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Layout Structures of Network Diagrams in Project Management Software: An Age-Differentiated Empirical Investigation Concerning Symmetry and Space

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ABSTRACT

The use of network diagrams in project management software is a useful tool when planning projects. However, working with these diagrams can quickly become confusing when dealing with complex project plans. This effect is even more pronounced for older persons as they have to deal with age-related changes in perception, cognition and motor control. Nevertheless, project planning is often accomplished by older employees due to their knowledge and experience. There are certain aspects of layout structures that can support perception and decision making when working with complex diagrams. This paper describes an age-differentiated study in which the factors symmetry and spatial distance between activities were investigated. In order to gain practical relevance, the study combined different tasks and different complexities of visualization. In addition to reaction times and errors, eye tracking data was analyzed to acquire additional information. The results of this study reveal that the work with network diagrams can benefit from a proper designed layout structure regarding symmetry and distance. A symmetrical structure and narrow distances led to improvements in performance for all age groups.

Keywords: project management software, layout structures, network diagrams, space, symmetry, visual search

INTRODUCTION

Not only the working environment in general, but in particular the field of project management, is currently dominated in Europe by two trends - the increasing use of software support and the demographical change. Due to their knowledge and experience project planning and controlling is often accomplished by older project managers. Because of the high complexity of the planning tasks and the connection to risks, the use of project management software (PMS) can provide an essential support of the planning process. Attributable to age-related changes of the perceptual (Schaie and Willis, 2011), cognitive (Anstey and Low 2004), and motor (Carter et al. 2001) system, however, working with complex software tools can become particularly difficult for older persons.

One frequently used planning technique is the network diagram method, which is able to show relationships between activities more clearly on the basis of graph theory on the one hand, but on the other hand can quickly become confusing especially for complex project plans. This is supported by the results of an age-differentiated usability study of the PMS de facto standard that was realized to investigate project planning when typical project planning tasks were solved with three off-the shelf software solutions (Bützler et al., 2013). The study revealed significant ergonomic deficits regarding the design of network diagrams. Accordingly, the design of network diagrams in PMS for older users should be subject of detailed research. Furthermore, a review of commercial project management software solutions shows that layout design of network diagrams ranges widely between the different products and there exists no standard design. Some software solutions arrange network diagrams on the top of the screen resulting in asymmetrical layouts whereas others use a symmetrical arrangement. Regarding spatial arrangement between activity size and in between activity distance, the variations are even higher ranging from ratios 10:1 to 1:1.

Therefore, we investigated the factors symmetry and spatial distance in layout structures of network diagrams in an age-differentiated study. By using different tasks and complexities in visualization we aim at generalizable results. In addition to the performance measures execution time and errors, we also analyzed the visual scan path to gain further information about visual perception.

Space and symmetry in graphical layout structures

One frequently used visualization technique to support project planning is the network diagram method. Based on graph theory, a network diagram is a structure that consists of nodes and edges. From the discipline of graph drawing it is known that there are certain aesthetic aspects that facilitate graph reading such as symmetry, minimization of link crossings, area and bends in links (Battista, 1999). Purchase (1997) proved some of these aspects in empirical studies where the participants for example had to detect the shortest path in the graph. One result was that symmetry leads to shorter reaction times.

More than half a century earlier, the Gestalt psychologists already postulated that symmetry belongs to the structuring factors which can be perceived pre-attentive as a whole (Koffka, 1935). Accordingly, symmetry in graphical structures has a positive effect on working memory. This proposition is underlined by the information theory whereupon mirrored structures do possess less information content according to redundancy (Attneave, 1954). Hence, when memorizing a symmetrical structure, less information needs to be hold in working memory. This results in better memory performance for symmetrical than for asymmetrical structures (Attneave, 1955; Howe and Jung, 1986; Schnore and Partington, 1967). In visual search symmetry plays also an important role. Wolfe (1992) showed that for distractors that form a symmetrical background texture, search is easier. This is in accordance to the assumption that spatial working memory is involved in visual search (Woodman and Chun, 2006). Visual working memory, however, is not part of visual search tasks.

Moreover, in visual search the eccentricity of a target object has an effect. Targets that are closer to the fixation are detected faster and with fewer errors than targets in peripheral regions (Carrasco 1995, Wolfe 1998a). Rayner and Fisher (1987) assume that while searching for letters, there is a central area in which all information about the target object is available and a preview area in that some information can be discovered but does not suffice to identify the target. The studies of Wolfe et al. (1998b) revealed that the eccentricity effect cannot be ascribed to a pure visual process but also includes attentional control processes. Attention is allocated to central items before peripheral items. The proximity compatibility principle (Wickens and Carswell, 1995) suggests that objects should have close spatial display proximity for effective mental processing. Jochems (2010) showed that the proximity compatibility principle can be hold for interpretation tasks in network diagrams. However, for pure memorizing tasks Jochems found the inverse effect. In this case larger distances between the activities could be proven as beneficial. Closer proximity can have a negative effect on memorizing performance due to the model of Winkelholz and Schlick (2007) which proposes that the closer two objects are in space, the higher the risk of mistaken them.

