

The Influence of Grids on Spatial and Content Memory

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1 Problem and Motivation

In my research, I address the question how human spatial and content memory can be supported by purposeful interface design. Not only in human-computer interaction is this an important problem, but even other fields in computer science can profit by the outcome of investigations relating this research question. Findings could be used to support orientation in extensive interactive graph visualizations or ease and quicken navigation in other visual presentations of vast data spaces, for example reducing the risk of getting lost in zoomable user interfaces (see [6]).

While most usability studies conducted in computer science focus on easy-to-measure aspects like error rate and task completion time, other potentially interesting and influential factors are seldom addressed. Since human memory influences both efficiency and effectiveness, its detailed analysis opens up an interesting and relatively new research area which is well worth exploring to be able to form a deeper understanding of how human cognition is affected by user interface design. So far, very few researchers in the fields of psychology and computer science have evaluated the effects of digital design components on memory (e.g. [1], [11]) and by my approach I will contribute to the foundation of research in this topic, especially through the lens of computer science and human-computer interaction.

Therefore, I conducted an experiment letting participants test a simple static setup where the influence of different kinds of visual grid structures on both spatial and content memory was analyzed. This can serve as the basis for follow-up studies addressing other aspects of interface design, all separately or – if any interaction effects between the different factors are to be expected – jointly evaluated.

2 Background and Related Work

Many graphical user interfaces use an underlying grid structure to arrange objects on a canvas. Examples are the iPhone menus or a default Microsoft Windows desktop, both providing a grid-structured environment. In other areas, however, such as interfaces designed for larger multi-touch tables, free floating and thereby “chaotic“ arrangements are quite common (e.g. [8]) and seem to reflect the reality-based approach of these interfaces. This raises the question to what extent the alignment eases navigation and if using grid structures really helps people to remember objects and their positions better. Such a grid structure can also be represented visually through lines which divide the canvas into an array of smaller areas. Grid lines are widely seen as a help for spatial memory, thus intentionally used or left out¹ to achieve or avoid certain effects. However, actual research backing the assumption that grid lines help spatial memory is rare. Both in human-computer interaction and psychological research, grids are only used implicitly, to provide a structure during memory experiments. Only in cognitive research do grids appear as the subject of recognition studies themselves. The results, however, are quite diverse. While some studies found no difference in recognition between grid and blank backgrounds (e.g. [2]), other, more abstract experiments pointed towards a strong influence of the structured alignment as well as the presence of grid lines on spatial memory (e.g. [7]). Since these studies merely refer to recognition experiments, their findings can only offer a slight hint towards the possible outcome of a memory experiment, thereby decreasing their predictive value for human-computer interaction and the influence of grid structures in user interfaces on spatial memory.

¹For example, Puglisi et al. [10] do explicitly hide grid lines of a matrix because they “provided a structural context within which locations could be purposefully anchored“.

However, spatial information is not processed independently of other sensory perception. Visual memory does also take content information into account. According to Cestari [3], spatial and content memory develop independently from each other in childhood. In psychology, researchers thereby tend to study them separate from each other with specified tasks (e.g. [3], [9]). However, in the context of human-computer interaction, separating these two on a task level is not a sensible choice, as any real world navigation task would involve both spatial and content memory. For example, in order to find a document on the Windows desktop, the user needs to remember the position as well as the document name to validate the search. In the following paragraphs, I use the term spatial memory as the ability to remember spatial locations of objects. Content memory refers to the ability to recall an object’s content. This does not only include the mere visual information but its understanding and interpretation as well.

3 Approach and Uniqueness

In the following, I will present the experiment, which analyzes the potential effect that different variations of grids (both in terms of spatial arrangement and visual representation) might have on spatial and content memory. In light of the increasing importance of large multi-touch displays, the experiment was conducted on a Microsoft Surface. Thereby, I contribute to a stronger theory building for the interface design on such form factors and interface types. I present an experimental design which can swiftly be reproduced or adapted to related evaluations. Since the setting is not specialized on a certain software, the results can more easily be generalized and used in other contexts.

24 university and high school students (9 male, 15 female) between the age of 17 and 28, participated in the study. They all had to have German as their mother tongue to avoid systematic error caused by unforeseeably complex linguistic representations in a foreign language which they might use for describing and memorizing objects.

