Influences of Context on Memory for Routes

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Abstract. Possible influences of contexts on memory for routes are investigated. Route knowledge was established by learning a route which was presented on a computer screen. Activation of knowledge of items along the route was tested. The main goal was to decide whether the surrounding context in the learning and the test phase has an effect on memory for routes. Beyond general context effects, we looked for a possible indirect or mediated context effect. Such a mediate context effect would occur, when memory improves also in cases where context and the to-be-remembered items are separated by a spatial distance. The results reported here provide evidence for immediate context effects. A mediate context effect is not very strongly supported.

1 Introduction

There is ample evidence in the literature that human memory is context dependent and there is in particular evidence for the influence of environmental context on memory. The environmental context effect refers to the phenomenon that individuals who learn and who are tested in the same environment perform more accurately than do individuals who are tested in a new, unfamiliar or interfering physical surrounding (Nixon & Kanak, 1981). The facilitative effect of same context on memory performance has been found with humans (Godden & Baddeley, 1975, 1980; for a review see Smith, 1988) as well as with animals (Dellu, Fauchey, Le Moal & Simon, 1997; Jobe, Mellgren, Feinberg, Littlejohn & Rigby, 1977; Zentall, 1970). Matching context information has been found to be an important factor in the successful retrieval of specific items and learning episodes (e. g. Gillund & Shiffrin, 1984). Mismatching context information at learning and at test on the other hand has been identified as an important cause for forgetting (Bjork & Richardson-Klavehn, 1989; Mensink & Raaijmakers, 1988).

In the present study the influences of context on memory for routes are investigated. Route knowledge refers to the remembered spatio-temporal relations

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between objects along a path connecting two places (Siegel & White, 1975; Stern & Leiser, 1988). As Allen puts it: "...simple linear-order knowledge structures involved in navigating from a starting point to an unseen destination by means of coordinating motor behavior with a sequence of perceptual events ..." (Allen, 1987, p. 274).

The motivation for our research comes from an everyday observation: Assume someone has travelled a route that connects two places. When trying to remember this route after some time and while being at a different location, he or she will perhaps not remember every detail of the route, as for example turn-offs or particular objects. But when being on the route again and having already traveled some distance, locations, houses, turning points etc. will come to mind, which could not be remembered before. And finding the correct way is – in many cases – no problem. Most of us probably have had similar experiences (e.g. Searleman & Herrmann, 1994). Such connections between landmarks and context have also been stressed by Chown, Kaplan and Kortenkamp (1995, pp.15), "...landmarks are intimately linked to context. A good landmark in one environment may be a poor one in another environment. In addition, in a familiar environment the activation of a landmark might not even require seeing it. Conversely, seeing a familiar landmark is often enough to call to mind its setting...".

In a study by Anooshian (1996) different strategies for learning large-scale environments were explored. The results also shed some light on context effects in the domain of spatial memory. The environment used in this experiment consisted of three large laboratory rooms, which were connected by corridors. Participants learned a route that connected simulated landmarks (e.g. photographs of distinctive places in an urban environment) which were placed in the laboratory rooms. The acquired spatial information was tested two days later either in the same environment (while walking along the route again) or in a separate lab room. When tested in the same environment, participants' performance was generally better. This was the case for configurational knowledge (tested by bearing estimates), procedural knowledge (the ability to turn correctly at a particular place) and sequence knowledge (being able to name the next landmark correctly while standing in front of the preceding landmark and seeing it). Only memory performance for place knowledge did not differ when tested in the same environment (participants had to name the landmark while it was still covered) or in the lab room (participants were asked to recall the landmark names verbally). Thus, the results of Anooshian (1996) provide evidence for a general facilitating effect of context on memory of spatial information. And the context effects concerning sequence knowledge provide empirical evidence in line with the everyday observation described above.

