. There are already such names and abbreviations in the ETSI documents e.g. ETS 300 738 [30]. In designing these names, usability issues need to be taken into account.

The choices of individual names, the name-operation mappings and how they fit together as a set are important, and what is known about choosing command name sets should be applied (see Barnard and Grudin, 1988 [8]). The names should not be used only for distinguishing among the referents, but to describe them and to indicate the goals.

There should be standard names for particular services, so that they do not vary from one supplier or system to another. Particularly disruptive would be different suppliers using the same name for different services or using different names for the same service.

Specific rather than general words are often better, particularly in avoiding ambiguity. On the other hand, Rosenberg and Moran, 1985 [62] point out that general names may be better when they allow one name to be used for similar operations in different contexts, thus providing greater consistency and predictability, but they argue that generic commands have to be designed carefully in conjunction with the set of objects to which they apply.

An example of the generic use of commands in the present context is that the following set of operations can be applied to many of the services:

- to set it up (registration);
- to turn it on (activation);
- to turn it off (deactivation);
- to cancel setting it up (erasure);
- to find out whether it is set up and if so how (e.g. if call forwarding is set up and if so under what situations, such as after so many rings or when the line is busy, and to which number the calls are forwarded) (interrogation).

Trying to optimize each name individually without considering the other names the user will be learning and will have to distinguish from it is unlikely to produce a good set. In order to provide consistency, choosing a set of names should be done as an ensemble, bearing in mind that users may try to guess or recall commands by analogy with one they know, and may also confuse names that are too similar. Congruence of commands (e.g. *up* and *down* or *raise* and *lower* but not *up* and *lower*) is sometimes an advantage (Carroll, 1982a [12] & 1982b [13]). In the set in the previous paragraph, *activation* and *deactivation* are clearly more congruent than *registration* and *erasure* (though these are at least syntactically congruent, both being noun derivatives of verbs).

In reviewing work on command names, Barnard and Grudin, 1988 [8] emphasized the sensitivity of results to many variables including the task structure, and so recommended usability testing and iterative design; for example:

> "Given the sensitivity of command use to the many factors discussed, and the strong indications that nameset designers tend to stick with initial choices even when these are demonstrably flawed, we cannot re-emphasize enough the necessity of user testing, preferably carried out by a collaborator of the designer rather than the designer himself or herself" (p 25).

They also see as a problem designing large namesets and designing the initial commands for sets that will grow as extra functions or, in the current case services, become available. The issue of the size of command set could be investigated further.

5.7.2 Distributed practice and practice retrieval effects

The distributed practice effect has already been described above. It may be relevant if users are actively trying to learn the codes. The available time should be spread over several days rather than concentrated in one or a few. On any one day it would be better to spend four sessions of five minutes each, rather than one session of 20 minutes. Taken on its own, the distributed practice effect would suggest that in any one session it is better to space out multiple learning trials of any one code as much as is reasonable.

However, the *practice retrieval effect* described by Baddeley, 1990 [4], seems to act in the opposite way. If on is learning a number of words or names by being tested (or testing oneself) and having any errors corrected (or looking at the correct answer), then one learns more from a correct recall than from a correction, (or from looking at the correct answer). One of the least surprising and most replicated results is that test performance declines with increased retention interval, (although this can vary with the activity during the interval). So, the longer between learning trials, the more likely one is to fail to recall an item correctly and have to be corrected, with less learning occurring than if one had recalled it correctly.

Combining these two effects one arrives at a technique reported by Landauer and Bjork, 1978 [48]. In this technique, tests start with small intervals, gradually increasing to longer ones, in an effort to achieve the longest interval at each stage that will produce correct recall. If an error is made, the interval should be shortened. When several items of completely new material are to be memorized, the first item to be learned is presented and then tested immediately, similarly with the second before returning to the first, and so on (Baddeley, 1990 [4]). This technique has been used successfully with widely different subjects and materials (Gettinger, Bryant and Mayne, 1982 [33]; Rea and Modigliani, 1988 [60]).

