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Influence of Presence in Three-Dimensional Process Control

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Abstract

Nowadays with increasing automation, monitoring production processes in a continuous way gets more and more difficult. We investigate how the application of graphical 2D and 3D displays influences conductive and interfering aspects during monitoring situations. Our goal is to develop an appropriate visualization of process data, which enhance the operator's understanding of the current process. On the one hand, we consider presence and the possibility to interact with the visualized data as conductive factors. On the other hand, we see task complexity and additional activities added to monitoring task as interfering factors, which can negatively disturb operator's performance. For examining our research questions, we used different data visualizations from a thermo-hydraulic process producing particleboards. Presence was measured with a self-developed questionnaire.

Keywords--- **3D, Presence, Process Control**

1. Introduction

Conventional two-dimensional man machine interfaces hardly meet the requirements of the increasing complexity of production processes and the growing number of process information that have to be observed [1]. This quickly induces monitor overcrowding. Thus a clear arrangement of measuring data and process variables and therewith a fast and reliable error detection cannot be guaranteed any more. A spatial visualization in term of three-dimensional process visualization may remedy these deficiencies by supplying the operator with process information in a way adapted to human perception and information reception. Smallman, St John, & Oonk (2001) [2] report several benefits of a three-dimensional display compared to a two-dimensional one. At first, they state that three-dimensional displays seem to be ecologically more feasible, because our retinal pictures are perspective projections of the environment. However, this argument does not take into account that various monocular and binocular spatial cues are responsible to create a three-dimensional projection of the environment. At second, three-dimensional displays may induce a reduction in the users´ mental workload through the integration of all three spatial dimensions into only one representation. Wickens & Andre (1999) [3] have also pointed out these considerations. At third, users seem to prefer the familiarity with and the simplicity of three-dimensional displays. However, the authors also point out to the risk of ambiguity of three-dimensional displays that can result in problems with exact position determination. Empirical results regarding the comparison of two- and three-dimensional displays are not unique [2, 4], which is attributed to the fundamental format difference between two- and three-dimensional displays and the different task demands of the experiments [2].

In our study, we assume that presence is one of the conductive factors that effects the operator's understanding of processes and that presence is triggered more with three-dimensional (3D) than two-dimensional 2D displays. We investigate how the application of graphical 2D and 3D displays influences conductive and negative aspects during monitoring process data from a thermo-hydraulic press producing particleboard. Our goal is to develop an appropriate data visualization that enhances the operators understanding of the current process and facilitates his work by reducing mental workload. As stated above, one of the considered conductive factors is the degree of presence that a person experiences during observing the process data. Presence seems to play an important role in three-dimensional visualizations, especially when we regard the conjunction to attention processes. We assume that 3D visualizations lead to a higher sense of presence and therefore to the higher ecological perception described by Smallman, St John, & Oonk (2001) [2].

1.1. Presence

Most researchers agree that presence refers to the subjective feeling of "being there" [5, 6]. It is commonly understood as a psychological phenomenon [7] that can be described by means of a multidimensional construct [8]. None the less there exist different concepts regarding the components that are involved and the way they are related to one another. Witmer and Singer (1998) [6] view involvement and immersion as necessary conditions for developing a sense of presence. Based on theoretical considerations they designed a questionnaire that should assess factors assumed to influence these two dimensions, namely control factors, sensory factors, distraction factors and realism factors (Presence Questionnaire = PQ). In order to also assess personal characteristics that influence the experience of presence they added a second questionnaire (Immersive Tendencies Questionnaire = ITQ). However, Slater (1999) [9] points out that a measure of presence cannot be constructed from the factors influencing it. Moreover, he criticizes the subjectivity of their item formulation. According to him, it is necessary to differentiate between individual differences in the experience of presence and the influence of different system factors. He emphasizes the importance of obviously measurable aspects of the VE system and their contribution to the presence experience. In this regard, he agrees with Schubert, Friedmann, & Regenbrecht (2001) [7] who understand immersion as an objectively quantifiable variable while the experience of presence is assumed to be subjective in nature. For them presence is a direct function of immersion. However, the relation is mediated by cognitive processes that are involved in the construction of a functional spatial mental model of the virtual space. The authors suggest three components of the presence construct: spatial presence, involvement and judgment of realness.