Age-related changes and robust software design

Regarding age-robust software design it has to be taken into account that the aging process goes along with changes in the perceptual, cognitive, and motor system. The process of aging is often accompanied by a reduction of the visual field (Werner et al., 2010) and a loss of visual acuity (Schieber, 2006) whereas the dynamics of the eye-movements does not change with age (Abrams, 1998). The changes in the cognitive system concern e.g. the decline in capacity of the visual-spatial and verbal working memory (Park, 2002) as well as a decline in selective attention (Kramer and Madden, 2008). For visual search a shift in the speed accuracy tradeoff can be observed: older people typically need longer but also make fewer mistakes (Rogers and Gilbert, 1997; Strayer and Kramer, 1994). Regarding the motor system an increase in movement time for pointing movements can be observed with increasing age (Vercruyssen, 1997).

In order to adapt software and web pages to these age-related changes, a number of authors proposed guidelines of how to design web pages for older users (e.g. Chadwick-Dias et al., 2007; Czaja and Lee, 2007; National Institute on Aging, 2009). Empirical studies for example focus on the development of age-robust prototypical email client applications (Arnott et al., 2004; Hawthorn, 2003) and web-pages (Chadwick-Dias et al., 2003; Chevalier et al. 2007). Hart et al. (2008) evaluated websites designed for older adults regarding the fulfillment of senior friendly guidelines and conducted an empirical study to investigate efficiency, ease of use and satisfaction. They found that websites which fulfill most of the guidelines result in higher task success but not in significantly better efficiency and satisfaction. The findings underline how important it is to use both guidelines as well as empirical studies while designing software for the elderly.

Based on the described literature we expect that a symmetrical layout of a network diagram leads to shorter execution times and lower error rates than an asymmetrical layout in visual search and related tasks. Furthermore, due to the eccentricity effect, we expect narrow distances between activities to have a positive effect on execution times and error rates. We expect this effect also to show for the length of the scan path. Regarding the age group we expect an increase of execution time with age but at the same time we assume error rates to decrease with age.

METHOD

An age differentiated empirical study was conducted to investigate layout structures in network diagrams concerning spatial distance and symmetry. The investigation was carried out in four parts as the aim was to combine basic analysis with practical relevance covering three different types of tasks (Figure 1). In the first part a highly abstract and aggregated plan was presented to investigate the effects of structure within a setting where the diagram was shown on only one screen area and no information was distracting. In the second part aggregation was decreased by displaying the diagram on three screen areas due to a more realistic size of the activities so that a change between these different screen areas was necessary to solve the task. By using an application-oriented presentation based on the popular Metra Potential Method (MPM) notation (Kerbosh and Schell 1975) in the third part, the information density was enlarged resulting in a lower abstraction. In part one, two and three the activities were labeled by numbers, whereas in part four realistic the activities were labeled following the work breakdown structure of a realistic project plan. The search and the predecessor task had to be solved in part one, two and three whereas in part four, the interpretation task was conducted.

Design

Performance in terms of execution time and error rate as well as eye tracking measures were investigated while accomplishing visual search, predecessor and interpretation tasks with different layout structures of a network diagram. Within the visual search task subjects were instructed to search one prior specified activity within the network diagram and select this with a mouse click. After that they had to confirm their answer with a “finish”-button. For the predecessor task, the assignment was to search the predecessor(s) of the prior defined activity, select this/these with a mouse click and confirm the selection with the “finish”-button. Within the fourth part a more practical task was chosen. In this interpretation task the subjects had to compare the duration of two activities and select the activity with the longer duration. Like in the prior tasks, confirmation of the selection was done by pressing the “finish”-button.