One major question pursued in the present paper concerns a possible generalization of environmental context effects. The environmental context effect as described in the literature refers to the case, when the to-be-remembered items and the environmental context are present simultaneously. We call this the *immediate context effect*. Thus an immediate context effect would be observed where the facilitating context elements and the to-be-recalled targets had been simultaneously present during the acquisition phase. However, a facilitating effect of context might in principal also occur when the to-be-remembered items and the context elements have not been observed simultaneously but have been separated by a certain distance in space and/or time. For example, when traveling along a route, details might come to mind which still lie ahead and are not yet visible. Better memory performance in this case would also be evidence for a context effect. But in this case the facilitating context elements and the recalled objects have never been observed simultaneously. We call this a *mediate* or *generalized context effect*. Similar ideas have also been described by Chown et al. (1995). But to our knowledge there is yet no experimental evidence for a mediate context effect. By manipulating the spatial distance between cue and to-be-remembered items, the influences of the different types of context effects can perhaps be separated. Previous studies on spatial context effects for route knowledge in our lab provided evidence for an immediate context effect but we did not find evidence for a generalization (Wender, 1998).

2 Experiment 1

2.1 Method

Participants. In this experiment, 40 students participated in 30-minute sessions and were paid for their services. Most of them were psychology students at the University of Trier.

Material. Participants were presented a map-like structure on a computer screen. The map showed a country road that in the drawing had a width of 1 cm and had several curves and intersections. The road was colored in gray with white lines in the middle. A black and white picture of part of the road is presented in Figure 1.

Fig. 1. A part of the road with landscape (Experiment 1)

The experiment was carried out on a Macintosh PowerPC with a 17-inch Apple color monitor. The visible part of the route was displayed in a 17.5 by 4.5 cm large window. The total route covered 29 pages of the monitor. Movement along the route was simulated by scrolling the visible part of the route continuously from top to bottom (moving background technique). Thus, the impression of riding along the road from the bottom (subjectively closer) to the top (subjectively further away) was produced. One ride along the road from start to finish lasted for approximately 2 minutes.

Twenty-nine white rectangles were posted along the street in regular distances. Each of these rectangles contained the name of an animal. These animal names had to be learned. The size of the window with respect to the spacing of the rectangles was just large enough to show one animal name at one time. The assignment of the animal names to the positions on the street was randomly determined for each participant.

To the left and to the right of the road there were additional items – the surrounding context. These additional items were colored drawings, for example of houses, trees, a play ground with a swing, a fence, a wind mill etc. These drawings constituted the possible context. They had the purpose of conveying the impression that the road was embedded in a landscape.

Two experimental conditions were introduced. In the conditions *with context*, the animal names and the landscape were visible. In the conditions *no context* only the rectangles with the animal names were shown, but neither the street nor the landscape. All other aspects of the presentation were identical.

Procedure. The experiment combined two learning phases with two subsequent test phases. The first learning phase consisted of five rides along the route. Participants initiated a ride by pressing a button on the keyboard. A ride took approximately 2 minutes of continuous movement. Thus the presentation time per stimulus was about 4 seconds. Participants were instructed to remember the route so that they would be able to describe it to a friend. They were also instructed to learn the animal names along the route.

The learning phase was followed by the test phase, a cued recall test. Each test started from a randomly determined place somewhere along the route. From there the participant had the impression of driving along the road for a short distance with two stimuli (animal names) passing through the visible window. When the third stimulus appeared on the screen the ride stopped. These three stimuli were always presented in the same order in which they had occurred in the learning phase. The task for the participant was then to recall *the following three animal names* along the road. The responses had to be typed into the computer.

By this task the distance between cue and target items was manipulated. The size of the window and the spacing of the to be learned stimuli were constructed in such a way that at one moment only one stimulus was present in the window. But as soon as one stimulus disappeared at the bottom of the window, because the map was scrolled downwards, the next stimulus entered the window from above. As a consequence, two consecutive stimuli had approximately one half of their context in common. So, if the first of these two stimuli in one particular test is the cue and if we find a context effect for the next stimulus, this would be an immediate context effect because the cue and the target share a common context. This is not true anymore for the second stimulus along the road because a cue and a second target have no context elements in common.

Four locations were predetermined from which a test ride could depart. The actual sequence of tests was randomly determined for each participant. After having finished the first test phase, a second learning phase started consisting of three further rides along the route. In the following second test phase a different set of four cues was presented.

