The Influence of Grids on Spatial and Content Memory

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Abstract
In this paper we present an experiment that aims at understanding the influence that (visual) grid-based structuring of user interfaces can have on spatial and content memory. By the term grid we refer to two different aspects. On the one hand, this relates to the structured alignment, the layout of objects on a canvas. On the other hand, a grid can also be indicated visually by inserting lines that form an array which divides a canvas into smaller fields. In both cases we detected a strong positive influence on spatial memory. On content memory, however, grids have a less beneficial influence. Only if grid lines are visible, the structured alignment has a positive effect. On the other hand, the visibility of grid lines always leads to worse results in content memory performance, independent of the spatial arrangement.

Keywords
Spatial memory, content memory, grid lines, alignment

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User interfaces.

General Terms
Experimentation.

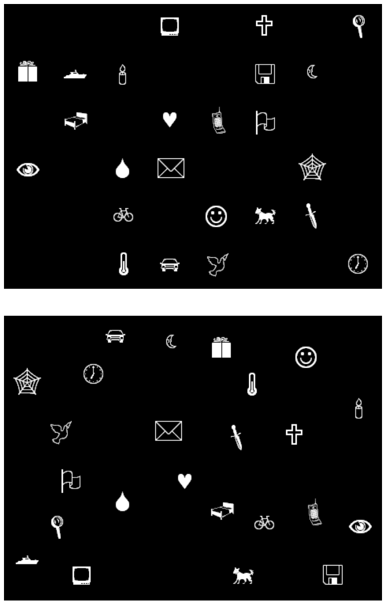

Figure 1. Two of the experimental conditions regarding the structures of object arrangement on a canvas: structured alignment (top) and chaotic arrangement (bottom).

Introduction & 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. [6]) 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 out[1] 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. [1]), 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. [5]). 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 HCI and the influence of grid structures in user interfaces on spatial memory.

However, spatial information is not processed independently of other sensory perception. Visual memory does also take content information into account. According to Cestari [2], 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. [2], [7]). However, in the context of HCI, 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 chapters, we 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.

In this paper, we present an experiment that 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, we conducted the experiment on a Microsoft Surface. Thereby, we contribute to a stronger theory building for the interface design on such form factors and interface types.

[1] Puglisi et al. [8] do explicitly hide grid lines of a matrix, ”because it provided a structural context within which locations could be purposefully anchored”.

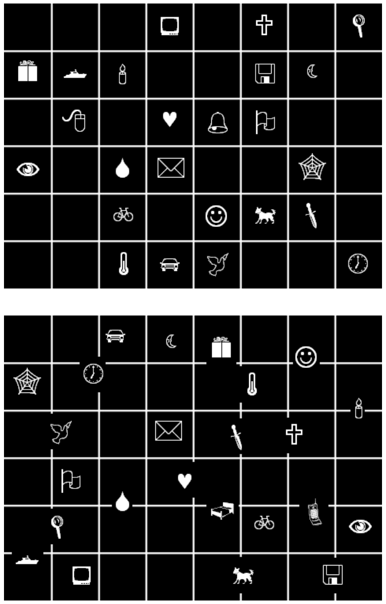

Figure 2. The two further experimental conditions showing the visible grid lines: structured alignment (top) and chaotic arrangement (bottom.

The Memory Experiment

In our experiment, we analyzed the influence of the two independent variables spatial arrangement and grid lines on the two dependent variables spatial and content memory. 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.

Experimental Design

We 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 [2], we 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 [3]. However, content memory should not benefit by the grid lines. The factorial design was chosen to enable us 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, as we wanted 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 us to compare the rate of learning between the conditions.

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 (see Figure 1 and Figure 2). In addition, we used two different object pools 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 (see Figure 3).

Figure 3. 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.

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

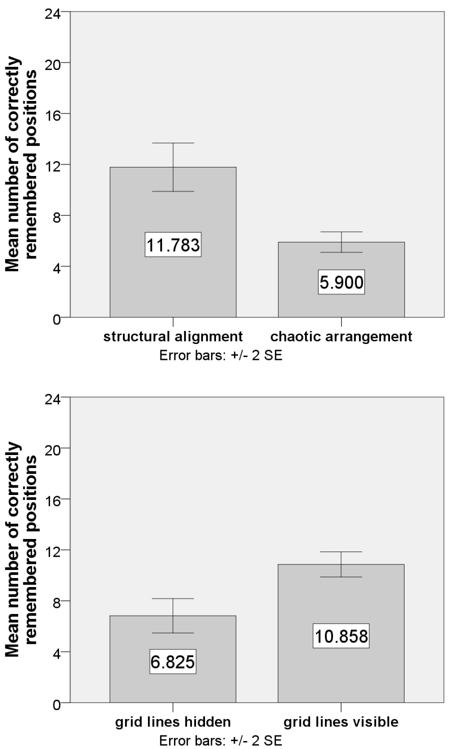

Figure 4. Influence of both factors (top: spatial arrangement, bottom: grid lines) on spatial memory.

the canvas into a 6x8 grid (Fig. 2). 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.