1.2. Virtual reality vs. 3D visualization

A review of literature shows that presence is often investigated in virtual environments (e.g. [10, 11, 12]). These virtual environments are computer generated applications which simulate a synthetic environment for users. Studies of presence then focus on immersion and the feeling of "being there" in the media world. Often navigation/coordination or exploration tasks are used, like searching for an object or exploration rooms in a virtual environment [11, 12, 13]. The egocentric perspective of the user seems to be a basic requirement to have a greater sense of being in another synthetic place [9]. Often technical equipment like head-up-displays or a CAVE is needed to immerse in the virtual environment. These devices enclose people's visual perception.

The visualization of process data is different from virtual reality because it is a presentation of data in a three-dimensional surface-plot. Single data are continuously updated at different points of the chart and interpolated for the intervals without data. In this study, we investigate how far it is possible to apply the construct of presence to the 3D spatial data visualization in the monitoring process. Witmer & Singer [6] specify four main factors with presence from which two can be pointed out as relevant for the task of process data visualization:

1) Control factors: degree of control, immediacy of control, anticipation of events, mode of control, physical environment modifiability.

2) Sensory factors: sensory modality, environmental richness, multimodal presentation, consistency of multimodal information, degree of movement perception, active search.

An increase of the control over the environment can be achieved by interaction with the 3D visualization.

As stated above, we regard presence as a conductive factor which is able to facilitate monitoring work tasks by reducing the mental workload.

2. Visualization of the process

To examine the research question we used a thermo-hydraulic process to produce particleboards. The process is typically monitored by an operator. In a critical situation, the operator is required to intervene fast and correct. Monitoring in reality takes place in a control room, where different displays show lots of information usually on – conventional 2D man-machine-interfaces. On the one hand, managing those 2D-displays in a control room require high performance in terms of operators attention or mental workload. On the other hand, observing the monitors for a long period is also fatiguing. According to the proximity compatibility principle Wickens & Andre (1990) [3] assume that the described work tasks which require the integration of information benefit from a perceptual proximity of the display or visualization. In order to improve the 2D displays, which are state of the art in process visualization, Beuthel [14] and Hoppe [15] proved the advantage of 3D process visualizations for the application of a coal-fired power plant and electric power grit. We have, furthermore, developed the use of surface patterns as 3D process data displays in an interdisciplinary research project [16]. Figure 1a gives an example for the 3D display of a certain status in the thermo-hydraulic process (for explanations see section below). In addition a comparable 2D visualization is depicted (figure 1b).

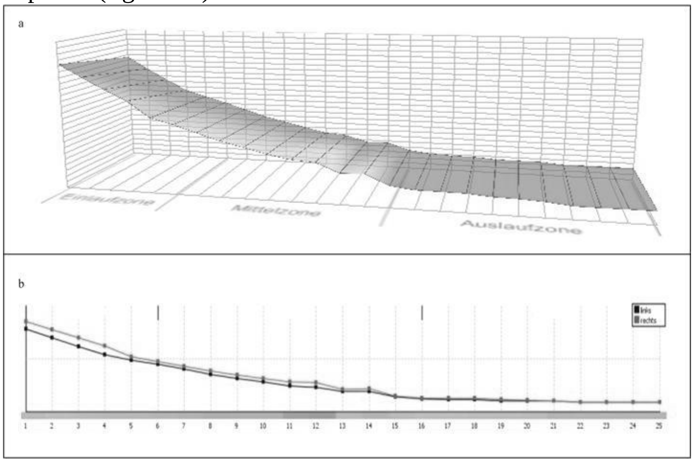

Figure 1 A 3D display of the distance of the steel bands in the hydraulic press, b 2D display of the distance of the steel bands in the hydraulic press (for explanations see text below)

For the experiment described below two screens were allocated to monitor the complete hydraulic process from the beginning to the final product. Three sections of the process were visualized in four graphs. At first, the material comes on a belt and is weighed. At second, the next step includes the material transportation through the machine where it is pressed, heated and compressed. This section is visualized in two graphs: one shows pressure that is exerted on the material and the other one for the distance of the steel bands in the hydraulic press (see figure 1), which indicates the thickness of material. At third, the final product has to be verified at the end of the process.

In our experiment, 2D and 3D graphs include the same information in different ways. According to the PCP [3] the three-dimensional presentations integrate more information in the graphs in question while 2D graphs show it separately. In contrast to 3D graphs (see figure 1), 2D graphs supply two lines to monitor the right and the left hand side of the steel bands in the hydraulic press. Deviations of the process data from correct course are color-coded either through the complete graph (3D) or on the bottom of the display (2D) and could although be seen in changes of graph characteristics.