3.1 Experimental Design

I used a 2x2 split-plot design with grid lines (visible, hidden) being the between-subjects factor and spatial arrangement (structured, chaotic) being the within-subjects factor and randomly assigned 12 participants to each group. Based on Martin [7], I expected the structured alignment to have a positive influence on spatial but none on content memory, since the change merely affects the spatial arrangement. The display of grid lines was also expected to help spatial memory because of humans’ need of categorization and structure [4]. However, content memory should not benefit by the grid lines. The factorial design was chosen to enable me to detect possible interaction effects between the factors spatial arrangement and grid lines. The latter were studied between-subjects to avoid asymmetrical learning effects due to the use of imaginary grids. Of the alignment, no such phenomenon was to be expected, so that it could be tested within-subjects. The within-subjects factor alignment and the two item pools were counterbalanced within the groups. Repetitions were used to compensate for initial learning effects caused by differences in the effectiveness of memory strategies. The task was furthermore designed in such a way, that it was impossible to successfully reconstruct the object-screen after the first trial, regardless of experimental condition. This allowed me to compare the rate of learning between the conditions.

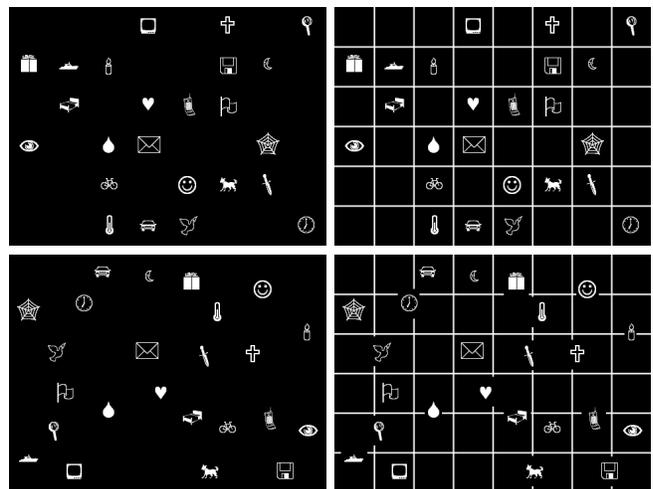


Figure 1: All experimental conditions regarding the arrangement of objects on the canvas (top: structured, bottom: chaotic) and the visibility of grid lines (left: hidden, right: visible).

3.2 Tasks and Materials

Memory was tested by showing participants an object-screen, a canvas which contained several small objects on the screen of a Microsoft Surface. Four different combinations of the grid lines and spatial arrangement factor existed and each participant was confronted with both variants of spatial arrangement (*Figure 1*, top and bottom). In addition, two different object pools were used to avoid learning effects in the within-subjects factor. Participants were first asked to memorize these object-screens and then had to reconstruct the positioning by arranging printouts of the small objects on an empty background (*Figure 2*). In-between, they had to solve arithmetical calculations for distraction. Each object-screen consisted of a black background and 24 white pictograms. In case of the factor level “visible grid lines“, white grid lines divided the canvas into a 6x8 grid (*Figure 1*, right). During the reconstruction phase, participants were handed 24 black paperboard cards showing the pictograms in their original size, together with 12 distractor objects not included in any of the object pools, as a means of testing content memory. Additionally, 6 blank cards were offered as “jokers“ to mark positions without having to specify an object. If, on the other hand, only the object was remembered, not its position, subjects were asked to place the corresponding card at the border of the screen.



Figure 2:
During the reconstruction phase, object cards were laid out to be rearranged to the memorized picture. The arithmetical problems were placed next to the Surface.

A lot of time and effort was invested in choosing the 72 objects in total and dividing them into two object pools carefully (48 objects and 24 distractors). Pictograms were chosen as object representations since pictures are easier to remember than written words [12]. Besides, chosen items had to fulfill certain conditions to prevent as much systematic error as possible. Because people would probably assign names to remember objects, only simple items with short and unique names were used to avoid confusion. The objects were divided equally between the two item pools with respect to their length, complexity, and thematic groups (e.g. animals, vehicles). Even the phonetic similarity of words was taken into account. For example, the German words “Hund“ (dog) and “Handy“ (cell phone) only differ from “Hand“ (hand) in one letter. Thus, the item for “Hand“ was put in a different object pool to lessen the risk of mix-ups. Multiple Pretests were done to optimize the division into item pools.