Design. During the learning phase the surrounding context was either present or not. This constitutes the first independent variable: *learning with context vs. learning without context*. The second independent variable was whether *testing* was also conducted *with or without context*. These two factors were combined resulting in a two by two design. Independent samples of 10 participants each were assigned to each of the four conditions.

Two more factors were included. The third factor was the *time of test* (first or second test). And the last independent variable was the *position* of the remembered *item*: first or second or third item after the cue.

2.2 Results

A 2 (learning with or without context) x 2 (testing with or without context) x 2 (time of test) x 3 (item position) ANOVA with repeated measures on the last two variables and number of correctly remembered animal names as dependent measure was computed.

The ANOVA yielded two significant main effects for *item position* and *time of test*. For *item position*, we found $F(2, 72) = 18.48$, $p < .001$. The animal name, which directly followed the cue was remembered best (52 %) followed by the second animal name (39 %) and the third animal name (32 %). *Item position* did not interact with any of the other variables.

Time of test also had a significant influence on the results, $F(1, 36) = 89.42$, $p < .001$. In the second test phase participants remembered more than twice as much targets (56 %) compared to the first test phase (26 %). *Time of test* did not interact with any of the other variables.

There were no other significant effects, neither an effect of *learning condition* ($F < 1$) nor an effect of *testing condition*, $F(1, 36) = 1.21$, $p < .276$. The interaction between *learning* and *testing condition* was also not significant ($F < 1$). In Figure 2 the mean percentage of correctly remembered animal names in the four experimental conditions is shown. The results are summarized over the first and second time of test. Most surprisingly, memory performance was worst in the condition where learning and testing took place in the context of the landscape.

2.3 Discussion

Obviously, the manipulations of the surrounding context in the learning and the test phase did not lead to the expected effects. On a descriptive level, the results are even contrary to our expectations and to typical results about context effects reported in the literature (e.g. Smith, Glenberg & Bjork, 1978; Smith, 1988). Memory performance was worst in the condition, where learning and testing took place in the landscape-context, and best in the condition, where learning was with and testing without context. We interpret this result as an unfortunate consequence of the form of the stimulus presentation on the screen. Most of the objects, which constituted the surrounding landscape, had a larger size than the visible part of the road. Therefore, it was difficult to identify the objects while seeing only parts. Possibly, our participants in the context-condition paid more attention to the identification of the objects than to the animal names on the road. Therefore, in Experiment 2a the visible part of the screen was enlarged, so that two animal names were visible at the same time while riding along the road and the surrounding objects of the landscape could be identified easily. Also, in the test phase each cue was presented immediately without scrolling the window across the map as in Experiment 1.

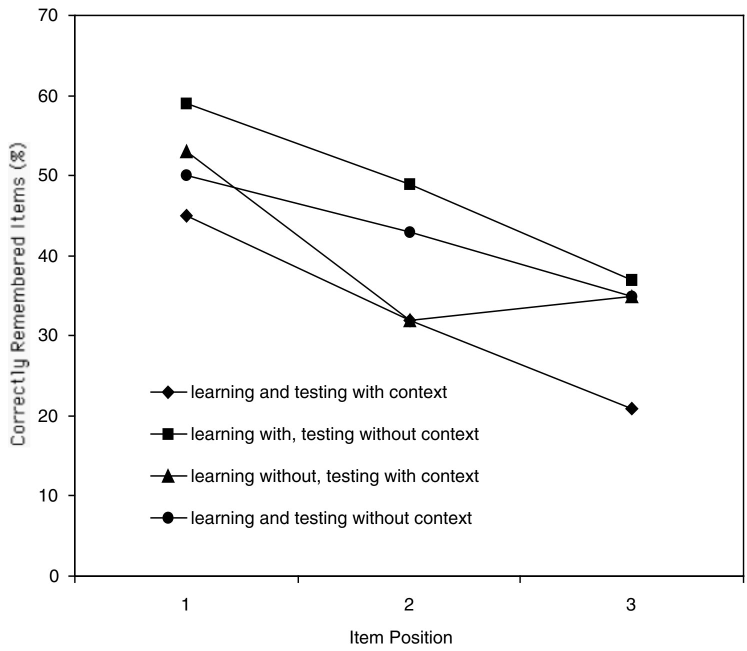

Fig. 2. Mean percentage of correctly remembered animal names as a function experimental condition and of item position in Experiment

3 Experiment 2a

The main goal of this experiment was similar to the one in Experiment 1. As a consequence of the results from Experiment 1 the procedure was changed as described below. Otherwise the experimental design remained identical.