3. Method

3.1 Participants

The participants were 38 students (17 female, 21 male) of different departments at two universities who were rewarded with credit point for their participation. Their age ranged from 18 to 31 (*M*=22.21, *SD*=2.79). We asked our participants about their experience with 3D-visualizations (e.g. games or architecture software) and had to state that exactly half of the sample indicated that they were experienced and half of the sample that they were not. All participants took individually part in a session that lasted two and a half hours.

3.2. Questionnaire of presence

Most presence questionnaires are conceived for virtual reality applications. For examining our research task we developed an own questionnaire of presence because the three-dimensional presentation in this study differs from virtual environment. Appropriate items were taken from different presence questionnaire, rephrased and completed by new formulated items.[33]Three factors should be measured: feeling of involvement [7], control [6] and spatial presence [7, 17]. All items were transferred in a consistent format with a 7-point-rating scale. The resultant questionnaire includes 19 items.

3.3. Experimental design

The study employed five groups with different forms of dimensional data presentation (2D vs. 3D) and varying forms of training (slider vs. freeze image). The fifth group had the additional possibility to use interaction with the three-dimensional display. Interaction means the possibility to choose an arbitrary viewpoint for each of the 3D graphs. Table 1 summarizes the constituted conditions.

	Freeze	**Slider**	**Slider with interaction**
2D	group 1	group 2	
3D	group 3	group 4	group 5

Table 1 Experimental conditions

The slider condition is characterized by the possibility to move across the problem while exploring the task. Participants can go forward or backward, slow or fast through the actual problem. In contrast, the freeze condition shows only static pictures of different problem sections at various points of time. Moving within the problem is possible, but only three points in time are available. After the training, each participant had to monitor critical and normal situations. When participants thought that they discovered a critical situation in the current process, they had to react as fast and as correct as possible.

3.4. Training

Each participant received a training regarding the functionality of the hydraulic press and the characteristics of selected critical situations (problems), which can appear during work tasks. The first part of the training was an audio-visual presentation, which included necessary information about the constitution and functionality of the system and how to react if a problem appears. An exploration phase was also provided in which participants could explore each problem. Afterwards a training phase was inserted to assure participants knowledge. Finally, participants were automatically given feedback for each reaction.

3.5. Hypothesis

Our hypothesis concerning the influence of presence was that the sense of presence as a conductive factor in process visualization is rated higher when working with 3D displays compared to 2D displays.

3.6. Procedure

At the beginning, all participants were trained as described above. At first, the audio-visual presentation was shown. Afterwards, they completed the exploration and the training phase. In between, we presented a summary of problem characteristics. Subsequently the properly test followed. During this test phase, the participants should monitor different critical and non-critical situations. As soon as a critical situation appeared participants were to make a correction input. After the test phase, we interviewed the participants and asked them about their thoughts and presentations of problems and functioning of the hydraulic press. Finally, the presence questionnaire and NASA-TLX [18] were filled out.

[33] the questionnaire can be explored on the following website: http://www.es.eecs.uni-kassel.de/pastp/

3.7. Measures

3.7.1. Assessment of presence Participants completed a presence questionnaire that had been developed for this investigation. Since presence is a multidimensional construct, items were intended to measure three factors of presence: (1) feeling of involvement, (2) control and (3) spatial presence.

3.7.2. Assessment of workload Mental demand through the experimental tasks was measured by selected items of NASA-Task Load Index (TLX) [18]. It considers how the task is perceived, e.g. mental and sensory requirement, time pressure and frustration. The degree of occurrence was marked with an "x" on the scale from "low" to "high". The response measure was the distance from "low" to the marked position divided by the total length of the scale.

4. Data analysis and results

In this section, we firstly describe the results of the factor analysis for the presence questionnaire (4.1.) and secondly report the results of the hypothesis testing for all groups (4.2.) and for the conditions with 2D vs. 3D displays (4.3.). As stated above, we regard presence as a conductive factor, which is able to facilitate monitoring work tasks by reducing the mental workload. Under point 4.4., we therefore illustrate the results with respect to the measures on mental demand by the NASA TLX.