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). We chose pictograms as object representations since pictures are easier to remember than written words [9]. 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 the 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" and "Handy" only differ from "Hand" (dog, cell phone and 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.

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 counter-balanced to avoid carry-over effects. Each session lasted for about 1 hour and was recorded on video tape and stills. Participants were compensated with 8 EUR.

Results & Discussion

All data collected during the experiment was analyzed with repeated-measures ANOVA. Tests showed that gender, the item pools, and the order of the alignments had no statistically significant effect.

We measured spatial memory 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. 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 memory performance with a strongly significant difference

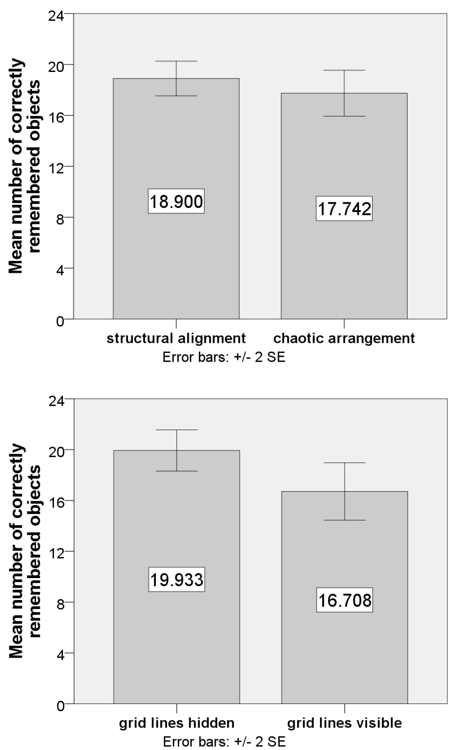

Figure 5. Influence of both factors (top: spatial arrangement, bottom: grid lines) on content memory.

($F(1,22) = 73.129$ and $F(1,22) = 23.232$, both $p < .001$, fig. 4). This is fairly consistent with our 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 $p= 0.001$.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 (see Figure 6). Nevertheless, the best results were attained in the most structured context where objects were laid out systematically and grid lines were visible.

Content memory was measured by counting the correctly remembered objects. In both factors, a significant difference could be found. 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; $F(1,22) = 3.674$, $p < .05$; fig. 5). 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 7 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.

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 latter results could be due to the simpler spatial relations between the objects, since they could, for example, be re-membered 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.

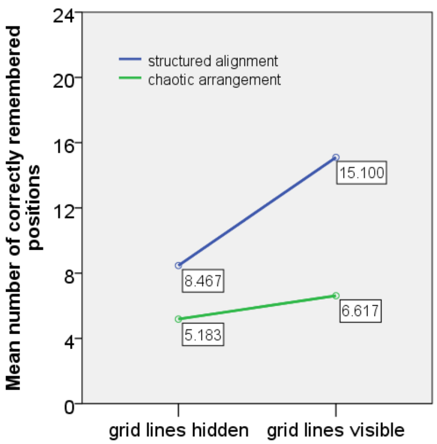

Figure 6. Interaction effects on spatial memory.

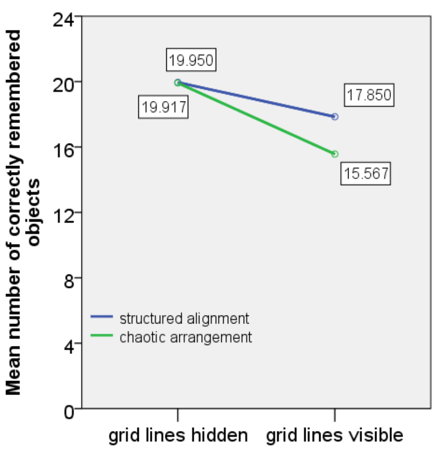

Figure 7. Interaction effects on content memory.

Conclusion & Outlook

In our experiment, we 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. Another interesting angle could be to study the desert fog problem known from ZUIs (e.g. Jul [4]) with respect to memory performance. Together with the results of our 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.

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