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Memory for Everyday Objects: Where are the Digits on Numerical Keypads?

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SUMMARY

Memory for the layout of the ten digits 0 to 9 on the keypads of push-button telephones and calculators was investigated in five experiments. Experiments 1 and 2 revealed that, despite frequent usage of these devices, free recall of the numerical layouts is quite poor; and that the layout on calculators is even harder to recall than the telephone layout. Experiment 4 showed that the same is true for recognition of the layouts. Experiment 3 revealed that part of the recall advantage of the telephone layout can be attributed to its being more plausible and more similar to a schematic or prototypical layout of digits. Experiment 5 indicated that a single case of directing attention to the layouts can enhance recall significantly. The results are integrated into earlier research on memory for everyday objects, and concepts used in laboratory memory research such as interference, inference, and attention are used to explain memory for these everyday objects. Copyright © 1999 John Wiley & Sons, Ltd.

Before you turn the page or look at one of the devices, please try to recall where the ten digits 0 to 9 are located on the keypads of your push-button telephone and your pocket calculator! Most probably, you will find it hard to recall the correct layouts of the digits, and you might be surprised to find that the way the digits are laid out on telephones differs from their layout on calculators.

Memory for everyday objects such as numerical keypads, coins, and other objects has been of interest to applied memory researchers for quite some time, although the number of published studies and the range of studied objects are surprisingly small. Most of the studies have investigated people's memory for the details shown on coins. In a now classical study, Nickerson and Adams (1979) asked American participants to recall the features of a US penny. In a series of experiments involving free recall, cued recall, and recognition, they found that people's ability to recall the details shown on both sides of the coin was very poor, despite the fact that they had seen thousands of pennies before. Rubin and Kontis (1983) reported very similar results for four different US coins. They also asked their participants to design new coins. These had many features in common with each other and with existing coins, which speaks for the existence of a common schema of coins. In addition to poor recall, Jones (1990), Jones and Martin (1992), and Richardson (1992) found a systematic bias in the recall attempts: the faces shown on the coins were usually drawn facing left,

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although they face right on the coins studied by these authors. Jones and Martin (1992) were able to show that this bias can be attributed to the existence of a common schema for coins and stamps.

The basic result of these studies, namely poor recall despite frequent usage, was replicated using everyday objects other than coins. Except for a study on the facing of the moon (Martin and Jones, 1995), most of these studies used keypads as the to-be-remembered object. In one of the first studies, Morton (1967) asked his participants to recall the letters shown on the round British telephone dial. Not a single one of his 151 participants was able to recall how the letters were laid out across the ten digits on the round dial, and their recognition performance did not exceed chance level. Very similar results were observed by Foos (1989) who tested recognition of a matrix-type push-button telephone dial. Due to the nature of his recognition task, he mainly tested his participants' ability to recognize the correct position of the letters on this dial. He found that only 40% of his younger participants and 7% of his elderly participants were able to recognize the letters correctly.

Given these unequivocal results, one might wonder why the present paper reports even more experiments on people's ability to recall the features of numerical keypads. In answer to this question, I would like to argue that numerical keypads have some features that make them particularly worthwhile everyday objects to investigate, and that the most interesting questions regarding memory for these objects have not yet been asked, much less answered. First, and much to many people's surprise, the ten digits are laid out in different ways on different devices such as push-button telephones, automatic teller machines, pocket calculators, computer keyboards, and others. Naturally, these devices contain a variety of keys with letters as well as digits. However, for the questions investigated here, only the ten digits are of interest. These digits are almost always arranged in a matrix made up of four rows and three columns. The two most common layouts, which were used in the experiments reported here, are depicted in Figure 1. The left side of Figure 1 shows the layout that is used for telephones and most automatic teller machines, and the layout found on pocket calculators as well as on the extra numerical keypad of computer keyboards is depicted on the right. As Figure 1 shows, both layouts have only the arrangement of the digits 4 to 6 in common. The row containing the digits 1 to 3 and the row containing 7 to 9 are exchanged. The

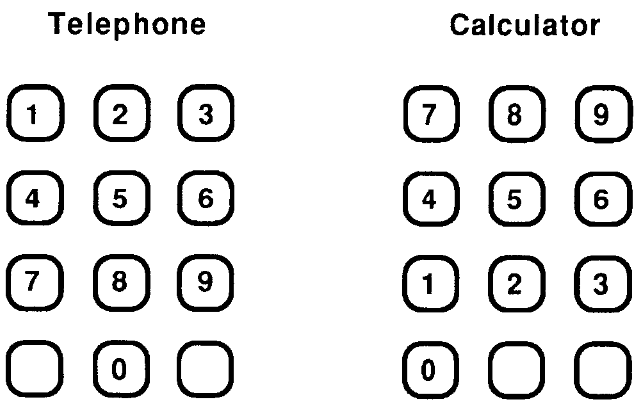

Figure 1. Layout of the ten digits 0 to 9 on telephones (left) and calculators (right)

digit 0 is always located in the fourth row, however, either in the left column or the middle one. These layouts seem to be used quite universally. The only minor variation occurs with calculators: some calculators have a double-sized key for the digit 0, which encompasses both the left and the middle key of the fourth row. Nevertheless, even with this variation, the digit 0 is still located in the usual bottom-left corner. For the sake of simplicity, the terms 'telephone layout' and 'calculator layout' will be used in the following to refer to the two layouts shown in Figure 1. Although both layouts are used for several devices, the telephone and the calculator seem to be the most common ones.

It seems that the reasons for choosing two different numerical layouts for a number of very similar devices are mostly historical in nature. Instead of agreeing on a common layout, the 'Comité Consultatif International Télégraphique et Téléphonique' chose the telephone layout, and the 'International Organization for Standardization' chose a different layout for calculators. The fact that two different layouts were chosen might be surprising or even annoying to users of the corresponding devices. However, it is very helpful for answering some of the questions investigated in everyday memory research. In addition to assessing people's memory for these frequently used objects in general, one can test whether one layout is easier to recall than the other, and whether they interfere with each other during recall. Moreover, variables that might explain overall memory performance, as well as variables predicting differences in memory for the two layouts, can be tested empirically. So far, mainly *post-hoc* explanations for the generally poor recall of everyday objects have been suggested. In the experiments reported here, an attempt was made to empirically test predictions regarding overall memory performance as well as predictions regarding memory differences between the layouts.

The predictions tested in the current experiments were derived from concepts developed in standard 'laboratory' memory research, e.g. interference, inference, number of learning trials, retention interval, plausibility, schema, retrieval strategies, attention, and elaboration. Therefore, the present experiments were also intended to advance the integration of 'laboratory' and 'everyday' memory research, advocated by many authors (e.g. Conway, 1991; Gruneberg and Morris, 1992; Tulving, 1991).

The five experiments reported in this paper were conducted to investigate in detail people's memory for numerical layouts. The experiments were intended to answer two main questions regarding memory: is memory for numerical layouts as poor as it was found to be for other everyday objects, and if so, why? Is one of the two common layouts more easily recalled than the other one, and if so, why?