Supplementary service users may be able to make use of this technique if they want to learn the code numbers for several services.

5.8 Interference

Supplementary service codes are all similar, being 2 digit or 3 digit numbers. The technique outlined above starts with immediate recall that relies on short-term memory, and unfortunately short-term memorizing of different items of similar material on successive trials is known to lead to interference between them (Keppel and Underwood, 1962 [46]). Having many subjects do one trial each produces much better recall than having a few subjects doing several trials each. Proactive interference builds up quite quickly.

Switching to numbers after a series of trials with consonants (Wickens, Born and Allen, 1963 [70]) produces a jump in performance on the first number trial. The effect of such switching to dissimilar material is known as release from proactive interference. Interference is also reduced by increasing the inter-trial interval. Loess and Waugh, 1967 [50] showed that an inter-trial interval of two minutes eliminated the interference. The difference in the internal representations of the current item and an item presented so much longer ago may be sufficient to allow them to be easily discriminated, or perhaps the earlier representations have merely decayed to a point where they do not interfere. An experiment by Turvey, Brick and Osborne, 1970 [67] supports the first interpretation, which is now generally accepted as the explanation of interference effects in short-term memory.

With the supplementary service codes so similar to one another, there may be short-term interference between them, increasing the chances of incorrect recall when the technique of increasing inter-trial intervals is used with the intervals filled with learning other codes. On the other hand, if the users can be shown ways of discriminating the codes, such interference can be avoided (Gardiner, Craik and Birtwisle, 1972 [32]). For example, if users have already learned that codes beginning with 2 have to do with call forwarding and codes beginning with 8 have to do with conferencing, learning new codes to do with forwarding and conferencing should not interfere so much with each other.

Another implication is that it is probably better to learn the codes in small groups rather than all at once. In the initial group fewer items means less scope for interference among them. (This may be a reason why the individual referred to above learned the number 77 at the hotel so easily: he was only learning one code so there was no interference from other numbers.) Once some of the commands have been thoroughly learned, they will be easily distinguished from new ones being held in short-term memory, even if both sets are being practised together.

This technique of learning a subgroup of the to-be-learned material fairly thoroughly before adding in more, subgroup by subgroup, and practising each new subgroup together with those already learned is quite common (it is called *snowballing* by Conrad et al, 1958-62 [19]). Typing courses are often taught in this way, starting with the home key row and later adding the top and bottom rows. The technique can lead to a greater level of learning for the groups introduced earlier, as they have been practised more; this can be counteracted to some extent by deliberately practising the "newer" items more than the "older" ones.

Both proactive and retroactive interference in long-term memory were much studied from the 1930s to the 1960s. Recently there has been much less interest, which Baddeley, 1990 [4] puts down to a reaction of cognitive psychologists against the sterile approach of much of the older work. One recent area of activity concerned the way in which the interference operates, which was disputed. For example, one type of retroactive interference is seen by Loftus as the original memory trace actually being changed by the later information (e.g. Loftus and Loftus, 1980 [51]), whereas Bekerian and Bowers, 1983 [10] see it as a retrieval phenomenon and that given the right conditions the original trace information can be retrieved intact. This debate was related to experiments on episodic memories rather than learned material such as the codes used for supplementary services.

Certainly, increased similarity of material leads to greater interference (e.g. McGeoch and MacDonald, 1931 [52]). At present, supplementary service codes are not standard and there will certainly be both proactive and retroactive interference between different codes for the same or equivalent service if people move between different coding systems, for example at work and at home, or on moving jobs and so on. There may even be interference between different codes within one set, which may contribute to why people seem only to learn a few of the available services.