3.3 Procedure

Each session consisted of a short introduction and five repetitions of the same memory task. First, the subject was given 30 seconds to memorize the canvas with the objects (either structured or chaotic). He or she then had to solve some simple arithmetic calculations for 60 seconds. Afterwards he or she was asked to arrange the objects, now printed on small cards, to reconstruct the canvas within 150 seconds. Before the start of the next repetitions, the subject had to solve arithmetic calculations for 60 seconds. During each repetition, the same objects were visible on the canvas at exactly the same position. After completing this first experimental condition, e.g. the structured alignment, participants continued with the chaotic alignment or vice versa. The order of the spatial arrangement factor was counterbalanced to avoid carry-over effects. Each session lasted for about 1 hour and was recorded on video tape and stills.

Spatial memory was measured by counting the number of objects or blank cards laid out at a position which matched an occupied position in the original object-screen. In this case, the content of the item did not play a role. The values for evaluating content memory were collected independently by counting the number of correctly selected objects independent of position. These also included items placed at the border of the screen.

All data collected during the experiment was analyzed with repeated-measures analysis of variance.

4 Results and Contributions

The results showed that both the spatial arrangement of the objects (structured: 11.783 with std. error .664, chaotic: 5.9 with std. error .382) and the display of grid lines (lines: 10.858, no lines: 6.825, both with std. error .592) led to better spatial memory performance with a strongly significant difference ($F(1,22) = 73.129$ and $F(1,22) = 23.232$, both $p < .001$; *Figure 3*, top left and middle). This is fairly consistent with my hypotheses, which expected a positive effect of both kinds of structure on spatial memory performance. Further analysis reveals that even the interaction effect is significant with $F(1,22) = 14.282$ and $p = .001$. The spatial arrangement is more important for spatial memory than the grid lines, since, no matter if lines are visible or not, the values of the structured alignment are always bigger than those of the chaotic arrangement (*Figure 3*, top right). Nevertheless, the best results were attained in the most structured context where objects were laid out systematically and grid lines were visible.