Regarding the first question, there is hardly any reason to expect better memory for numerical layouts than for coins or other objects. Although numerical information differs from the previously studied pictorial (e.g. Nickerson and Adams, 1979; Jones, 1990) and verbal (Morton, 1967; Foos, 1989) features of everyday objects, the very same variables should cause poor memory. Thus, several theoretical frameworks predict poor memory for the layout of the numerals on keypads: during goal-directed use of the keypads, e.g. to make a phone call or to compute a square root, little attention is paid to the location of the digits as long as they are easily visible (Hacker, 1982, 1985). The same prediction would be made by a levels-of-processing approach (Craik and Lockhart, 1972), assuming that the location of the digits is processed at a very shallow level. Also, this type of shallow processing fulfills the sufficiency criterion postulated by Nickerson and Adams (1979): successful use of the keypads does not require memory for the location of the digits, just as successful discrimination of coins does not require memory for every detail shown on them.

Regarding the second question, the available data does not allow a prediction whether one of the two layouts should be remembered any better than the other one. For instance, Conrad and Hull (1968) found that their participants were able to type in numbers more quickly and more correctly when using a telephone layout of digits rather than a calculator layout. This does not imply better memory for the telephone layout, however. In addition, the digits are laid out in systematic and plausible ways on both devices. On the telephone, the order of digits from 1 to 9 corresponds to the usual way of reading from top-left to bottom-right. On the calculator, the order corresponds to the rule 'up is more' (Kosslyn, 1994). Finally, one device might be used more often than the other. Frequency of using everyday objects, however, seems to be a weak predictor of memory performance (Nickerson and Adams, 1979). To summarize, it remains to be determined whether memory for the telephone layout differs from memory for the calculator layout.

Experiment 1 yielded a first answer to the two main questions discussed above: free recall of both numerical layouts was quite poor, and recall of the calculator layout was even worse than recall of the telephone layout. In addition, several potential explanations for this difference were investigated, namely frequency and recency of using the devices as well as retrieval strategies during free recall. In Experiment 2, these results were replicated and the role of interference during recall was studied. In Experiment 3, participants were asked to name the most plausible layout to find out whether the recall advantage for the telephone layout might be due to a schema for numerical layouts and reconstructions guided by plausibility, rather than to memory retrieval. Experiment 4 revealed that memory performance in a recognition task was as poor as in the previous free recall tasks. Finally, Experiment 5 indicated that paying attention to the numerical layouts improves learning and retention much more than repeated, but inattentive use of the corresponding keypads.

EXPERIMENT 1

Experiment 1 was conducted to answer the two main questions outlined above: is memory for numerical layouts as poor as for other everyday objects, and does memory for the telephone layout differ from memory for the calculator layout? In addition, Experiment 1 was designed as a first test of several explanations for the potential difference between the two layouts. One layout might be easier to recall than the other one because the corresponding device is used more often, or because the device was used a shorter time ago. These two variables correspond to well-known variables from memory research, namely number of learning trials and retention interval, respectively. Both variables have reliable effects on memory for materials learned in the laboratory. Their effect on memory for everyday objects such as numerical keypads is doubtful, however, given the poor recall observed for other frequently used objects, e.g. coins.

Another potential difference between the two layouts concerns the strategies people might use to retrieve the layouts from memory. Most of these strategies can be applied to both layouts, except for what might be called a 'motor' strategy. Some well-known phone numbers are dialled frequently, therefore they might produce a memory trace of the motor responses involved, particularly of the movements from button to button. In the memory test, participants could use this 'motor memory' (see Fendrich *et al.*, 1991; Rosenbaum, 1991) to determine the position of the dialled digits by pretending to dial a well-known phone number and watching where their fingers move. This should not be possible for the calculator layout because we hardly ever use the same numbers over and over again in computations. Thus, this line of reasoning would predict better memory for the telephone layout due to the availability of the motor strategy.

Method

Participants

A total of 186 students of the Technical University of Dresden participated in the experiment. Most of them were undergraduates in psychology.

Materials and procedure

Each participant received a paper-and-pencil free recall test. On a sheet of paper, a matrix of 12 empty cells (four rows and three columns) was shown. Half of the participants were asked to place the ten digits into the empty matrix as they are laid out on push-button telephones. The other half was asked to reproduce the layout on calculators. To control for possible effects of wording, half of the instructions in each group asked for the layout of the digits '0 to 9' and the other half for the layout of the digits '1 to 0'. Participants were allowed to correct their recall attempts if they thought they had made a mistake. In addition, all participants were asked to answer a number of questions that followed the empty matrix. They were asked about their age and sex, and about possible strategies they had used to recall the requested layout. Moreover, they rated their confidence in the correctness of their recall attempt on a 7-point scale ranging from 'completely unsure' to 'perfectly sure'. They also reported when they had used the device for the last time, using a 7-point scale ranging from 'today' to 'never'. Finally, they indicated how often they usually used the recalled device, using a 7-point scale ranging from 'daily' to 'never'. It took participants about 10 to 15 minutes to complete the free recall sheet. Some of them were tested in small groups and some as part of a classroom demonstration. In the latter case, they were supervised by a group of six experimenters who made sure that they could not copy from each other. In addition, participants seated beside each other never had to recall the same device.

Design

The experiment followed a 2×2-design with the factors 'requested layout' (telephone versus calculator) and 'wording of instruction' (digits '0 to 9' versus '1 to 0'). Both factors were varied between-subjects. Free recall of the telephone layout and the calculator layout was requested from 93 participants each. In each group, 46 participants received one type of wording, and 47 received the other. Frequency of correctly recalled layouts was used as the dependent variable, with correctness of the complete layout as well as correctness of the first three rows versus the fourth row considered separately. Since the data collected in this experiment were nominal and ordinal data, they were analyzed using χ^2-tests, ordinal correlations, and Mann–Whitney U-tests.

Results and discussion

The analyses of the recall protocols revealed that wording of the instruction had no effect at all, therefore, all analyses reported below were collapsed over this factor. Free recall of the layouts was quite poor, only 38% of all recall attempts (71 out of 186) were completely correct. Recall of the calculator layout was even worse than recall of the telephone layout (49% telephone versus 27% calculator correct, $\chi^2(1) = 10.05$, $p < 0.01$).[1] This advantage for the telephone layout was most obvious for the digits 1 to 9 in the first three rows of the layouts (78% versus 48% correct, $\chi^2(1) = 18.2$, $p < 0.001$), while the smaller difference regarding the position of the digit 0 in the fourth row just fell short of statistical significance (58% versus 46% correct, $\chi^2(1) = 2.6$, $p < 0.11$).

Layout exchanges constitute a particularly interesting class of errors. They occur when participants reproduce the telephone layout (or parts of it) instead of the requested calculator layout, or vice versa. Naturally, complete layout exchanges occurred less often than other mistakes, and both types of exchanges were rarely observed (8% towards the calculator versus 14% towards the telephone, $\chi^2(1) = 2.0$, n.s.). Participants frequently exchanged the position of the digit 0 in the fourth row, with both types of exchanges being comparably frequent (30% versus 39%, $\chi^2(1) = 1.52$, n.s.). For the first three rows, however, a preference for the telephone layout of the digits 1 to 9 was observed: participants reproduced the layout on telephones instead of the requested layout on calculators significantly more often than vice versa (12% versus 35%, $\chi^2(1) = 14.4$, $p < 0.001$).