Sometimes inter-number interference seems to be an action slip or an absent-minded action. People sometimes ring the wrong telephone number; for example, one of the authors of the present report accidentally used the stored number for his younger sister when he meant to ring the older one and he has had people who know his number ring him when they meant to ring someone else. If a user often uses a command that starts with a particular string of characters, he may absent-mindedly enter this string when he intended to enter one that starts in a similar way (see Reason, 1990 [61]).

The supplementary service code numbers should be made as distinctive as possible to minimize interference between them, but it is difficult to know how this can be done. Perhaps some form of organization would allow some groups to be distinguished from others.

5.9 Organization and improving memory performance

In discussing various issues above, certain topics of organization and mnemonics have already been encountered. In this section, the issues and principles involved will be drawn together.

A convenient way to classify methods of improving long-term memory performance has been set out by Harris, 1992 [37] as follows:

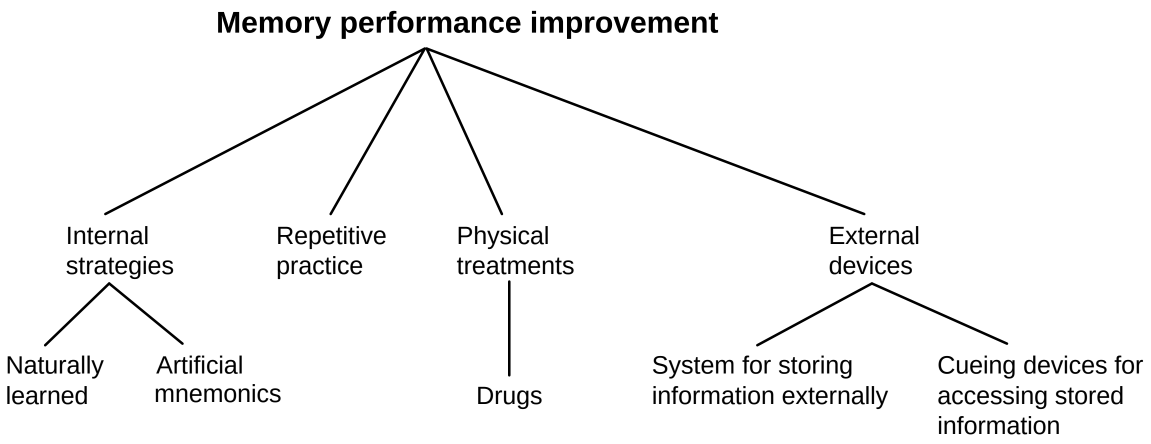

Figure 1: Classification of methods to improve long-term memory performance

Each of the bottom level groups will be considered in turn, starting at the right-hand side of the diagram.

Cueing devices for remembering to do things, such as to-do lists and appointment books, may be relevant for reminding one to use a supplementary service (e.g. to remind one to initiate call forwarding when leaving for a meeting at another location), but they are not relevant for remembering the command codes for carrying out the to-be-remembered action. Therefore they will not be dealt further with in this report. They can be combined with a type of reminder that *is* relevant, and which is described in the next paragraph.

In the current context, systems for storing information externally can include:

- writing lists of (usually frequently used) complete commands;
- writing lists of (usually frequently used) number codes and/or telephone numbers;
- use of published reminder cards and directories.

The use of such reminders depends on short-term memory, in order for the information read from the external source to be stored until it has been entered (dialled). This is a very different topic from long-term learning and is covered separately in the last clause of this report.

Drugs are not relevant to this report and repetitive practice has already been covered above.

The two types of internal strategies remain: those that are naturally learned and are part of normal memory skills, and those that are usually called mnemonics; the term "mnemonic" is usually reserved for artificial devices or techniques that are not naturally used and have to be specifically learned and consciously used. However, the boundary is not necessary so neat as this implies; what comes naturally to one person may need to be learned by another and while some naturally learned strategies may be automatic (one may not even be aware of using them); others may still require a conscious decision, or even effort, that is more usually associated with learned techniques.