3.1 Method

Participants. In this Experiment, 120 students participated in 40-minute sessions and were paid for their services. Most of them were psychology students at the University of Trier.

Material. The same route was used as in Experiment 1 but the visible part of the road was now made large enough to present two of the to-be-learned stimuli at the same time. By this change, the objects of the surrounding landscape could be identified more easily (see Figure 3).

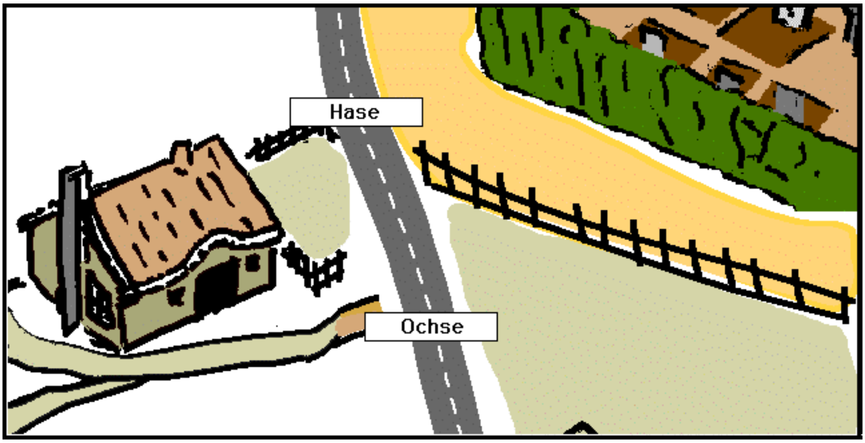

Fig. 3. A part of the road with landscape (Experiment 2a)

A second consequence of the larger window was that now the context of the cue and the context of the second stimulus overlapped to some degree. Therefore, only the responses to the third stimulus can be analyzed for a mediate (or generalized) context effect in this experiment.

In the experimental conditions without context, only the rectangles with the animal names were visible, but not the street and the landscape. All other aspects of the presentation remained the same.

Design. The dependent variable was again the number of correctly remembered targets. The independent variables were presence of the surrounding landscape in the learning condition (context or no-context) and the testing condition (context or no-context). These factors were combined in a two by two design. Four groups of 30 participants each were assigned to the four conditions. Additional independent variables were *position* of remembered *item* (first or second or third after the cue) and *time of test* (first or second test). Animal names, the to-be-remembered stimuli, were randomly assigned to the positions on the street.

Procedure. Participants were instructed to imagine that they had to leave a freeway because of a traffic jam and to continue their way on a country road. Along this road signs with animal names are posted – the remains of a paper chase. Participants were further instructed to learn these animal names in their correct order and their positions in the landscape. Those participants, who saw the animal names in the context of the landscape, were also told to pay attention to the surrounding landscape. While riding along the route in the learning phase the acquisition of the stimuli was passive, i.e. active navigation along the route was not possible.

The experiment consisted of two learning phases with two consecutive test phases. The memory test was again a cued recall test. As a cue participants saw a part of the road with two rectangles. In the rectangle at the bottom of the screen an animal name was visible, the upper rectangle contained a question mark. Participants had to recall the three animal names that had followed the cue. First, that animal name had to be reproduced, which belonged to the rectangle with the question mark. Then, the two animal names had to be recalled, which in the learning phase had followed on the road. The animal names had to be typed in using the keyboard. The cues were either presented within the surrounding landscape as context or without the landscape.

The first learning phase consisted of four rides along the route and was followed by the first test phase. In contrast to Experiment 1, nine stimuli were used as cues in order to enlarge the number of test items. As a consequence, the test procedure was changed slightly. The cues were presented in the order in which they had appeared on the route, starting with the first animal name on the road. Participants then had to recall the following three animal names. The third to-be-recalled animal name then served as the next cue and so on. After the first test phase, a second learning phase started consisting of three further rides along the route. The following second test phase was identical with the first test phase, i.e. the same cues were presented in the same order as before.