The advantage observed for recall of the telephone layout compared to the calculator layout may be explained in part by the telephone being used more frequently. Participants' ratings indicated that they used telephones more often than calculators ($z = 5.5$, $p < 0.01$, by a U-test) and that they had used a telephone more recently than a calculator ($z = 5.9$, $p < 0.01$). However, the correlations of frequency of usage with correctness of recall were very low: $r = 0.11$ (n.s.) for the telephone and $r = 0.18$ ($p < 0.05$) for the calculator. The same was true for recency of usage, both for the telephone ($r = 0.09$, n.s.) and the calculator ($r = 0.17$, $p < 0.10$). Moreover, the advantage for the telephone was still apparent even when frequency and recency of usage were held constant. In an additional analysis, only participants who had reported that they used the recalled device once a week were included. Still, recall of the telephone layout was better than recall of the calculator layout (58% versus 27% correct, $\chi^2(1) = 6.0$, $p < 0.05$). A similar, but non-significant, result was observed for selected participants who had used the recalled device a week ago (42% versus 25% correct, $\chi^2(1) = 1.7$, n.s.).

Another potential reason for superior recall of the telephone layout can be found in the retrieval strategies reported by the participants. Only two strategies were reported frequently, namely a visual strategy (e.g. 'I imagined what the layout looked like') and a motor strategy (e.g. 'I watched my fingers as I dialled a well-known phone number'). The visual strategy can be used on both layouts, but the motor strategy should only be helpful for recalling the telephone layout. Indeed, the motor strategy was reported more often by participants who tried to recall the telephone layout than by participants who tried to recall the calculator layout (26 versus 13 times, $\chi^2(1) = 5.45$,

[1]In the following, whenever the telephone layout and the calculator layout are compared to each other, values for the telephone layout are given before the corresponding values for the calculator layout.

$p < 0.05$), while the opposite was true for the visual strategy (28 versus 47 times, $\chi^2(1) = 8.02$, $p < 0.01$). Consequently, the interaction of retrieval strategy and recalled device was statistically significant ($\chi^2(1) = 8.78$, $p < 0.01$). Thus, better recall of the telephone layout might be partially based on more effective retrieval strategies due to differential availability of the motor strategy.

To summarize, the results of Experiment 1 indicate that memory for the layout of digits on everyday devices such as telephones and calculators is indeed as poor as it was found to be for other common objects such as coins. In addition, a clear dependence upon the way the digits are laid out on telephones and on calculators was found: memory for the calculator layout is even worse than memory for the telephone layout. Finally, several potential explanations for the observed results were investigated, namely frequency and recency of using the devices, as well as differing retrieval strategies. The following experiments were conducted to replicate the two basic results and to investigate them in more detail. This was done by testing potential explanations for the memory difference between the telephone layout and the calculator layout, as well as explanations for participants' poor overall memory performance.

EXPERIMENT 2

Experiment 2 was designed with two aims in mind. First, the main results of Experiment 1 had to be replicated, i.e. participants' overall poor recall performance, and the better recall of the telephone layout compared to the calculator layout. Particularly, the difference between both layouts regarding the position of the digit 0 in the fourth row was tested again, employing a more powerful experimental design. Second, interference during the subsequent recall of both layouts was studied by giving participants a surprise free recall test of the second layout (calculator or telephone) after they had finished recalling the first (telephone or calculator, respectively). If interference occurs in this situation, recall of the second layout should be impaired by the preceding recall attempt of the other layout. This 'interference hypothesis' was contrasted with the opposing 'improvement hypothesis' which states that recalling both layouts will draw participants' attention to the fact that the layouts might be different, thereby improving recall of the second layout rather than impairing it.

Method

Participants

A total of 120 students of the Technical University of Dresden participated in the experiment. All of them were second-year undergraduates in psychology.

Materials and procedure

These were very similar to those of Experiment 1, except that each participant was asked to recall both numerical layouts. Half of the participants were tested on the telephone layout first, the other half recalled the calculator layout first. Participants were unable to amend earlier recall attempts because the first recall sheet was collected before the second one was distributed. Wording of the instructions was not varied because this variable had not had any effect in Experiment 1. Thus, all participants were asked to recall the layout of 'the digits 0 to 9'. The free recall test sheet was almost identical to the one used in the first experiment, and the same questions about age and sex, recall strategies, subjective confidence, frequency and recency of usage were asked. It took participants about 20 to 25 minutes to complete both free recall test sheets.

Design

The experiment followed a 2×2-design with the factors 'requested layout' (telephone versus calculator) and 'test order of layouts' (calculator first versus telephone first). Requested layout was a within-subjects factor, while test order was varied between-subjects. Sixty subjects each tried to recall the calculator layout or the telephone layout first. The dependent variables and analyses were identical to those of the first experiment with the addition of McNemar tests used to analyze effects of the within-subjects factor 'requested layout'.

Results and discussion

The analyses of the recall protocols revealed that test order of the layouts affected free recall of the calculator layout. Contrary to the interference hypothesis, and in agreement with the improvement hypothesis, free recall of the way the digits are laid out on calculators tended to be better if the calculator layout was recalled after rather than before recalling the telephone layout (23% versus 10% correct, $\chi^2(1) = 3.81$, $p < 0.10$). Recall of the telephone layout was not reliably affected by test order (50% correct first versus 45% second, $\chi^2(1) = 0.30$, n.s.). Except for this effect on recall of the calculator layout, no other statistically reliable effects of test order were observed. Therefore, the results reported in the following were collapsed over both test orders. These results replicated those of the first experiment very well.

As in the first experiment, free recall of the layouts was quite poor, only 32% of all recall attempts (77 out of 240) were completely correct. Again, recall of the telephone layout was better than recall of the calculator layout (47% versus 17% correct, McNemar's $\chi^2(1) = 22.44$, $p < 0.001$). As before, this difference was more pronounced for the digits 1 to 9 in the first three rows of the layouts (77% versus 32% correct, McNemar's $\chi^2(1) = 37.45$, $p < 0.001$). These results closely resemble those of the first experiment. Due to the increased power of the second experiment, however, even the smaller advantage for the telephone layout regarding the position of the digit 0 in the fourth row was statistically reliable (58% versus 41% correct, McNemar's $\chi^2(1) = 6.21$, $p < 0.05$).

Complete layout exchanges were observed as rarely as in Experiment 1. However, reproducing the correct telephone layout instead of the requested calculator layout occurred slightly more often than the reverse exchange (3% versus 12%, McNemar's $\chi^2(1) = 5.56$, $p < 0.05$). The position of the digit 0 in the fourth row was exchanged more frequently. Again, both types of exchanges were comparably frequent (23% versus 28%, McNemar's $\chi^2(1) = 0.64$, n.s.). For the first three rows, the same preference for the telephone layout as in Experiment 1 was observed. Participants reproduced the telephone layout of the digits 1 to 9 instead of the requested calculator layout significantly more often than vice versa (15% versus 42%, McNemar's $\chi^2(1) = 15.52$, $p < 0.001$).