Baddeley, 1990 [4] distinguished three different levels of memory organization:

- organization that already exists in long-term memory;
- organization that can be perceived or generated within the to-be-remembered material;
- organization linking the to-be-remembered material to existing material in long-term memory.

These types of organization underlie a majority of the mnemonics and methods suggested above. Organizing the material to be learned in the current situation could involve:

- organizing the services into groups;
- organizing the names associated with commands, both within a service and between services, providing consistency across services;
- organizing the numbers assigned to commands so that there are consistencies among related services (e.g. different types of call forwarding) and conceptually related commands (e.g. turning on services and turning off services);
- organizing the syntax and use of the * and # symbols.

5.9.1 Summary of using organization

5.9.1.1 The services

Users first need to learn what the services are. If there is some structure to the services, such that they are related to each other in some systematic and meaningful way, this structure should be made clear to the users, as it may make the services easier to remember. If there are many services available, it is probably best to plan several stages of learning, rather than learning to use all the services at the same time.

5.9.1.2 Service and command names

Names should be assigned to the different services and commands. These should be carefully designed to act as mediators between the number codes and the commands and services they represent. The structure of the set of command names is important as has been set out above in the subclause on *Names for services and commands*.

5.9.1.3 Code numbers

In assigning code numbers to services, account should be taken of the structure of the services and commands, so that, as far as possible, the structures are represented in the numbers in a systematic way.

Users learning the codes may be able to make use of structures already in their long-term memories to provide hints and mnemonics. It has been noted that they can make use of noticing organization such as repetitions (e.g. 222), rising and falling sequences (e.g. 234, 357, 987), regular multiples (369) and so on. Other sequences of numbers may be similar to others they already know and use in other contexts.

There are also ways of linking codes to the command names, such as the one noted, call forwarding *TO* another number starts with 2. (Patton, 1986 [59] investigated the effect of a phonetic mnemonic on memory for numeric material (dates, street addresses and telephone numbers). His findings were that subjects trained in the phonetic method tended to perform worse than untrained subjects, except for subjects given extended training who still recalled no more numbers than untrained subjects.)

5.9.1.4 Ordering of arguments

Argument order should be generated by a rule or a simple set of rules, consistently applied so that users do not have to learn the order separately for each command or set of commands.

6 Using a reminder card

Reading and then dialling a supplementary service code bears at least a superficial similarity to digit span tests. They both involve remembering a string of symbols that does not lend itself to the sorts of encoding that are available for remembering, say, letters making up meaningful words or even a sentence.

There are rather different situations to consider, such as:

1) users simply typing in a whole string "parrot fashion", without any understanding (or ignoring any understanding they may have) of the syntax and when to use * and # symbols, and having to look up any argument numbers (such as their own phone number or a number to forward calls to).
2) users knowing the syntax (or some other way of generating when to use * and #) and the argument numbers and just having to look up the code number.

There are of course some intermediate positions, but if they know the syntax and the service codes (and are confident of their knowledge), they do not need to use the prompt card.

There have been many experiments on short-term and working memory that have used digits, nonsense syllables and word lists, and so there are a number of findings that are worth considering. Many of the studies concern free recall which contrasts with entering codes, in that codes must be entered in the same serial order as presented.

Also, in most experiments subjects cannot decide to pause the presentation while they recall what they have been presented with so far and then continue in this chunk by chunk manner. This makes the code users' task easier in one way - they can keep well within the capacity of the short-term store they are using - but adds a place-keeping task: when looking back to read the next chunk from the card, they need to recall how much of the code sequence they have already entered. As they can usually do this by remembering what they have just entered, it should not be to much of a problem so long as they are not interrupted and that there are not easily confusable sequences. However, separators may be a problem here.