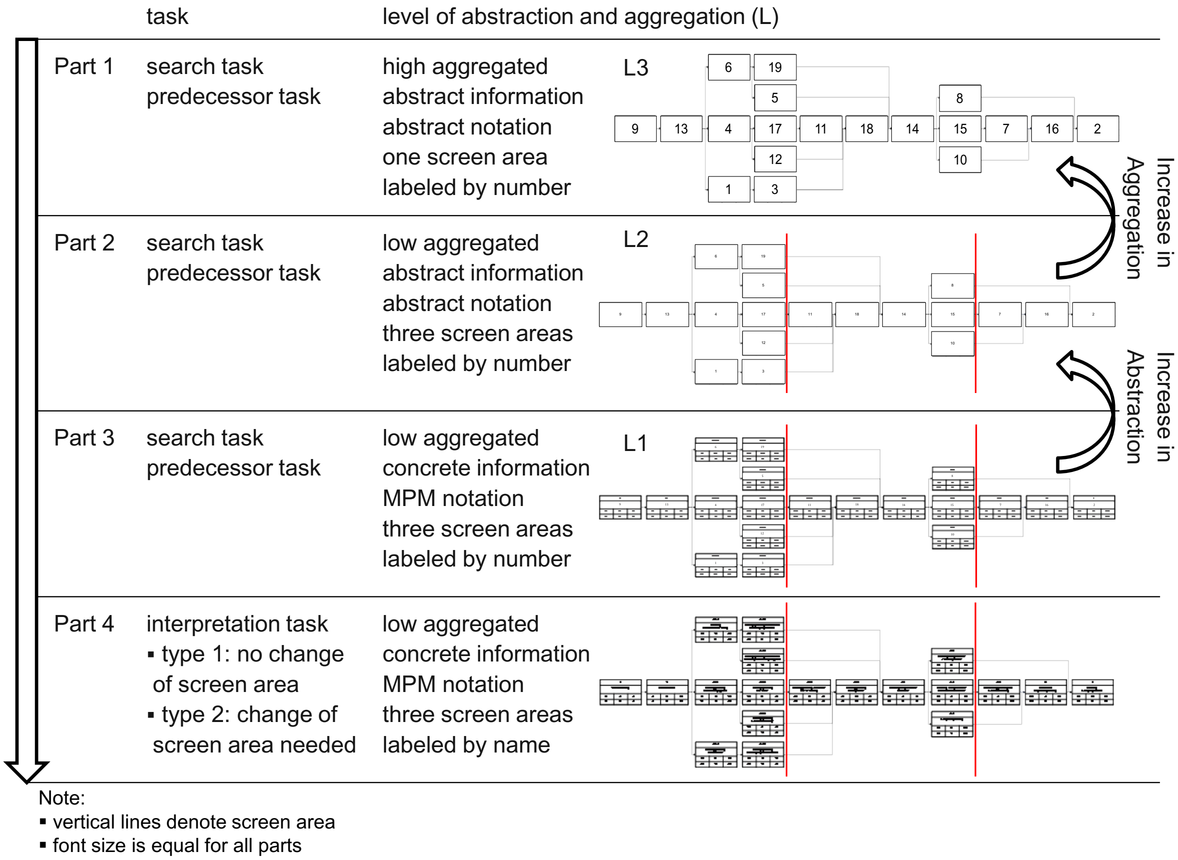

Figure 1. Depiction of the different parts and task types

A network diagram with 19 activities was chosen. With respect to the loss in visual acuity with increasing age, the font size was set for all parts to 22' (Vetter et al., 2010). The ratio between activity height to width was 1:2 for all parts of the experiment (part 1: h=1cm, w=2cm; part 2/3/4: h=2,25cm, w=4,5cm). The horizontal distance was set to 0,5* activity width. For each search and predecessor task the prior defined activity was generated randomly to prevent learning effects. Each position was presented six times within one age group and for each condition. The first position was excluded due to the primary effect.

The experimental design was a combination of 4 independent variables, whereas three of these served as within-subject factors and one as between-subject factor. Within subject factors were the vertical distance between the activities depending on the activity height (3 levels: 0.1*object height, 0.5*object height, 1.0*object height) and the symmetry of the layout (2 levels: symmetrical, asymmetrical). For the search and predecessor task, the level of abstraction and aggregation (3 levels as described above) was also investigated as a within subject factor. For the interpretation task only the fourth part of the task was used but in this case, it was additionally differentiated between the task types (2 levels: No change if screen area needed for solution, change of screen area needed for solution). Furthermore, the sample was divided into three age groups (Group I: 25-39 years, Group II: 40-54 years, Group III: 55-68 years) which served as in-between subject factor for all tasks. This resulted in a 3x2x3x3 design for the search and predecessor task and a 3x2x2x3 design for the interpretation task with repeated measures on the within-subject factors. Dependent variables were the execution time, error rate, as well as the length of the visual scan path.

Participants

Altogether, a 108 subjects participated in the experiment. They were paid volunteers aged from 25 to 68 years. 36

younger subjects aged between 25 and 39 years (mean=28.97, SD=3.056), 36 subjects between 40 and 54 years that build the medium age group (mean=46.81, SD=4.070) and 36 persons between 55 and 68 years (mean=61.81, SD=3.838) were investigated. We did not investigate subjects older than 68 or younger than 25 in order to get a representative age range for persons working with project management software.

Regarding experience with projects and project management, 80.6% of the younger age group, 50% of the medium age group and 63.9% of the older age group have ever been involved in project management in their job but only 8.3% of the younger, 8.3% of the medium and 13.9% of the older age group rated their experience with project management as high. Within the younger age group, 38.9% of the subjects have ever used project management software and within the medium and older age group 13.9%. Regarding the experience with project management software, participants of all age groups had low or little experience with PMS.

Apparatus

The experiment was conducted using a 17" TFT-monitor. Eye movements were measured during the task using a Tobii T120 Eye Tracking system. A chinrest was used that allowed a central eye position to the monitor and reduced head movement of the participant while solving the task. The viewing distance was set to 50cm and the illumination was kept constant at 300lx.

Regarding the software, in addition to the network diagram (main part of the screen) the instruction was displayed permanently in the lower screen area so that no head movement took place during the task. Changing between different screen areas was realized via a mouse click on the arrow on the left respectively right screen area. Pressing this arrow activates a slide to the next screen area similar to the gestural sliding navigation on touch screens.