As in Experiment 1, participants reported that they used telephones more frequently than calculators ($z = 7.55$, $p < 0.001$, by a *U*-test) and that they had used a telephone more recently than a calculator ($z = 7.35$, $p < 0.01$). However, the same low correlations as in Experiment 1 between correctness of recall and frequency of usage were observed, both for the telephone ($r = 0.16$, $p < 0.05$) and the calculator ($r = -0.01$, n.s.). The same was true for recency of usage, both for the telephone ($r = 0.14$, $p < 0.10$) and the calculator ($r = 0.06$, n.s.).

To summarize, the results of Experiment 2 replicate those of Experiment 1 very well. A similar low rate of correct free recall attempts, a similar recall advantage for the telephone layout compared to the calculator layout, a similar pattern of layout exchanges, and similarly low correlations of memory performance with frequency and recency of using the devices were observed. In addition, increasing statistical power in the second experiment by employing a within-subjects design yielded a significant difference between the two layouts for the position of the digit 0 in the fourth row of the layouts. With regard to the second aim of Experiment 2, the results are in accord with the improvement hypothesis and clearly contradict the interference hypothesis: it seems that recalling the telephone layout first helped participants to realize that the calculator layout differs from the telephone. This interpretation is also in agreement with reports that some participants gave spontaneously after the experiment was finished. Thus, taken together, Experiments 1 and 2 indicate that better recall of the telephone layout compared to the calculator layout cannot be explained very well by frequency of usage, recency of usage, or interference during memory retrieval.

EXPERIMENT 3

Experiment 3 was designed to test another possible explanation of the recall advantage that was observed for the way the digits are laid out on telephones compared to calculators. This explanation is very critical to the investigation of everyday memory phenomena such as the ones reported here because it refers to inferences and plausible reconstructions guided by a schema for numerical layouts, rather than to retrieval from memory. Naturally, every retrieval attempt, and therefore every answer given in response to a memory test, will be based partly on retrieval and partly on reconstructions and inferences, which are guided by plausibility. However, it is usually very hard to distinguish between the processes, and to determine their relative effects just on the basis of the retrieval product. In laboratory experiments, control of the learning phase can be used to manipulate the probability of fabrications in free recall, and to identify them without ambiguity. Fabrications are particularly informing because it is clear that their 'recall' must be based on reconstruction rather than retrieval. Also, in recognition tests, the choice of foils (i.e. items not presented before) can be used to induce different strategies during recognition.

Usually, no such manipulation is possible with regard to memory for everyday objects, mostly because the 'learning phase' of the study is not under the experimenters' control (but see the literature on 'implanted' autobiographical memories, e.g. the review by Loftus, 1997). Nevertheless, it is important to determine the role of inferences and plausibility-guided reconstructions in everyday memory. Particularly for the two numerical layouts studied here, it might be the case that, rather than being easier to recall, the layout of the digits on telephones is simply more plausible and more similar to a schematic or prototypical layout than the layout on calculators. As noted above, both layouts seem sensible. However, if a schema for the typical or optimal layout of the digits exists (such as the one for coins postulated by Rubin and Kontis, 1983), and if the telephone layout is more similar to the schema, people might choose to report this layout whenever they are in doubt. In an extreme case, the telephone layout would be produced in a memory test more often than the calculator layout, even if participants had no memory for the specific layouts at all. In short, this plausibility hypothesis states that a schema for numerical layouts exists and that the layout of the digits on telephones is reproduced more often than the calculator layout because it is more plausible, not because memory for it is any better.

Experiment 3 was conducted to test the plausibility hypothesis and to find out whether a schema for the layout of digits on keypads exists. The ideal way to do this would be to ask people who have never seen any numerical keypad what the best layout of the digits would look like on a 3×4 matrix (see Lutz and Chapanis, 1955, for an attempt to investigate preferences of naive participants). Given the abundance of numerical keypads in everyday life, it is obviously almost impossible to find people who fulfill this criterion. Therefore, a slightly different approach was chosen in Experiment 3: a large number of participants was asked to indicate what the optimal layout should look like. They were also asked to disregard all existing layouts, so their choice would be based on their own opinion rather than their view of what engineers had considered optimal when designing the existing layouts. This approach was based on the assumption that participants in memory experiments will consider the schematic layout the optimal and most likely one and therefore the one to produce in a memory test if they cannot remember the requested layout. Thus, the layouts chosen by the participants of Experiment 3 should closely resemble the ones that the participants of the first two experiments reconstructed on the basis of plausibility. If the participants of Experiment 3 call the calculator layout 'optimal' just as often as the telephone layout, fairly strong evidence against the plausibility hypothesis would be collected. In addition, the choice rates of the layouts can be used as a baseline to assess the chance rates of reproducing them correctly in the memory tests. If the layouts are not recalled correctly more often than they are called 'optimal' in Experiment 3, the responses in the memory tests can be attributed to inferences and plausible reconstructions.

Method

Participants

A total of 243 students of the Technical University of Dresden participated in the experiment. All of them were first-year undergraduates in economics attending an introductory class. The analyses reported below are based on the data of 228 of these participants who returned complete and interpretable answer sheets.

Materials and procedure

Each participant received a sheet of paper that contained the empty matrix used in the first two experiments. However, no memory test was involved. Instead, participants were told that it is unknown what the best layout of the ten digits on telephones, calculators, and other devices would be. Therefore, they were asked what they considered to be the best layout, no matter what existing layouts might look like. They gave their answer by writing the digits in their optimal locations in the matrix. They were allowed to correct their responses if they changed their mind during writing. As in Experiment 1, wording of the instructions was varied to avoid biasing the participants towards certain types of choices. Half of the 228 participants were asked to place 'the ten digits from 0 to 9' into the matrix, and the other half was asked to place 'the ten digits from 1 to 0'. It took participants about 5 minutes to complete the sheet. All of them were tested as part of a classroom demonstration, supervised by seven experimenters who prevented copying.

Design

The only independent variable in this experiment was the between-subjects factor 'wording of instruction' (digits '0 to 9' versus '1 to 0'). Each wording was presented to 114 participants. Frequency of participants calling each layout optimal was used as the dependent variable, with the complete layout as well as the first three rows versus the fourth row considered separately.