6.1 Relevant findings

6.1.1 Phonological coding

Coding in short-term memory for lists of items that can be spoken, such as words, letters and numbers, tends to be phonological rather than visual or semantic, irrespective of whether the items are spoken or presented visually (Conrad, 1964 [17], & 1967 [18]; Wickelgren, 1965 [69]), a finding that was very influential in differentiating between short and long-term memory stores in the models in the late 60s and 70s. (Studies by Baddeley and Levy, 1971 [6] and Levy and Craik, 1975 [49] show that this is an oversimplification. Whether material gets encoded semantically probably depends on the time available as well as the type of material.)

The precise code is a matter of theoretical importance and researchers use such terms as *acoustic*, *phonemic*, and *articulatory* to reflect different theoretical positions. In this report, the term *phonological* will be used without making any assumption about its precise nature. (It now seems the code is not *articulatory* as originally thought, because Bishop and Robson, 1989 [11] have shown most of the associated effects in a group of children anarthric from birth.)

The code means that material is particularly prone to interference from similar sounds. Sequences of similar sounding letters (PGTVCD) are more difficult to recall correctly than dissimilar ones, (RHXKWY). This has been shown in immediate serial recall by Conrad and Hull, 1964 [20] and by Baddeley, 1966a [1] for other monosyllables such as *pen*, *rig*, and *day*. Baddeley showed immediate serial recall was adversely affected by phonological similarity within the list but not by semantic similarity, whereas Baddeley, 1966b [2] found the opposite result in long-term recall. Wickelgren, 1965 [69] showed that the problem of remembering phonologically similar items for immediate recall was in remembering the order of the items rather than the presence of the items in the list. Digit names in English are not very similar in sound among themselves or to the words *star* (or *asterisk*) and *square* (or *hash, sharp, number)*; this may not be the case in other languages.

6.1.2 The modality effect

There is an advantage of spoken presentation over visual presentation. This effect is greater for recency items and so affects serial recall less than free recall. However, as number codes tend to be short, and anyway users may only keep small chunks in short-term memory at a time, all or most of the items may be regarded as recent.

6.1.3 The suffix effect and other disruption

If, at the end of a list, any word, such as "recall", is spoken which subjects know they can ignore, it impairs immediate recall (Conrad, 1960 [16]). This does not happen with a buzzer rather than a spoken word (Crowder and Morton, 1969 [24]). In order to avoid ceiling effects, these experiments, like others, tend to use longer sequences than code users may try to hold in their short-term memories; for example, Crowder, 1971 [23] used lists of 9 digits in two experiments and 8 consonants in another.

Like the modality effect, the suffix effect most affects the recency items. A small list of to-be-remembered items, such as the two or three digits of a service code number, may be largely or completely composed of recency items. Baddeley, 1990 [4] comments that "...if you ring Directory Enquiries, and the respondent gives you the number and follows this by a cheery “Have a nice day”, then you are substantially more likely to forget the sequence" (p 31).

Subjects in one condition of a study by Colle and Welsh, 1976 [15] performed immediate serial recall of visually presented numbers accompanied by a passage being read in German. Although they were not to attend to it and it was in a language that they did not understand, it still impaired their performance. Salamé and Baddeley, 1987 [64], & 1989 [65] produced similar effects. To their surprise spoken words and spoken nonsense syllables both disrupted immediate recall of nine visually presented digits (and did so to the same extent) although subjects had been told to ignore them. Noise pulsed to produce the same intensity envelope as continuous speech had no effect.

The speech effect is independent of intensity so long as it is clearly audible. Vocal music, pop in the native language, and opera in an unfamiliar one disrupted recall in the same way, while instrumental music, modern and classical, produced similar effects but to a lesser extent.

This indicates that people using prompt cards to dial numbers and codes are likely to do so less efficiently if people are speaking in earshot, as they may be in an open-plan office, but that other non-speech noises at moderate levels should not be disruptive.

6.1.4 Dialling long sequences

Dialling a service code sequence may involve more than the two or three digits between a start character (e.g. *) and a terminator (e.g. #). For example, users may need to identify themselves and/or particular telephones as part of the sequence. The numbers may come from different sources, for example:

- the start character may be known and recalled from long-term memory;
- the service code may have to be looked up on the reminder card;
- the separators may need checking elsewhere on the reminder card;
- the user's own telephone number may be known;
- the number to which the user wants the calls temporarily diverted may have to be looked up in a directory;
- the terminating character may again be known.