3.2 Results

A 2 (learning conditions) x 2 (testing conditions) x 2 (time of test) x 3 (item position) ANOVA with repeated measures on the last two variables and number of correctly recalled items as dependent measure was computed. The answers to the first and the last cue were not included in this ANOVA to avoid primacy or recency effects.

The ANOVA yielded a significant effect for *item position*, $F(2, 232) = 158.23$, $p < .001$. The target, which directly followed the cue was remembered best (38 %), followed by the second animal name (25 %), and the third animal name (18 %). This effect was further qualified by an interaction between *item position* and *testing condition*, $F(2, 232) = 6.03$, $p < .003$. The results are shown in Table 1.

The interaction between *item position* and *learning condition* ($F(2, 232) = 1.58$, $p < .209$) and the triple interaction ($F(2, 232) = 1.80$, $p < .168$) were not significant.

Table 1. Mean percentage of remembered animal names as a function of testing condition and item position

Context condition of test phase	position 1	position 2	position 3
With context	40%	26%	17%
Without context	35%	25%	20%

Time of test also had a significant influence on the results, $F(1, 116) = 117.20$, $p < .000$. In the second test phase participants remembered twice as many items (36 %) compared to the first test phase (18 %). This effect was further qualified by the significant interaction between *item position* and *time of test*, $F(2, 232) = 7.20$, $p < .001$. The results are shown in Table 2.

Table 2. Mean percentage of remembered animal names as a function of time of test and item position

Test phase	position 1	position 2	position 3
1st phase	27%	17%	14%
2nd phase	49%	34%	26%

There was also a significant interaction between *time of test* and *learning condition*, $F(1, 116) = 4.21$, $p < .043$. The interactions between *time of test* and *testing condition* ($F(1, 116) = 2.63$, $p < .108$) and the triple interaction ($F(1, 116) = 3.28$, $p < .073$) were not statistically significant. There were no main effects for *learning condition* ($F(1, 116) = 2.00$, $p < .160$) and *testing condition* ($F < 1$). Although the interaction between *learning condition* and *testing condition* is also not statistically significant, $F(1, 116) = 2.40$, $p < .124$, the results are given in Table 3.

Table 3. Mean percentage of remembered animal names as a function of learning condition and testing condition

	Context condition of the test phase	
Context condition of the learning phase	With context	Without context
With context	34%	26%
Without context	23%	28%

On a descriptive level they show that performance in the condition where learning and testing took place in the context of the landscape is highest, followed by the condition, where learning and testing were conducted without the surrounding landscape. Note, that this is also a same context condition. In the two experimental conditions, which involve a change of context between the learning and the test phase, memory performance is poorest. Insofar, the results are indicative for an immediate context effect as discussed in the literature.

In Figure 4 the mean percentages of correctly remembered targets are presented. The results are summarized for the first and second test phase. These results will be discussed together with the results from Experiment 2b.

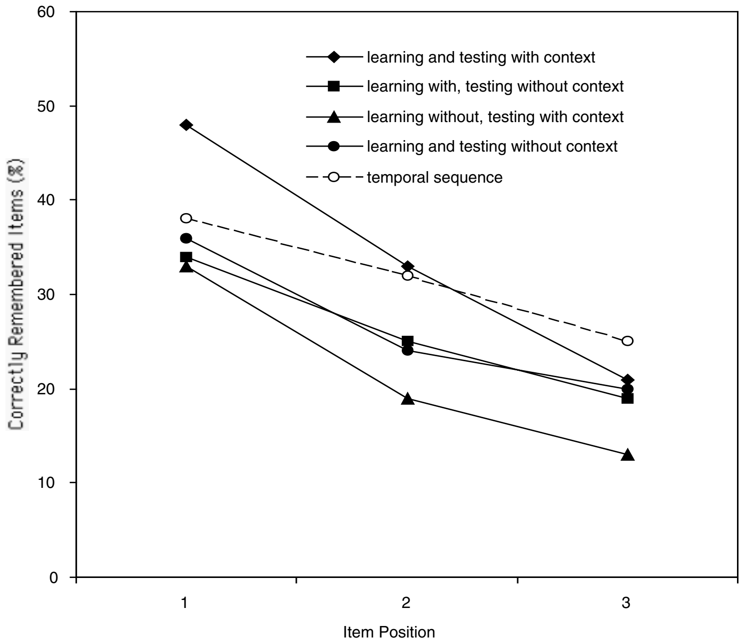

Fig. 4. Mean percentage of correctly remembered animal names as a function experimental condition and of item position in Experiment 2a and 2b