Results and discussion

The layouts chosen as optimal by the participants of Experiment 3 are shown in Figure 2. As in the first experiment, wording of the instructions did not affect the choices. Therefore the results are reported collapsed over both wording conditions. Figure 2 shows each layout that was produced more than once. The category 'others' contains all layouts that were produced only once. As can be seen from Figure 2, the layout chosen most often (by 29% of the participants) was the telephone layout. The participants' second choice (18%) was an amalgam of the telephone layout and the calculator layout: the digits 1 to 9 were laid out as they are on telephones, and the digit 0 in the fourth line was located as it is on calculators. The correct calculator layout was the participants' third choice. It was considered optimal by 10% of the

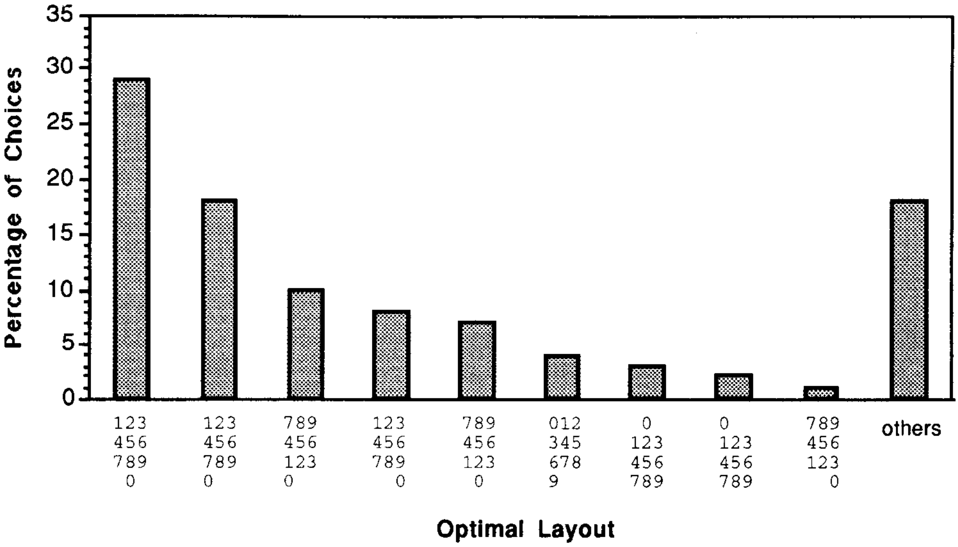

Figure 2. Numerical layouts considered optimal by participants in Experiment 3

participants. Thus, the telephone layout was chosen as the optimal one significantly more often than the calculator layout ($\chi^2(1) = 21.25$, $p < 0.001$).

Analyzing only the first three rows of the matrix yielded a strong preference for the telephone layout: 55% of all choices were identical to it, 18% were identical to the calculator layout, and 27% were different. Thus, the way the digits 1 to 9 are laid out on telephones was considered significantly more plausible than the way they are laid out on calculators ($\chi^2(1) = 54.34$, $p < 0.001$). A different result was found for the position of the digit 0: 30% of the participants placed it in the left-hand cell of the fourth row, as on calculators. Another 38% placed it in the telephone position, i.e. in the middle of the fourth row. This difference was not statistically reliable ($\chi^2(1) = 2.08$, n.s.). Thus, it seems difficult to explain the advantage for reproducing the digit 0 on telephones observed in Experiment 2 by a corresponding difference in plausibility. Finally, 11% of the participants placed the digit 0 in the right-hand cell of the fourth row, and 21% placed it in some other position, e.g. in the first row. The fairly even distribution of the digit 0 across the fourth row speaks against the existence of a complete schema for the layout of digits on keypads. For the layout of the digits 1 to 9, however, a schema or prototypical layout seems to exist which is identical to the layout on telephones.

The fact that the telephone layout was considered optimal by more participants than the calculator layout might be taken as evidence for the claim that the recall advantage of the telephone layout observed in previous experiments can be explained by its being more similar to a schematic layout, rather than by being easier to recall; at least for the way the digits 1 to 9 are laid out in the first three rows of the numerical keypads. Does this also indicate that the free recall results of previous experiments can be explained by plausible, schema-guided reconstructions rather than memory retrieval? Comparing the choice rates of Experiment 3 to the recall rates of Experiments 1 and 2 suggests that this is not the case. For instance, the percentage of correct recall of the telephone layout in Experiment 1 was significantly higher than the corresponding choice rate in Experiment 3 (49% versus 29%, $\chi^2(1) = 12.78$, $p < 0.001$). The same was true for the calculator layout (27% versus 10%, $\chi^2(1) = 19.13$, $p < 0.001$). Comparisons restricted to the first three rows yielded similar results: both for the telephone and the calculator, the percentage of correct recall of the digits 1 to 9 was significantly higher than the corresponding choice rate (telephone: 78% versus 55%, $\chi^2(1) = 15.08$, $p < 0.001$; calculator: 48% versus 18%, $\chi^2(1) = 31.04$, $p < 0.001$). Even for the position of the digit 0, percentages of correct recall were significantly higher than the corresponding choice rates (telephone: 56% versus 38%, $\chi^2(1) = 8.46$, $p < 0.01$; calculator: 44% versus 30%, $\chi^2(1) = 5.59$, $p < 0.05$). Similar results were found when the choice rates of Experiment 3 were compared to the recall data of Experiment 2. Thus, these comparisons indicate that the percentages of correct free recall observed in the first two experiments, despite their being quite low, did indeed involve memory retrieval in addition to schema-guided reconstructions and guesses.

EXPERIMENT 4

In both Experiments 1 and 2, free recall of the numerical layouts was quite poor; only 38% and 32%, respectively, of all recall attempts were correct. Experiment 4 was conducted to find out if better memory performance would be observed in a recognition task. Recognition of learned items is usually easier than free recall of the items, so this experiment should yield higher recognition performance compared to the recall performance of Experiment 1 and Experiment 2. However, it might be the case that the usual advantage for recognition compared to free recall does not necessarily hold for everyday objects. For instance, Nickerson and Adams (1979) found that recognition of the US penny was just as poor as free recall of its features. Morton (1967) reported the same equivalence of free recall and recognition for the positions of letters on a round telephone dial. Also, Foos (1989) found that the matrix-type telephone dial was recognized correctly by only 40% of his younger participants and 7% of his elderly participants. Therefore, Experiment 4 was conducted to find out whether the same lack of recall advantage for recognition compared to free recall would be observed with numerical layouts on everyday keypads. In addition, the positions of the digits were varied systematically in Experiment 4 to identify the layout parts that were particularly hard to recognize.

Method

Participants

A total of 120 students from different departments of the Technical University of Dresden participated in the experiment. All of them attended an introductory class on the psychology of memory.

Materials and procedure

Each participant was asked to recognize either the telephone layout or the calculator layout in a paper-and-pencil recognition test. On a sheet of paper, 12 different layouts of the digits 0 to 9 were shown. In each layout, the digits were distributed systematically across a matrix of 12 empty cells (as before, four rows and three columns). The 12 different layouts were constructed by complete combination of three features: the digit 0 was located in the first or the fourth row; it was located in the left, middle, or right column; and the digits 1 to 9 were laid out as on telephones (i.e. going down when counting from 1 to 9) or as on calculators (i.e. going up when counting from 1 to 9). In each layout, two of the 12 cells were left blank. By constructing the layouts in this manner, two goals were achieved. First, the correct numerical layouts of telephones and calculators were among the 12 alternatives. Second, all other layouts were systematic, plausible alternatives to the correct layouts, thereby decreasing the possibility of guessing the correct layout. Also, almost all of the layouts chosen as optimal in Experiment 3 were among the 12 alternatives of Experiment 4. The position of the 12 alternatives on the sheet of paper was varied as well to avoid order effects.