Procedure

In the beginning subjects had to fill in a questionnaire regarding their age and experience in project management. Then subjects were seated in front of the monitor and were asked to position their head on the chin rest. Before each part of the experiment, subjects watched a short video sequence in that the task and the visualization of the corresponding part were introduced. After that the participants were given a short training during which they could ask questions and were corrected by the instructor in case of occurring errors. After the training the eye tracking system was calibrated and subjects were instructed to fulfill the task as fast and as correctly as possible. All participants solved the different parts and tasks in the same sequence as depicted in Figure 1 starting with part one and the search task. For part one, two and three, subjects had to fulfill three search tasks and three predecessor tasks with the first layout (combination of distance and symmetry), then for the second and so on. In order to reduce switching costs the tasks were presented block wise and subjects were additionally informed about the change of task in between the two tasks. The sequence of the layout presentation was randomized between subjects. In part four subjects initially had to solve one interpretation task in that no change of screen area was needed for the solution followed by one interpretation task that required a change of screen area.

The data was analyzed by factorial analyses of variance with repeated measures (ANOVA). The age group of the participants served as a between-group factor and the level of significance was set to $\alpha = 0.05$. Post-hoc tests were performed using Bonferroni correction.

RESULTS

Search task

Regarding the execution time we found a significant age effect ($F_{(2;105)}=36.898$; $p<0.001$) with a strong effect size of $\omega^2=0.5$. Subjects of the medium ($p<0.001$) and the older ($p<0.001$) age group needed longer to execute the task than subjects of the young age group (Figure 2, left). Furthermore the medium-aged participants were faster than the older participants ($p<0.001$). For the level of abstraction and aggregation we also found a significant effect ($F_{(2;210)}=134.218$; $p<0.001$; $\omega^2=0.34$). As expected the execution time decreases with the level of abstraction and aggregation (p<0.001 for all pairwise comparisons, Figure 2, right).

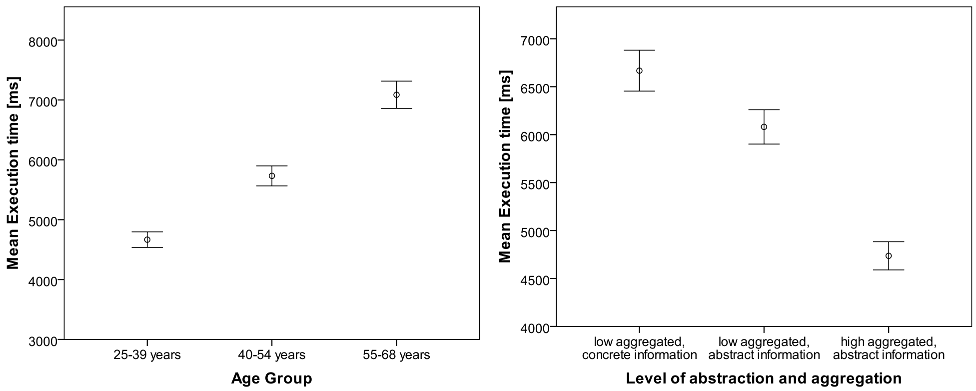

Figure 2. Execution time for the visual search task as a function of age (left) and level of abstraction and aggregation (right)

Furthermore, the distance had a significant effect on the execution time ($F_{(2;210)}$=5.387; p=0.005; ω^2=0.01). The large distance leads to significantly higher execution times than the small (p=0.014) and the medium (p=0.042) distance (Figure 3, left). In addition to these main effects, a significant hybrid interaction effect between symmetry and level of abstraction and aggregation was found ($F_{(1.743;183.012)}$=3.220; p=0.049), but the symmetry does not interfere the interpretation of the main effect of the level of abstraction and aggregation. A second interaction effect was found between symmetry, level of abstraction and aggregation and distance ($F_{(3.353;352.091)}$=2.700; p=0.040). More detailed analysis showed that the effect of the level of abstraction and aggregation can be interpreted for the difference between the third and the second as well as the third and the first level of abstraction and aggregation, whereas for the comparison between the second and the first level of abstraction and aggregation for one condition (symmetrical layout, large distance) no differences occur. Regarding the effect between the small and the medium distance, there is also one condition (L2, asymmetrical) for that no differences occur. But this effect does not show an opposite trend and the execution time is in all conditions higher or equal for the large distance than for the small distance. The medium distance and the large distance interfere stronger, so that the main effect cannot be interpreted. For the factor symmetry no significant effect was found, but a descriptive analysis showed that especially for the older age group the search task tends be solved faster with the symmetrical layout (Figure 3, right).

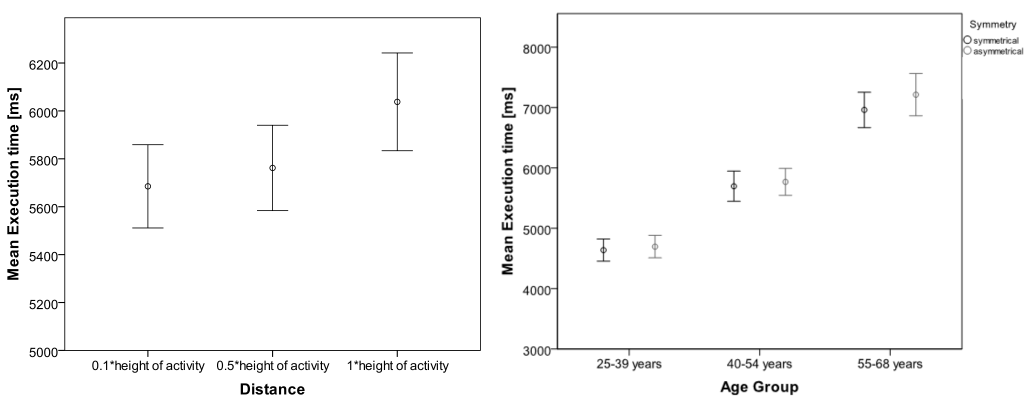

Figure 3. Execution time for the search task as a function of the distance (left) and the symmetry separated by age group (right)