If the user enters each of these as it becomes available, there may be problems, such as getting timed out and keeping track of where they are.

Getting timed out will be particularly frustrating if he has looked up a number in a directory and has dialled it without keeping the place in the directory; he will have to look the number up all over again, unless he can still remember it, which seems unlikely as he has little reason to make an effort to remember it after dialling it. This question could be tested by experimental simulation, but correct recall is insufficient – users need to be very confident that they have remembered correctly.

Maybe some users will assemble and write down all they need to dial, or at least those parts they have not already learned (i.e. have available in their long-term memories). There are then issues of reading what they assembled and dialling them; this is a similar task to using a reminder card for shorter sequences, but raises issues to do with copying longer sequences. Even individual telephone numbers are of lengths that approach or often pass average digit span capacities. Note that digit span is often defined as the number of digits serially recalled correctly 50 % of the time. Dialling needs to be more accurate than this! Capacity issues from studies of short-term serial recall are covered in the next subclause.

Keeping track of what has been entered could also be a problem. For example, having entered one telephone number, one may forget, while looking up the next, whether one has already entered the separator character that must go between the two telephone numbers.

6.1.5 Digit span capacity

Digit span is a very old test, probably first used by London schoolmaster Jacobs, 1887 [44]. One of the best known "facts" in psychology is that most people have a short-term memory capacity of between 5 and 9 items (Miller, 1956 [56]), digit span being a frequently cited example. The precise number of digits varies among individuals (digit span is often a component in IQ tests) and can be increased a great deal by "chunking" and other techniques that rely on long term memory (Miller, 1956 [56]; Ericsson, Chase and Falcon, 1980 [27]).

More recent studies, particularly those associated with exploring working memory, have shed more light on performance on this type of task. One of the most important in the current context is the word-length effect. Baddeley and others have shown that this type of memory span depends not on a precise number of items, but on how many can be fitted in a phonological loop. Baddeley describes this loop as comprising a store that can hold a small amount of speech-based information and an inner speech or articulation process. Rather in the manner of dynamic RAM, the information in the store fades rapidly and has to be refreshed after about two seconds by the articulatory process reading the information back to the store (Baddeley, 1986 [3], & 1990 [4]; Baddeley and Hitch, 1974 [5]). This means that the store's capacity is about two seconds of internal speech.

Baddeley, Thomson and Buchanan, 1975 [7] showed that immediate serial recall depended on the *lengths* of the words in the list. There was a strong relationship between the number of syllables in each word in a list, and the level of recall. However, the time the words took to read was an even better predictor of the recall level, as the research showed a linear relationship between the reading rate in words per minute and the level of recall.

This led to a number of studies to investigate the already observed phenomenon of varying average digit spans in different countries. By using bilingual subjects, Ellis and Hennelly, 1980 [26] showed that the consistent finding of Welsh-speaking children having lower digit spans than English-speaking ones could be accounted for by the longer time it takes to say the numbers in Welsh. The language also affected other tasks where they had to hold numbers in working memory, such as mental arithmetic. Naveh-Benjamin and Ayres, 1986 [57] showed similar results in comparing English, Spanish, Hebrew and Arabic speakers (students aged 20-30) (table 2).

Table 2: Average digit span for different languages

Language	Mean syllables per digit	Reading time seconds per digit	Reading time seconds per syllable	Predicted digit span (based on 2 seconds)	Actual digit span	Immediate recall capacity seconds
English	1,000	0,256	0,256	7,81	7,21	1,85
Spanish	1,625	0,287	0,177	6,97	6,37	1,83
Hebrew	1,875	0,309	0,165	6,47	6,51	2,01
Arabic	2,250	0,370	0,164	5,41	5,77	2,13
NOTE: To maximize the differences, the number 7 was not used, being two syllables in English; neither was 0, which (in English at least) can be pronounced in various ways (zero, nought, oh).						