The recognition task was very similar to the procedure chosen by Nickerson and Adams (1979) and Foos (1989). The participants were asked to rate each of the 12 layouts on a scale ranging from 1 to 4. They were asked to rate exactly one layout as a ‘1’, which corresponded to ‘This is the correct layout’. All layouts that were considered ‘possibly correct’, if the first choice were wrong, were to be rated as a ‘2’. A ‘3’ was given to all layouts that the participant considered ‘probably incorrect’. Finally, a ‘4’ was given to all layouts that the participant considered ‘definitely incorrect’. Thus, only one layout received a 1, whereas varying numbers of layouts could be rated as 2, 3, or 4. In addition to the recognition task, participants were asked to answer the same questions as in previous experiments about their age and sex, their recognition strategies, their confidence in the correctness of their answers, the last time they had used the requested device, and the frequency of using it. It took participants about 15 minutes to complete the recognition sheet. Again, they were tested in small groups or as part of a classroom demonstration.

Design

The only independent variable in this experiment was the between-subjects factor 'requested layout' (telephone versus calculator). Recognition of the telephone layout and the calculator layout was requested from 60 participants each. Frequency of the ratings 1, 2, 3, and 4 was used as the dependent variable to assess recognition performance.

Results and discussion

Table 1 shows the ratings that each of the 12 layouts received when participants were asked to recognize the telephone layout or the calculator layout. For easier tabulation, the matrix-like layouts are shown as linear strings in the left-hand column of Table 1. The order of digits in the strings is determined by the usual way of reading a

Table 1. Number of ratings given to layouts in Experiment 4

Layout	Rating category			
	1	2	3	4
Telephone recognition				
0 – 123456789	0	1	2	57
– 0 – 123456789	0	0	8	52
– 0123456789	0	1	6	53
1234567890 –	13	21	7	19
123456789-0- (correct)	31	12	10	7
123456789 – 0	4	24	8	24
0 – 789456123	0	7	15	38
– 0 – 789456123	1	5	14	40
– 0789456123	1	4	14	41
7894561230 –	3	5	12	40
789456123-0-	5	9	6	40
789456123 – 0	2	5	8	45
Calculator recognition				
0 – 123456789	0	5	8	47
– 0-123456789	0	4	9	47
– 0123456789	2	1	12	44
1234567890 –	5	14	9	32
123456789-0-	6	14	11	29
123456789 – 0	5	13	10	32
0 – 789456123	0	6	12	42
– 0 – 789456123	1	2	11	46
– 0789456123	0	6	10	42
7894561230 – (correct)	22	13	10	15
789456123 – 0 –	14	23	7	16
789456123 – 0	5	17	16	22

matrix from top-left to bottom-right, with blank cells indicated by ' – '. For instance, the string '123456789-0-' corresponds to the telephone layout, which is the fifth one in each of the two lists. The calculator layout is the tenth one in each list, given as '7894561230 – '.

The '1' ratings are the most important ones shown in Table 1 because each participant had to rate exactly one layout as a '1', i.e. as the requested layout. When participants were asked to recognize the telephone layout, significant differences between the 12 layouts were observed ($\chi^2(11) = 177.2$, $p < 0.001$). The correct telephone layout was rated as a '1' by 52% of the participants (31 out of 60). Although only slightly more than half of the participants recognized the telephone layout correctly, it was clearly their favorite. It was the most frequent choice, and it was chosen more often than the second choice, which was a very similar foil (52% versus 22%, $\chi^2(1) = 11.5$, $p < 0.01$). The calculator layout was chosen erroneously by only 5% of the participants (3 out of 60).

Similar results were observed when participants were asked to recognize the calculator layout. Again, the distribution of '1' ratings was uneven among the 12 alternatives ($\chi^2(11) = 99.2$, $p < 0.001$), although not quite as extreme as during recognition of the telephone layout. The correct layout received the most '1' ratings (37%, i.e. 22 out of 60 however, it was not chosen significantly more often than the participants' second choice, which was a very similar foil (37% versus 23%, $\chi^2(1) = 2.52$, n.s.). The telephone layout was the participants' third choice; it was chosen erroneously by 10% of the participants, significantly less often than the correct calculator layout itself (10% versus 37%, $\chi^2(1) = 11.8$, $p < 0.001$).

These results are complemented by the distribution of '4' ratings, i.e. the cases in which layouts were rated as 'definitely incorrect'. Again, reliable differences between the 12 layouts were observed for participants who were asked to recognize the telephone layout, ($\chi^2(11) = 62.4$, $p < 0.001$). All layouts with the digit 0 in the first line and all layouts that had the digits 1 to 9 laid out as on calculators were frequently rated as 'definitely incorrect'. Also, the layout which received the least '4' ratings was indeed the correct telephone layout. It received significantly fewer '4' ratings than any other layout, even fewer than the second-lowest one (12% versus 32%, $\chi^2(1) = 7.01$, $p < 0.01$). Similar results were observed for participants who were asked to recognize the calculator layout. Again, significant differences between the 12 layouts occurred ($\chi^2(11) = 45.47$, $p < 0.001$). All layouts with the digit 0 in the first line and all layouts that had the digits 1 to 9 laid out as on telephones were rated as 'definitely incorrect' more often than the three layouts with the correct layout of the digits 1 to 9. The differences between these three layouts were not statistically significant. However, the correct calculator layout received significantly fewer '4' ratings than the telephone layout (48% versus 25%, $\chi^2(1) = 6.97$, $p < 0.01$).

Overall, recognition of the telephone layout was slightly better than recognition of the calculator layout. The telephone layout was rated correctly with a '1' more often than the calculator layout (52% versus 37% correct, $\chi^2(l) = 2.71$, $p < 0.05$), although the difference regarding the incorrect 'definitely incorrect' ratings was not reliable (12% versus 25%, $\chi^2(1) = 2.14$, n.s.). Taken together, these results indicate that the correct layouts were indeed the participants' favorite choices in the recognition task. On absolute terms, however, it was quite difficult to recognize the correct layouts. Only half of the participants recognized the telephone layout and 12% called it 'definitely incorrect'. Even more, only a third of the participants were able to recognize the calculator layout, and almost as many participants considered it 'definitely incorrect'. In addition, a considerable number of incorrect layouts were called 'possibly correct'. Most of these differed from the correct one by the position of the digit 0 in the fourth row. In correspondence with the results described above, this reflects the particular difficulty of recalling the position of the numeral 0 on numerical keypads.