Regarding the error rate it has to be mentioned that overall few errors were made and only a significant effect of the age group was found ($F_{(2;105)}$=4.586; p=0.012; ω^2=0.12). The relative amount of errors that were made by the older participants (M=3.0%, SD=0.6%) were significantly higher than the amount of errors made by the medium age group (M=0.6%, SD=0.6%, p=0.017). The difference between the younger (M=1.1%, SD=0.6%) and the older age group cannot be proved statistically, but a trend can be observed descriptively that shows a higher relative amount of errors for the older age group. These results do not indicate the occurrence of a speed-accuracy trade-off.

For the length of the scan path a significant effect of the age group was found ($F_{(2;105)}$=3.237; p=0.043; ω^2=0.06).

Bonferroni adjusted post-hoc analysis only revealed a significant difference between the young and the older age group ($p=0.038$), but descriptive analysis showed that the length of the scan path rises with the mean age of the participants (Figure 4, left). Moreover, a significant effect was found for the level of abstraction and aggregation ($F_{(2;210)}=320.537$; $p<0.001$; $\omega^2=0.60$). As expected, due to the higher amount of screen areas that need to be discovered, participants show a significantly higher length of the scan path for the lowest and medium level of abstraction and aggregation than for the highest level ($p<0.001$). Higher abstraction also revealed a significant difference: for the lowest level of abstraction and aggregation the scan path was significantly longer than for the medium level ($p=0.005$) (Figure 4, right). A further main effect was found for the factor distance ($F_{(2;210)}=23.512$; $p<0.001$; $\omega^2=0.08$). The small distance differed significantly from the middle ($p=0.009$) and from the large distance ($p<0.001$), as well as the middle distance differed significantly from the large distance ($p<0.001$). As expected the larger the distance between the activities, the longer the scan path (Figure 5, left).

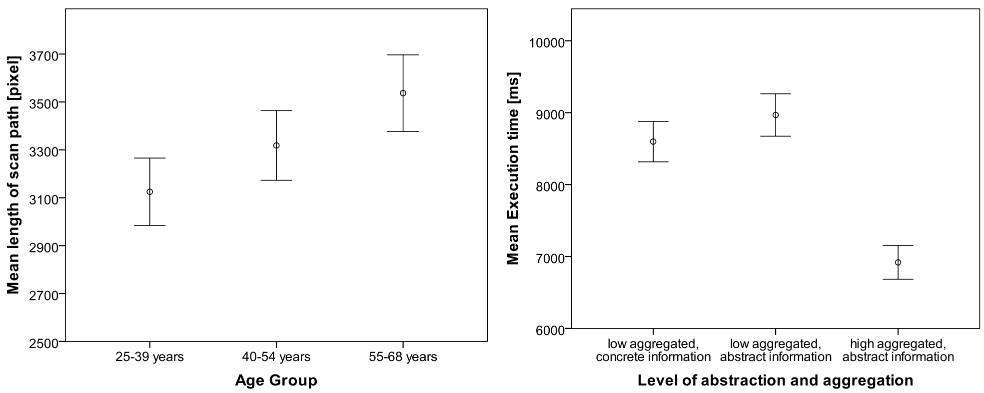

Figure 4. Length of the scan path for the search task as a function of the age group (left) and the level of abstraction and aggregation (right)

In addition, the symmetry had a significant effect on the length of the scan path ($F_{(1;105)}=4.770$; $p=0.031$; $\omega^2=0.02$). The asymmetrical layout resulted in a longer scan path than the symmetrical layout (Figure 5, right). Moreover, the ANOVA showed two significant interaction effects between level of abstraction and aggregation and symmetry ($F_{(1.733;181.974)}=3.453$; $p=0.040$) and level of abstraction and aggregation and distance ($F_{(3.422;359.318)}=3.228$; $p=0.018$). As both interactions are ordinal, they have no impact on the interpretation of the main effects.

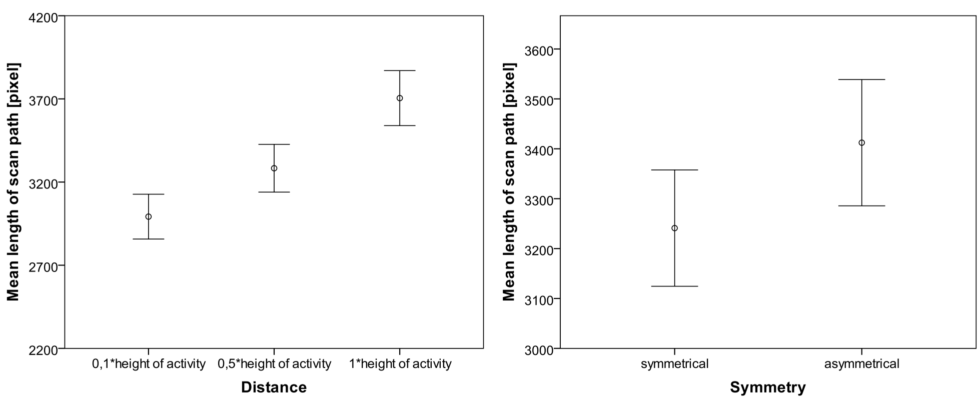

Figure 5. Length of the scan path for the search task depending on the distance (left) and on the symmetry (right)