Hoosain and Salili, 1987 [39], & 1988 [40]) extended the findings to Chinese. Comparing their results to those of Ellis and Hennelly [26], reveals (table 3):

Table 3: Comparison of digit span in three different languages

Language	Articulation rate seconds per digit	Digit span
Chinese	0,265	9,9
English	0,321	6,6
Welsh	0,385	5,8

Note that although Ellis and Hennelly's subjects were bilingual, their native language was Welsh, which may explain why their performance in English was not up to that of the English native speakers tested by Naveh-Benjamin and Ayres. (There is also another reference on this topic: Ellis, 1992 [25]).

It is well established that digit span in children increases with age. This was shown by Nicolson, 1981 [58] to be related to their increasing articulation speed. Further studies by Hulme, Thomson, Muir and Lawrence, 1984 [41] and Hitch, Halliday and Littler, 1984 [38] indicated that the increased memory span could be accounted for by the increase in articulation speed. This is the case for spoken presentation, though with items presented as drawings the effect does not appear until the ages of 8 to 10 (Hitch et al, 1984 [38]); it seems that rehearsal maintenance is acquired earlier than converting a visual item to a phonological code.

7 Issues still to be reviewed

There are some issues that could do with some further literature research.

7.1 Effect of age on remembering the codes

Most of the work reviewed in this report has been conducted with young adults, partly because students are the most usual subjects in psychology experiments. From previous experience of the literature and research, it should be expected that young children and elderly adults would be likely to have more difficulty in both the short-term retention needed to copy codes from a reminder card and in learning and retrieving codes using long-term memory.

One recent experiment whose abstract came up by chance in the investigations looked at memory for telephone numbers in adults ranging from 18 to 85 years old (West and Crook, 1990 [68]). With visual presentation and immediate recall, presumably analogous to using a reminder card or directory, performance declined with age for 10-digit numbers but not for 3-digit ones. With 7-digit numbers, the youngest group performed significantly better than the oldest (70-85 years). More marked decline with age was found when subjects had to redial following an engaged signal. Auditory presentation produced similar age patterns and chunked auditory presentation produced high performance in both young and old. This looks like an interesting start to reviewing age related issues.

8 Summary conclusions

This part 2 of the ETR reports on a review of memory and related issues that are relevant to the use of number codes and characters * and # in dialling supplementary services. Two very different memory areas are involved. One is learning the commands, or committing them to long-term memory, so that they can be dialled without looking them up. The second area is the use of short-term memory or working memory to store the commands between looking them up on a reminder card or in a directory and actually dialling them. There seem to be more short-term memory studies using numbers as to-be-remembered material than long-term memory studies, partly because of the use of digit span as a measure of short-term memory. However, theoretical frameworks allow speculation by reasoned and careful generalization from established long-term memory research.

Users will need to understand the services before they can remember or use them. It is probably best to learn a few at a time. Services need short names as well as code numbers. The nameset should be carefully designed, making use of what is known about designing command namesets. The code number set should be appropriately structured. The syntax involving * and # symbols should be simple and consistent. Mnemonics may be used to learn when to use the symbols and the different number codes. Users may finish up only using a small proportion of the available services.

The capacity of short-term memory for remembering digits will vary from language to language, depending on how long the words for the digits are, because they are stored in some type of phonological code. For the same reason errors are likely to involve confusion between similar sounding digits. Users trying to remember codes between looking them up and dialling them may suffer interference from people talking near them, an effect that is independent of intensity so long as it is clearly audible. Other types of noise are less of a problem. Users are likely to enter the codes, * and # symbols and any argument numbers in chunks rather than one long sequence. If they have to look up some of these, or if they are interrupted they may forget where they are in the sequence.

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