To summarize, it seems that recognition of these everyday numerical layouts was hardly easier than the free recall requested in Experiment 1 and Experiment 2. The following analyses were computed to compare the recognition performance observed in Experiment 4 to the free recall performance of Experiment 2 in more detail. Experiment 2 was chosen because it had yielded slightly lower rates of correct free recall than Experiment 1; thus the postulated advantage of recognition over free recall would have a greater chance to be detected. First, memory for the telephone layout was compared separately for the digits 1 to 9 in the first three rows and the digit 0 in the fourth row. 77% of the participants of Experiment 2 gave correct free recalls of the digits 1 to 9, and 80% of the participants of Experiment 4 recognized them correctly. These percentages do not differ from each other significantly ($\chi^2(1) < 1$, n.s.). The same conclusion can be drawn for the correct position of the digit 0 on both telephones and calculators: recognition performance was just as poor as free recall performance (telephone: 58% free recall versus 60% recognition, $\chi^2(1) < 1$, n.s.; calculator: 41% free recall versus 45% recognition, $\chi^2(1) < 1$, n.s.). The only substantial difference occurred for the layout of the digits 1 to 9 on calculators: recognition performance was significantly better than free recall performance (32% free recall versus 68% recognition, $\chi^2(1) = 21.71$, $p < 0.001$).

EXPERIMENT 5

Experiment 5 was conducted to investigate the role of attention and elaboration in the learning and retention of numerical layouts. According to several theoretical accounts (e.g. Craik and Lockhart, 1972; Hacker, 1982, 1985; Nickerson and Adams, 1979) memory for the layout of the digits on keypads such as telephones and calculators should indeed be poor because users do not pay conscious attention to the position of the digits when they use the keypads. Therefore, even hundreds or thousands of learning trials, i.e. uses of the keypads, might not lead to reliable memory for the layout of the digits (a similar case for verbal material was reported by Sanford, 1982). In short, it is quality rather than quantity of processing of numerical layouts that determines whether they will be recalled later on. If these accounts are correct, learning of the layouts and memory for them should be greatly improved by directing people's attention to them. At the very least, later retrieval attempts should be correct more often because people remember that the layouts on telephones and calculators differ. In the most extreme case, memory might be elevated to near perfect if people realized just once how the digits are laid out on different devices. Thus, a single learning trial involving attention to the layouts might outweigh hundreds of inattentive keypad uses. Experiment 5 was designed to test this attention hypothesis by directing participants' attention to the layout of the digits on telephones and calculators just once before testing their memory a week later. In all other respects, this experiment was equivalent to Experiment 1 and Experiment 2. Therefore, the recall data observed in Experiment 5 were compared to those of the other two experiments to determine whether directing people's attention to the numerical layouts would improve their memory for them.

Method

Participants
A total of 119 students of the Technical University of Dresden participated in this experiment. All of them were first-year undergraduates in psychology attending an introductory psychology class. The analyses reported below are based on the data of 98 of these participants who participated in both the learning session and the test session, who recalled the learning trial, and who returned complete recall sheets.

Materials and procedure
This experiment, unlike the others, contained a learning phase. In an introductory psychology class, the teacher talked about ergonomics and degrees of freedom during actions. Then he presented an example for detrimental effects of irrelevant degrees of freedom: the differing numerical layouts of telephones and calculators may cause confusion and interference during use of the devices. He proceeded to show both layouts to the students by presenting Figure 1. Then he explained how the first row and the third row of the layouts differed and how the position of the digit 0 in the fourth row differed as well. The description of the layouts took 90 seconds during which the layout was visible. Afterwards, Figure 1 was removed, and no further reference to the layouts or the devices was made. To the students, the description seemed to be perfectly embedded in the class, and did not seem to have any particular importance. Also, no reference whatsoever to memory for the layouts was made. Most importantly, students were not instructed to memorize the layouts and they were not aware of the later recall test.

Exactly one week later, in another meeting of the introductory class, a surprise free recall test was given to the students attending the class. Two other meetings of the class had occurred in the meantime. None of them had contained topics related to numerical keypads. A delay of one week was chosen because in the previous studies, most participants had indicated that they used telephones and calculators at least once a week. Indeed, the questionnaire responses of the participants of Experiment 5 indicated that the delay between learning session and test session was at least as long as the delay between their last use of the device and testing. Therefore, the expected improvement in recall of the layouts in this study cannot be attributed to a shorter retention interval. The free recall test was identical to the one used in Experiment 1, i.e. participants were asked to recall the telephone layout or the calculator layout. In addition, the participants of the free recall test were asked whether they had attended the class a week ago and whether they remembered the teacher speaking about telephones and calculators. This was true for 98 participants. Half of them were asked to recall the telephone layout, the other half attempted to recall the calculator layout. All of them were tested in the classroom, supervised by six experimenters who prevented copying.

Design
The only experimental factor was 'requested layout' (telephone versus calculator), which was varied between-subjects. As before, frequency of correctly recalled layouts

was used as the dependent variable. Correctness of the complete layout, as well as correctness of the first three rows versus the fourth row were considered separately. In addition, the recall data of this experiment were compared to those of Experiments 1 and 2.

Results and discussion

As in previous experiments, recall of the telephone layout was better than recall of the calculator layout (73% versus 47% correct, $\chi^2(1) = 7.12$, $p < 0.01$). The recall advantage for the telephone layout was statistically reliable for the digits 1 to 9 in the first three rows of the layouts (86% versus 63% correct, $\chi^2(1) = 6.43$, $p < 0.05$), as well as for the position of the digit 0 in the fourth row (82% versus 61% correct, $\chi^2(1) = 4.95$, $p < 0.05$).

Both numerical layouts were recalled better than in previous experiments. This improvement was statistically significant for the telephone layout when the present experiment was compared to Experiment 1 (73% versus 49% correct, $\chi^2(1) = 7.53$, $p < 0.01$), and when it was compared to Experiment 2 (73% versus 47% correct, $\chi^2(1) = 9.43$, $p < 0.01$). The same was true for the calculator layout, both when the present experiment was compared to Experiment 1 (47% versus 27% correct, $\chi^2(1) = 5.73$, $p < 0.05$), and when it was compared to Experiment 2 (47% versus 17% correct, $\chi^2(1) = 16.71$, $p < 0.001$). Since both layouts were presented during the learning session, one might expect that layout exchanges would occur more often than in previous experiments. This would be the case if participants were able to recall the two different layouts without knowing which layout belongs to which device. This did not seem to be the case: layout exchanges were slightly more frequent in this experiment than in Experiments 1 and 2 (14% versus 11% and 8%), but the differences were not statistically reliable (both $\chi^2(1) < 3.26$, n.s.).

The results of Experiment 5, when compared to the other free recall experiments, indicate that directing participants' attention to the layout of the digits on telephones and calculators just once did indeed improve recall of the layouts significantly. The participants' ability to recall the layouts was far from perfect, however, particularly for the calculator layout. Therefore, the results speak for a weak version of the attention hypothesis: paying attention to the numerical layouts did improve learning and retention of the layouts, but a single trial did not suffice for very good retention. It might be the case that some participants only remembered that the two layouts differ from each other. The question of exactly what is learned and retained in memory in a single trial like the one used here will have to be left to future research.