Predecessor Task

For the predecessor task we found a significant effect of the age group on the execution time ($F_{(2;105)}=24.505$; $p<0.001$; $\omega^2=0.40$). Post-hoc pairwise comparisons showed that the younger participants were significantly faster than the middle-aged ($p<0.001$) and the older subjects ($p<0.001$). In addition, participants of the oldest age group were significantly slower than participants of the medium age group (p=0.020) (Figure 6, left). Furthermore, a significant effect for the level of abstraction and aggregation was found ($F_{(2;210)}$=57.251; p<0.001; ω^2=0.18). The execution time was significantly lower for the highest level of abstraction and aggregation than for the medium (p<0.001) and for the lowest level of abstraction and aggregation (p<0.001). The execution times for the medium and the lowest level of abstraction and aggregation did not differ significantly for the predecessor task. Regarding the factor symmetry we also found a significant effect on the execution time ($F_{(1;105)}$=4.648; p=0.033; ω^2=0.01). When solving the predecessor task the execution time was shorter with the symmetrical layout than the asymmetrical layout (Figure 6, right). The distance had no significant effect on the execution time when solving the predecessor task.

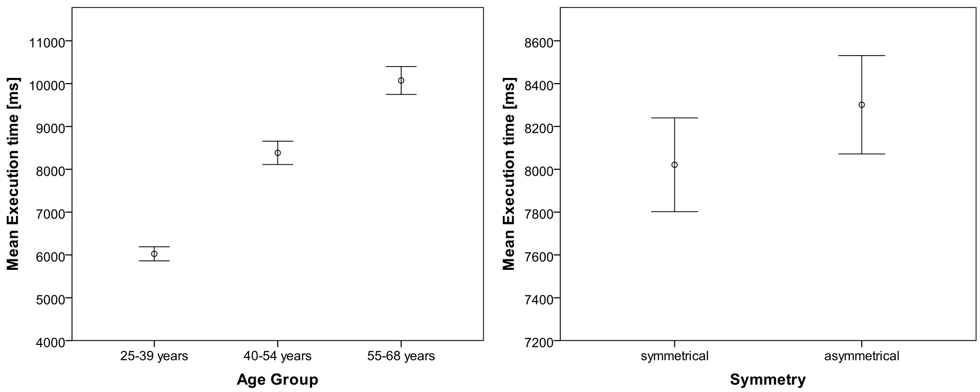

Figure 6. Execution time for the predecessor task as a function of the age group (left) and the symmetry (right)

Concerning the error rate, the ANOVA showed a significant main effect of the age group ($F_{(2;105)}$=7.104; p<0.001) with a high effect size ω^2=0.14. The subjects of the younger age group made significantly less errors (M=3.8%, SD=2.2%) than the subjects of the medium (M=12.0%, SD=2.2%, p=0.027) and older age group (M=14.9%, SD=2.2%, p=0.001). Furthermore, a significant interaction effect between level of abstraction and aggregation, symmetry and distance was found ($F_{(4;420)}$=3.281; p=0.012), but as none of these factors showed a significant main effect, the interaction was not interpreted in more detail. From these results it can be concluded that no speed-accuracy tradeoff occurred.

Regarding the length of the scan path, the ANOVA showed a significant effect of the age group ($F_{(2;105)}$=5.764; p=0.004; ω^2=0.12). Younger subjects showed a shorter length of the scan path than participants of the medium (p=0.035) and the older age group (p=0.005) (Figure 7, left). Moreover, the level of abstraction and aggregation had a significant effect on the scan path ($F_{(1.805;189.483)}$=276.829; p<0.001; ω^2=0.58) as expected. The scan path of the highest level of abstraction and aggregation was significantly shorter than the scan path for the medium (p<0.001) and the lowest level of abstraction and aggregation (p<0.001). The distance also had a significant effect on the length of the scan path ($F_{(2;210)}$=12.149; p<0.001; ω^2=0.04). As expected, the scan path was significantly shorter for the small distance than for the medium (p=0.008) and large distance (p<0.001) (Figure 7, right). For the factor symmetry no significant effect could be uncovered by the ANOVA, but the descriptive analysis showed a shorter scan path for the symmetrical layout than for the asymmetrical layout.