Two post-hoc analyses were performed. The first was a 2x2x3 analysis with the following factors, Factor A: *learning and testing with context* vs. *learning with context and testing without context*, Factor B: *time of test* (first or second), and Factor C *item position* (first, second, third). *Time of test* was significant ($F(1, 58) = 93.14$, $p < .001$), as was *item position* ($F(2, 116) = 85.77$, $p < .001$). More interesting, the interaction between Factor A and *item position* also reached significance: $F(2, 166) = 6.89$, $p < .001$. All other effects were not significant.

The second post-hoc analysis was also a 2x2x3 analysis with the following factors, Factor A: *learning and testing with context* vs. *learning without context and testing with context*, Factor B: *time of test* and Factor C: *item position*. Again *time of test* was significant ($F(1, 58) = 74.13$, $p < .001$) as was *item position* ($F(2, 116) = 91.94$, $p < .001$). But this time the Factor A was also significant ($F(2, 58) = 5.54$, $p < .002$. This effect was modified by a significant interaction between Factor A and *time of test* ($F(1, 58) = 7.14$, $p < .010$).

4 Experiment 2b

This experiment is an addition to the previous one. Now a pure temporal sequence of the stimuli was used. This was motivated by findings of Schweizer and Janzen (1996) who found in priming studies different results for temporal presentation of items as compared to spatial orderings like a route. Furthermore, according to the assumptions by Ebbinghaus (1885/1985) immediate associations between neighboring items in a list should be stronger than indirect associations between items that are separated by other items in between. Merely temporal sequencing of the items might lead to a comparable memory performance and thus should be compared to possible contextual influences.

4.1 Method

Participants. 30 students at the University of Trier participated and were paid for their services.

Material. The same animal names as in Experiment 2a were used. The sequence of the animal names was varied randomly for each participant.

Procedure. The animal names were presented one at a time and each at the same position on the screen. Thus, the items were only separated by time. The number of learning phases and test phases was the same as in Experiment 2a. In a test phase, participants also had to recall the three animal names following a cue.

4.2 Results

A 2 (time of test) x 3 (item position) ANOVA with repeated measures was computed. Dependent measure was the number of correctly remembered animal names. Answers to the first and the last cue were not included in this ANOVA.

This ANOVA yielded a significant effect for *time of test*, $F(1, 29) = 27.53$, $p < .000$. In the second test phase more than twice as much animal names were correctly remembered (44%) compared to the first test phase (20%). *Item position* also had a significant influence on the results, $F(2, 58) = 23.08$, $p < .000$. Animal names following directly the cue being remembered best (item position 1: 38%, item position 2: 32% and item position 3: 25%). The interaction between *time of test* and *item* *position* was not significant, $F(2, 58) = 1.90$, $p < .158$. The mean percentage of correctly remembered animal names in this condition is also included in Figure 4.

5 Discussion

Influences of spatial context on memory for routes were investigated in a laboratory set-up. We were mostly interested in mediated context effects, i.e. better recall of not yet visible parts of a route, when the context of the cue word from the learning phase was present at recall. Higher recall rates especially for the third item when learning and testing took place in the same context would have been evidence for mediated context effects. Better recall rates for the first and second item when the animal names were learned and tested in the context of the landscape, would provide evidence for an immediate context effect. In these cases the cue and the recalled items had shared the same context at least partially. The third animal name after the cue had never been seen in the same spatial context with the cue-word.