GENERAL DISCUSSION

The five experiments reported here were conducted to investigate people's memory for the layout of the digits 0 to 9 on frequently used objects such as telephones and calculators. The experiments were designed to find out if memory for these numerical layouts is as poor as it had been found to be for other everyday objects, and if one layout is easier to recall than the other. In addition, an attempt was made to predict everyday memory performance using concepts developed in standard laboratory memory research, e.g. interference, inference, number of learning trials, retention interval, plausibility, schema, retrieval strategies, attention, and elaboration.

Two major results were replicated in all the experiments reported here. First, memory for the layout of digits on everyday devices such as telephones and calculators is indeed as poor as it is for other common objects such as coins (e.g. Jones, 1990; Nickerson and Adams, 1979; Rubin and Kontis, 1983). Second, memory for the way the digits are laid out on calculators is even worse than memory for the telephone layout. In addition, a number of potential explanations for these results were tested in the five experiments reported in this paper.

Both Experiments 1 and 2 tested variables that might account for the fact that recall of the telephone layout was better than recall of the calculator layout. Two of these variables, namely frequency and recency of using telephones and calculators, correspond to the number of learning trials, and to the retention interval in controlled laboratory memory experiments. The results of both experiments indicate that these variables are insufficient predictors of memory performance. Although participants had used telephones more recently and more often than calculators, both variables correlated only weakly with free recall of the layouts. Moreover, better recall of the telephone layout was observed even when frequency and recency of usage were held constant. Finally, the validity of these variables is questionable because of the poor overall memory performance observed despite frequent usage of the devices. Interference during memory retrieval is another potential explanation of the observed difference in memory performance, and it was investigated in Experiment 2. The results of this experiment were not in accord with the interference hypothesis, however. Participants were asked to recall both layouts, and free recall of the calculator layout was better for participants who had tried to recall the telephone layout first. Obviously, recalling the telephone layout first helped participants to realize that the calculator layout differs from the telephone layout rather than causing interference. Therefore, Experiments 1 and 2 indicate that better recall of the telephone layout compared to the calculator layout cannot be explained easily by frequency of usage, recency of usage, or interference during memory retrieval.

Differential availability of retrieval strategies seems to be a more promising explanation of the memory advantage observed for the telephone layout. In particular, there is at least one effective strategy that should be helpful solely for recall of the telephone layout. This strategy makes use of 'motor memories' (e.g. Rosenbaum, 1991) developed during repeated dialling of phone numbers. During free recall of the telephone layout, this memory can be used successfully by pretending to dial a well-known phone number and watching the finger's movements. The motor strategy can hardly be used to improve recall of the calculator layout, and indeed it was reported more often by participants of Experiment 1 who had to recall the telephone layout. In addition, the handedness of the participants might have influenced their performance in the experiments, e.g. in placing the calculator zero on the left (see Martin and Jones, 1998, for a review of handedness effects). The handedness of the participants was not elicited in the experiments reported here, therefore, this issue remains open for further investigation.

In Experiment 3, plausibility-guided reconstructions and inferences were tested as an explanation both for poor overall memory performance and for better performance with the telephone layout. This plausibility hypothesis predicts that people know very little about the layout of digits on everyday devices such as telephones and calculators. Therefore, rather than being able to retrieve the layouts from memory, they have to infer and reconstruct them when they are asked to recall them. Naturally, the reconstructions are based on plausibility and on a possible schema for the layout of digits. Experiment 3 investigated whether the memory advantage observed for the telephone layout, as well as memory performance in general, can be attributed to inferences and plausibility-guided reconstructions rather than memory retrieval. The participants of Experiment 3 did not have to recall any layouts; rather, they were asked to indicate what the optimal layout should look like while disregarding all existing layouts. The layouts chosen as optimal in this experiment argue against the existence of a complete schema for the layout of digits on keypads. For the digits 1 to 9 in the first three rows, a schematic or prototypical layout seems to exist which is identical to the layout on telephones. For the digit 0 in the fourth row, however, the left-hand position and the middle position seem comparably plausible. Thus, it seems difficult to explain the recall advantage for the digit 0 on telephones by a difference in plausibility. Moreover, comparisons of the choice rates of Experiment 3 to the recall rates of Experiment 1 and 2 indicate that the free recall results cannot be explained by schema-guided inferences and reconstructions rather than memory retrieval. In both free recall experiments, rates of correct recall were significantly higher than the corresponding choice rates observed in Experiment 3.

Experiment 4 was designed to test if the poor memory performance observed in previous experiments could be due to the particularly difficult nature of free recall. Thus, Experiment 4 employed a recognition task rather than the free recall test used before. Recognition should be easier than free recall, thus better memory performance might be expected in Experiment 4. In accordance with previous results observed for other everyday objects (e.g. Nickerson and Adams, 1979), however, recognition turned out to be just as difficult as free recall. The correct recognition rates observed in Experiment 4 did not exceed the free recall rates of Experiments 1 and 2, except for a particular aspect of the layouts, namely the way the digits 1 to 9 are laid out on calculators. Thus, it is unlikely that the poor memory performance observed in free recall was caused by problems in re-creating the requested numerical layouts from information stored in memory. Rather, it seems that the information was not available in memory in the first place, so performance was not improved by the conceivably easier recognition test.

Finally, the effects of attention and elaboration on memory for numerical keypads was investigated in Experiment 5. Several theoretical accounts would predict poor memory for the layout of digits on keypads because users do not pay conscious attention to the position of the digits when they use the keypads (e.g. Craik and Lockhart, 1972; Hacker, 1982, 1985; Nickerson and Adams, 1979). Thus, memory performance should be improved by paying attention to the layouts rather than by using the keypads repeatedly. This attention hypothesis was tested in Experiment 5 by directing participants' attention to the layouts on telephones and calculators just once. This single case of attending to the numerical layouts and elaborating on the fact that they differ did indeed improve memory performance in a subsequent surprise recall test: the participants of Experiment 5 showed better memory than participants of Experiments 1 and 2. Their ability to recall the layouts was far from perfect, however, particularly for the calculator layout. Therefore, the results suggest that paying attention to the numerical layouts does improve learning and retention much more than repeated, but inattentive use of the corresponding keypads would, but that a single trial did not suffice for very good retention.

The experiments reported in this paper reflect the advantages and problems associated with ecological studies of everyday memory. Lack of experimental control over learning and intervening activities as well as the necessity to rely on retrospective self-reports are among these problems. On the other hand, the experiments also illustrate the advantages of using everyday objects for the investigation of memory phenomena: theoretical concepts derived from more strictly controlled laboratory experiments gain ecological validity if they can be applied to everyday situations. Moreover, using two simple and similar, yet different objects such as the numerical layouts on telephones and calculators yielded comparative measures of memory performance. Thereby, theories of memory could be applied to the explanation of both poor performance in general and differences in memory performance in particular. In this respect, the experiments reported here were intended to advance the integration of applied and basic memory research. Both applied and basic memory research should benefit from an integrated approach: the validity of 'basic' theoretical concepts is increased by their successful application to everyday phenomena, and the explanation of these phenomena is improved by using methodological standards as well as theoretical concepts developed in laboratory research.

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