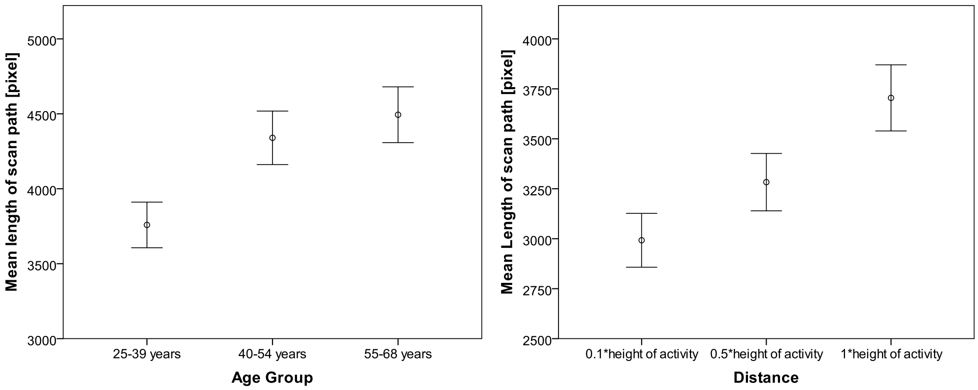

Figure 7. Length of the scan path for the predecessor task depending on the age group (left) and on the distance (right)

Interpretation Task

For the interpretation task the ANOVA showed a significant effect of the age group on the execution time ($F_{(2;105)}$=33.899; p<0.001; ω^2=0.48). Participants of the older age group had significantly higher execution times than participants of the medium (p<0.001) and younger age group (p<0.001). Moreover the younger age group showed lower execution times than the medium age group (p=0.001) (Figure 8, left). We furthermore analyzed the type of the task. Unsurprisingly we found that a task without screen changing was faster than a task with screen changing ($F_{(1;105)}$=146.00; p<0.001; ω^2=0.59). As in the predecessor task we also found a significant main effect of the factor symmetry in the interpretation task ($F_{(1;105)}$=5.580; p=0.020; ω^2=0.01). Symmetrical layouts resulted in shorter execution times (Figure 8, right). No significant effect could be found for the activity distances.

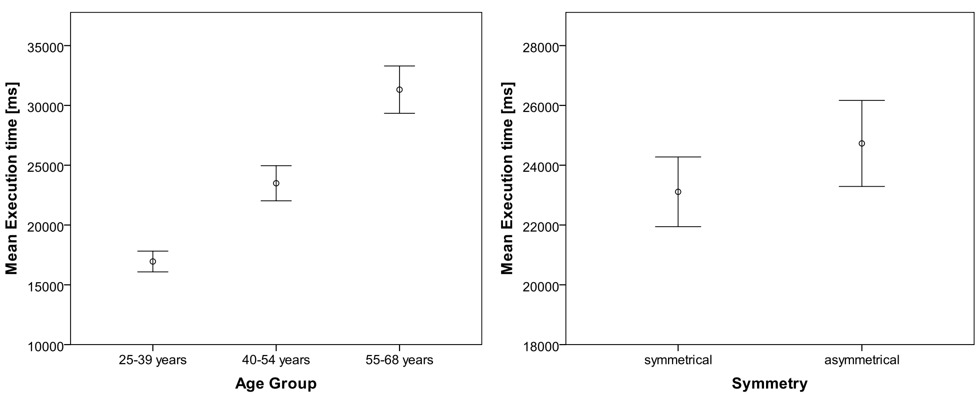

Figure 8. Execution time for the interpretation task as a function of the age group (left) and the symmetry (right)

Regarding the error rate, a significant main effect of the age group was found ($F_{(2;105)}$=4.286; p=0.016; ω^2=0.09). Younger participants made significantly less errors (M=2.3%, SD=1.5%) than participants of the older age group (M=8.3%, SD=1.5%, p=0.018). The error rate of the medium age group did not differ significantly from the error rate of the younger and older age group, but descriptively range in-between (M=3.7%, SD=1.5%). These results indicate no speed-accuracy tradeoff for the interpretation task.

Regarding the length of the scan path, the ANOVA showed a significant effect of the age group ($F_{(2;105)}$=1385.285; p<0.001; ω^2=0.33). Bonferroni adjusted pairwise comparisons showed a significantly shorter scan path for the younger age group than for the medium (p=0.011) and the older age group (p<0.001). Moreover, the scan path of the medium age group was significantly shorter than the scan path of the older age group (p=0.007) (Figure 9, left). As expected, the type of the task had a significant effect on the scan path length ($F_{(1;105)}$=226.303; p<0.001; ω^2=0.61). The scan path was shorter on one screen presentation. A third main effect was found for the symmetry. Symmetrical layouts resulted in a shorter scan path length (Figure 9, right). A descriptive analysis showed that the length of the scan path increases with increasing activity distance. But these differences were not significant statistically.