However, our results provide only mixed evidence for mediated context effects. In the first post-hoc analysis we find no main effect between the condition where learning and testing took place in the context of the landscape and the condition where learning was conducted with and testing without context. However, the interaction of this factor with item position was significant. An inspection of Figure 4 shows that this is due to item positions one and two and that there is no difference anymore in position three. This would argue that there is an immediate context effect as shown by the first two positions but that we do not find a mediated effect because there is no difference at position three.

The second post-hoc analysis, however, revealed a main effect of context conditions *learning and testing with context* versus *learning without but testing with context*. As Figure 4 shows, this difference extends also to item position three. This result then speaks for a mediated context effect in this situation. The result may remind us of failures to find the correct way after having received a route description and then trying to find our way in the context of the real world. However, the result must be viewed with caution, because it is clearly a post-hoc result and was not expected before hand.

For the immediate context effect the recall rate is highest in the condition where in the learning and test phase the landscape is present (see Table 3). Although this result is not statistically significant, it provides a hint on immediate context effects. Congruence between learning and test phase, i.e. no change in context between the learning and the test phase, leads to better recall rates (see Grant, Bredahl, Clay, Ferrie, Groves, McDorman & Dark, 1998; Wippich & Mecklenbräuker, 1988). This is especially the case, when the environmental context provides richer memory traces.

It is interesting to note that the results of Experiment 2b, where the animal names were presented as single items and only separated by time are quite comparable with the results of Experiment 2a in the experimental condition where learning and testing occurred in the same context. The memory performance in the temporal condition (Experiment 2b) can be explained by the associative strengths between the items of the list. Immediate associations, i.e. between neighboring items, are stronger than between indirect associations. Thus, the mean percentage of correctly remembered stimuli decreases from item position 1 to item position 3. One has to keep in mind that in Experiment 2b the stimuli were presented separately, whereas in Experiment 2a always two animal names were presented at the same time. Thus, it was easier in Experiment 2b to concentrate on the items. Nonetheless, the memory performance is better in the context condition in Experiment 2a for item positions 1 and 2 compared to the temporal condition in Experiment 2b. This can be explained by contextual influences.

Not surprisingly, there is evidence for effects of practice. The recall rate is much higher in the second test phase compared to the first test phase – this effect is even stronger, when the animal names are learned in the presence of the surrounding landscape. All three stimuli are better remembered in the second test phase, especially the first item after the cue.

The results do provide only post-hoc evidence for a spatial generalization of context effects. But they are providing evidence for an immediate context effect. Richer memory traces facilitate retrieval. These context effects may occur as a result of incidental associations found between the general contextual stimuli and the list items. The contextual stimuli automatically activate and elicit the list responses when the same contextual stimuli are physically present during the acquisition phase and the retention test (Nixon & Kanak, 1985).

One aspect of our study that should not be neglected was that it was conducted in the laboratory and the route was presented on a computer screen. Our participants learned a two-dimensional map of a route in a fictitious landscape with animal names being placed on the route. It is quite possible that this context was not strong enough. In fact, the more general context of the laboratory room was present under all conditions. We did not transfer our subjects to a different room for recall. It is quite possible that a mediated context effect can be found more easily in real situations.

Events we experience and decisions we make are usually perceived as being embedded within a structure of other events. And, more important for the present discussion, the events that occur within one environment usually are related to the environment itself. While riding along a road in the real world, the environment may be perceived as causing specific events or requiring particular decisions, like making a specific turn when there are alternative routes. As Fernandez and Glenberg (1985, pp. 344) argue, the relationships between environmental context and events are integral to the representation of naturally occurring events.

The animal names, which were presented in our studies, possibly were not perceived as being closely related to the environment – the drawn road – in which they occurred nor were they perceived as causing or enabling each other (see Fernandez & Glenberg, 1985). The laboratory task our participants had to fulfill most probably is not characterized by strong links like those occurring between natural events. However, such links presumably underlie the anecdotal reports about generalized context effects that were mentioned at the outset.

Other experiments (Wender & Rothkegel; in preparation) found that in real environments mediated context effects may occur. If such context effects can be convincingly demonstrated this would have consequences for assumptions about spatial memory. Models of spatial memory like mental maps e.g., would then have to represent not only landmarks and the relationships between them but the context would also have to be included. In addition, different types of relations or associations between landmarks and context elements may be necessary.

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