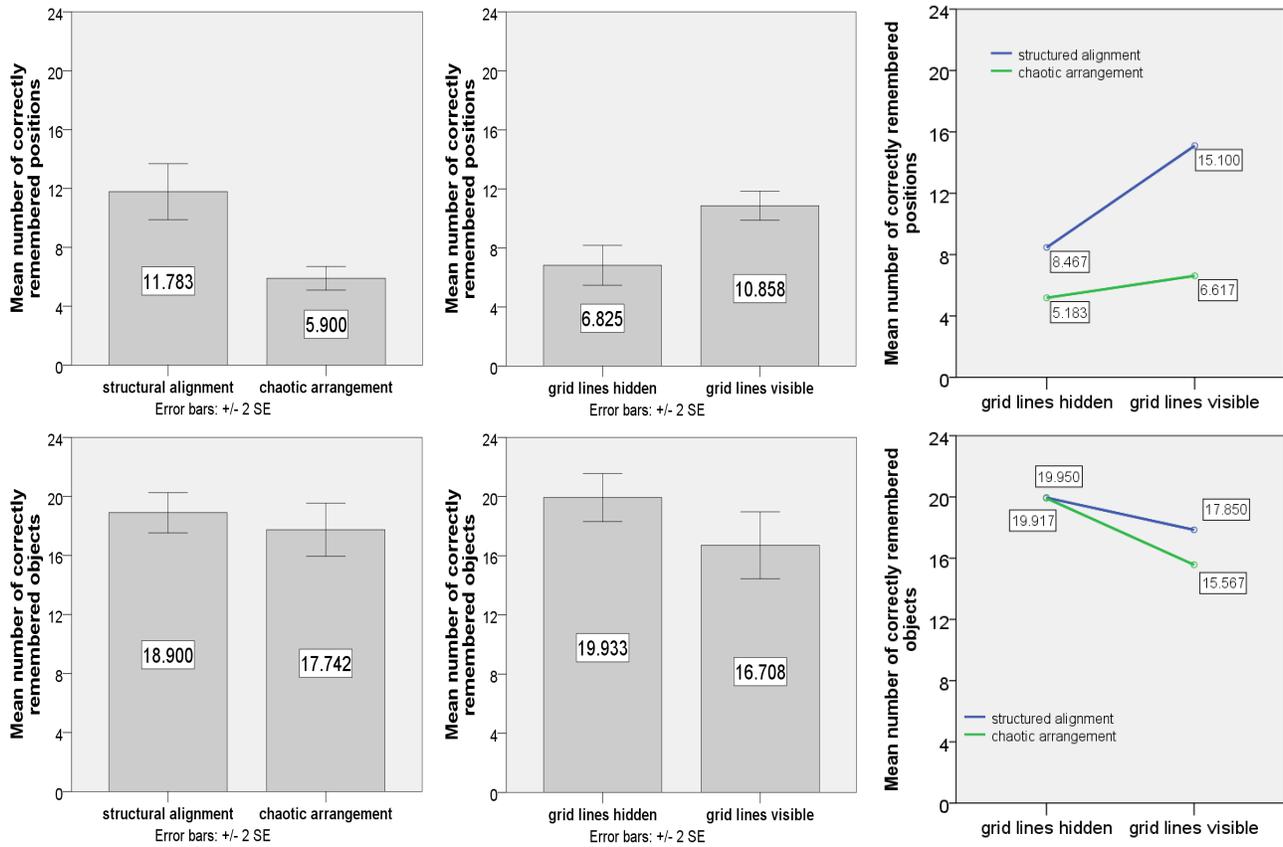


Figure 3:
Influence of both factors (left: spatial arrangement, middle: visibility of grid lines) and interaction effects (right) on memory (top: spatial, bottom: content).

For content memory, a significant difference could be found in both factors as well. The display of grid lines had a negative influence on remembrance (lines: 16.708, no lines: 19.933, both with std. error .984; $F(1,22) = 5.369$, $p < .05$), while a spatial arrangement had a positive effect on content memory (structured: 18.9 with std. error .66, chaotic: 17.742 with std. error .799; $F(1,22) = 6.374$, $p < .05$; *Figure 3*, bottom left and middle). In the latter case, a further analysis revealed that the difference is only significant if grid lines are visible (structured: 17.85 with std. error .983, chaotic: 15.567 with std. error 1.384; $F(1,11) = 8.059$, $p < .05$), while the subjects performed equally well without grid lines (structured: 19.95 with std. error .881, chaotic: 19.917 with std. error .799; $F(1,11) = .006$, $p = .941$). In this case, apparently, the results have to be reviewed more carefully. *Figure 3* (bottom right) shows that, if no grid lines are displayed, the spatial arrangement does not have an effect on content memory. This does not hold for the case that grid lines are visible. On the one hand, the alignment

consistent with the array proposed by the grid lines leads to a better memory performance. On the other hand, the inconsistency in combining visible grid lines without using them for spatial arrangement, has a negative influence on content memory.

For each factor, even the learning curves depicting the development of performance for each of the five trials were calculated. However, they did not provide any interesting information which was not already found in the analysis of spatial arrangement and grid lines. Tests showed that gender, the item pools, and the order of the alignments had no statistically significant effect either.

Interestingly, most subjects in the no-grid group didn't even notice a difference between the alignments, which would explain the similar performances in content but not the differences in spatial memory. The results for the latter could be due to the simpler spatial relations between the objects, since they could, for example, be remembered as „above“ rather than „above but a little to the right“ in the structured alignment, making it easier to code the spatial arrangement of the whole picture.

Another interesting result is the very different effects that grid lines have on spatial and content memory. While they do apparently help the subjects to remember spatial locations, no matter how objects are aligned on the surface, they have a contrary effect on content memory. This could either be caused by the distraction which the grid lines inflict on content memory by adding supplemental visual information or by a shift in the subjects' attentiveness from content to spatial memory. While they concentrated more on remembering the locations of objects with the help offered by the grid lines, they neglected the contents, which lead to different results from those obtained from spatial memory analysis.