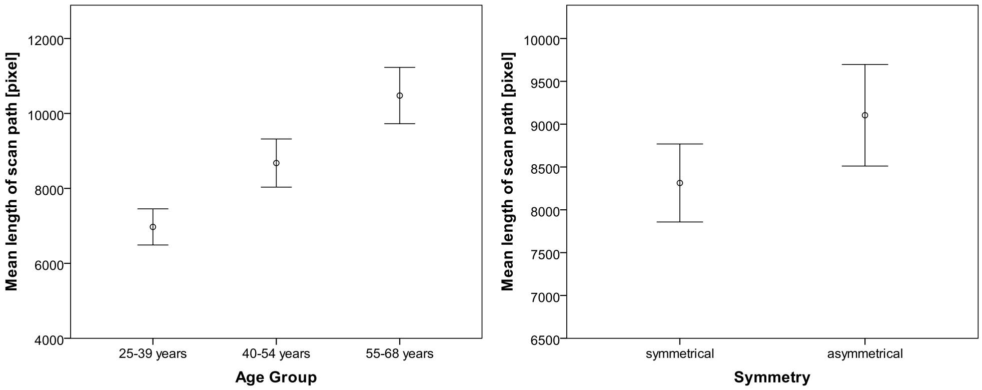

Figure 9. Length of the scan path for the interpretation task as a function of the age group (left) and the symmetry (right)

GENERAL DISCUSSION

Regarding the age, we found for all kind of tasks, that execution time and spatial length of the scan path increase with age and that more errors were made by the older than by the younger age group. For the medium age group it depends on the task: in the search task the participants made even less errors than the young group but for the predecessor and the interpretation task they range in between the young and the old age group. As in general there were only few errors made in the search task, it is assumed that this result occurred due to random effects. Interestingly our results did not confirm the age-dependent shift in the speed accuracy tradeoff in visual search described in literature.

The spatial distance between the activities only had a significant effect on the execution time in the search task. Execution times were significantly lower or equal in layouts with small distances than in layouts with large distances. For the predecessor and interpretation tasks, the distance had no effect on the execution time and the descriptive analysis also showed no difference in execution time for the three distances. This might be due to the higher difficulty of these and the different cognitive functions that are involved when solving these tasks. For the search task the primary cognitive function is attention. In addition, according to Woodman and Chun (2006) we assume that the spatial but not the visual working memory is involved in the search task. In the predecessor task the subject first needs to search for a specified activity and after they found the activity to track the connection to detect the predecessor(s). In case of more than one predecessor they need to re-fixate the specified activity and track the connection to the additional predecessor. Here, in addition to the cognitive functions that are involved in the search task, we assume that also the visual working memory is involved. Finally, for the interpretation task we also have a component of visual search as the first specified activity needs to be detected in a first step. After detecting the first activity, the second specified activity needs to be searched while memorizing the duration and the position of the first activity. It is assumed, that in addition to the visual working memory, the verbal working memory is involved due to verbal rehearsal strategies. In the last step, deductive reasoning occurs as the two durations are compared. To sum up, a larger capacity of visual-spatial working memory is needed for the solution of the predecessor and interpretation task than for the search task. For pure memorizing tasks, according to the model of Winkelholz and Schlick (2007) and the study of Jochems (2010), larger distances are beneficial whereas for visual search tasks in general it was assumed that due to the compatibility principle (Wickens and Carswell, 1995) and the eccentricity effect in visual search (Carrasco 1995) smaller distances are advantageous. Due to the combination of visual search and working memory in the predecessor and interpretation task, it is assumed that for these tasks these two effects compensate so that for the whole task no effect could be found. The error rate was for none of the investigated tasks affected by the distance whereas length of the scan path was influenced by the distance. For the search task, the length of the scan path rises with increasing distance between the activities. Whereas for the predecessor task only the difference between the small and middle as well as small and large distance showed a significant effect and for the interpretation task only a tendency could be detected descriptively. These results underline an occurrence of the eccentricity effect due to the component of visual search in all tasks. This effect is most pronounced for the pure search task.

Concerning the factor symmetry it was assumed that using a symmetrical layout to arrange a network diagram results in shorter execution times and less errors. Regarding the errors this hypothesis could not be rejected as there was no difference in error rate between the symmetrical and asymmetrical layout. Whereas for the execution it was confirmed, that working with a symmetrical layout results in shorter execution times than working with the asymmetrical layout. This difference was also indicated as statistically significant by the ANOVA for the predecessor and the interpretation task. For the search task, this effect could only be shown descriptively. Furthermore, the analysis of the scan path showed that symmetrical layouts result in shorter scan paths than asymmetrical layouts. This effect was statistically proven for the search and the interpretation task while for the predecessor task the tendency could be described only descriptively. It might be assumed that the longer scan path resulted in the longer execution times.

As expected regarding the level of abstraction and aggregation, a higher level of abstraction and aggregation resulted in lower execution times and shorter scan paths. This effect was more pronounced for the aggregation of information than for the abstraction of information. Furthermore, when change in screen area was needed for the solution of the interpretation task this also resulted in longer execution times and longer scan paths as predicted.

CONCLUSION

As conclusion, the results of this study reveal that the work with network diagrams can benefit from a proper designed layout structure regarding distance and symmetry. Based on the described results we recommend a symmetrical activity structure in a network diagram as this leads to shorter execution times for all investigated tasks. This is true for diagrams in which information is reduced and that can be depicted in one screen area but also for diagrams that show detailed information and are spread via different screen areas. Regarding the distance we recommend to use narrow distances between the activities (0.1*activity height) especially for tasks where only visual search is involved. As for more applied tasks as predecessor and interpretation tasks small distances do not increase execution time or errors and in some cases the use of narrow distance can lead to less screen areas, we recommend using the narrow distance regardless the task. These results apply to all age groups and confirm a design-for-all approach.

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