4.1 Conclusion

In my experiment, I showed that grids are clearly useful for supporting spatial memory, but need to be carefully handled if content memory plays a role as well. While both the spatial arrangement and a visually perceptible grid have a positive influence on recalling locations, the ability to remember contents does not rely on a structured surrounding. On the contrary, if grid lines are visible, the results are generally worse. Even if the structured alignment leads to better results than a chaotic arrangement, no differences in performance of content memory can be detected in the absence of grid lines. Therefore, grid lines should be used with great care, not to undo the beneficial effects the structured environment has on spatial memory by impairing content memory at the same time and by the same means.

Thus, research on spatial memory should not be conducted independently of content memory. Especially in human-computer interaction, these two aspects seldom appear apart from each other and can therefore not be easily divided when attempting to evaluate the influence of a certain factor on memory. This knowledge could serve as the basis for further research aimed at a better understanding of how spatial and content memory could be supported by prudent software design. There is a huge need to form a solid foundation for further research in this area. Additional studies in the context of multi-touch tables could focus on the effect different input modalities, such as touch vs. mouse input can have on spatial and content memory.

In a follow-up study conducted at our research group, the influence of both input device and the ability to pan or zoom and pan on spatial memory have already been analyzed [5], using an adaption of the above-mentioned experimental setting and procedure. Another interesting angle could be to explicitly study the desert fog problem in zoomable user interfaces (e.g. Jul [6]) with respect to memory performance. Together with the results of my experiment and further research this could lead to user interfaces that optimize the support of spatial and content memory to ease orientation and navigation according to the setting's individual context.

References

- [1] Beck, M. R., Peterson, M. S. and Vomela, M. Memory for Where, but Not What, Is Used During Visual Search. *Journal of Experimental Psychology: Human Perception and Performance*, Vol. 32, No. 2 (2006), 235-250.
- [2] Biederman, I. Do background depth gradients facilitate object identification? *Perception*, Vol. 10 (1981), 573-578.

- [3] Cestari, V., Lucidi, A., Pieroni, L. and Rossi-Arnaud, C. Memory for Object Location: A Span Study in Children. *Canadian Journal of Experimental Psychology*, Vol. 61, No. 1 (2007), 13-20.
- [4] Flaphler, S. Warum sind wir so ordentlich? *Psychologie heute*, Vol. 1 (2010), 70-73.
- [5] Jetter, H.-C., Leifert, S., Gerken, J., Schubert, S. and Reiterer, H. Does (Multi-)Touch Aid Users' Spatial Memory and Navigation in 'Panning' and in 'Zooming & Panning' UIs? To appear in: *Proceedings of Advanced Visual Interfaces International Working Conference*, ACM Press (2012).
- [6] Jul, S., & Furnas, G. W. Critical Zones in Desert Fog: Aids to Multiscale Navigation. *Proceedings of User Interface and Software Technology*, ACM Press (1998), pp. 97-106.
- [7] Martin, R., Houssemand, C., Schiltz, C., Burnod, Y. and Alexandre, F. Is there continuity between categorical and coordinate spatial relations coding? Evidence from a grid/no-grid working memory paradigm. *Neuropsychologia*, Vol. 46 (2008), 576-594.
- [8] Morris, M. R., Lombardo, J., and Wigdor, D. WeSearch: Supporting collaborative search and sensemaking on a tabletop display. *Proceedings of Computer Supported Cooperative Work*, ACM (2010), 401-410.
- [9] Petrini, L., Hennings, K. and Arendt-Nielsen, L. The effect of visuo-spatial organisation in recognition-memory tasks. *Perception*, Vol. 5 (2009), 763-774.
- [10] Puglisi, J. T., Park, D. C., Smith, A. D. and Hill, G. W. Memory for two types of spatial location: Effects of instructions, age, and format. *The American Journal of Psychology*, 98, 1 (1985), University of Illinois Press.
- [11] Tan, D. S., Stefanucci, J. K., Proffitt, D. R. and Pausch, R. Kinesthetic Cues Aid Spatial Memory. *Proceedings of Conference on Human Factors in Computing Systems Extended Abstracts*, ACM Press (2002), 806-807.
- [12] Zechmeister, E. B. and Nyberg, S. E. Human memory, an introduction to research and theory. Brooks/Cole Publishing Company, USA, 1982.