4.1. Questionnaire of presence

4.1.1. Factor analysis To analyze the questionnaire of presence we put all groups in one sample (N=38). The data were factorized using the Principal Components Analysis and rotated using the Varimax rotation method. The screeplot suggested four factors. The KMO (Kaiser-Meyer-Olkin) measure of sampling adequacy had a middling value of .739, which indicated that a factor analysis was useful with the data (limited usually at KMO >.500) [19]. The detailed consideration of the measure of sampling adequacy showed, however, that five items (2, 6, 7, 13 and 14) had poor values. We, therefore, excluded these items computed a second factor analysis with the remaining items. Now the KMO measure suggested a middling value of .766. All MSA-data had acceptable values. The screeplot advised the extraction of three factors. A strong first factor, which was followed by two factors with lower eigenvalues was extracted. 66.27 % of total variance could be explained by these three factors.

1) Five items (3, 16, 17, 18 and 19) could be attributed to the first factor. It accounted for 43.78% of the total variance. All items described the classic characteristics of presence like "being and acting in the simulated situation" as well as "being involved in the experimental scenarios". We concluded to constitute this factor as *involvement*.

2) Factor 2 constituted of items (8, 10 and 12) describing how realistic the visualization was and to what extent the simulated situations could be controlled by the participant. 12.85% of total variance was explained by this factor. Based on the attributed items this factor is named *realness/ control*.

3) The third factor explained barely 9.65% of total variance. The factor comprehended items (1, 4, 9 and 15) indication how participants tried to understand the handling of the application and implemented preliminary learned information in performance. The items comprised also the imagination to act in a simulated situation and to direct attention. Because of the included items, this factor will be termed as *action alignment*.

4.1.2. Reliability analysis the next step was to examine the reliability and item values. Therefore, we computed the reliability of each factor. Table 2 shows the Cronbach's alpha, separated for factors, which reliability was acceptable.

Factor 1 **Involvement**	**Factor 2** **Realness/ control**	**Factor 3** **Action alignment**
Alpha = .844	Alpha = .851	Alpha = .722

Table 2 Reliability for each factor

Subsequently discriminatory power and item difficulty were assessed. Discriminatory power of factor 1 items lay between .635 up to .706. Items of factor 2 reached values from .554 to .841 and for factor 3, the discriminatory power extended from .523 to .534. All values were acceptable; no items had to be excluded. Item difficulty is listed in table 3. Most items had a middling difficulty except those of factor 3. Here three of four items had a high difficulty.

Factor	Item	Difficulty
1	3	.65
1	16	.64
1	17	.58
1	18	.48
1	19	.65
2	8	.61
2	10	.55
2	12	.62
3	1	.70
3	4	.56
3	9	.78
3	15	.74

Table 3 Item difficulty separated for each factor

The resultant questionnaire consists of three factors with totally 12 items.

4.2. Presence and different forms of visualization

To test our hypothesis that the specific form of visualization has an impact on the sense of presence when working with 3D and 2D displays we computed a sum score of all items that were answered with 6 or 7 in each factor according to Slater (1996) [10] and additionally a total sum score over all factors. Afterwards we calculated the average for each group in each factor. Figure 2 presents a plot of mean scores for each presence factor.

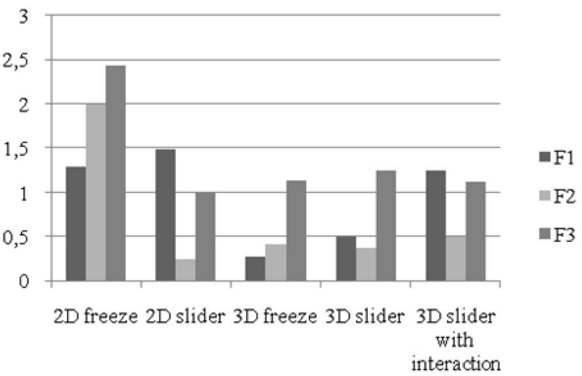

Figure 2 Averages of groups in different presence factors

The hypothesis was then tested by the Kruskal-Wallis-Test. The five different groups differed significantly in factor 2 scores, the experience of realness and control. Subsequently Mann-Whitney-Tests were executed. The results showed that in factor 2 scores of group 1 (2D freeze) were significant different from all other groups. The same procedure was applied to investigate the sum score of presence. In this case only the groups working with 3D displays group (3, 4 and 5) differ significantly from the 2D freeze group. Group 1 was also significantly different from group 3 concerning the second factor of presence. Table 4 presents an overview of the results of the Mann-Whitney-Tests (significant results are printed bold).

group	Factor 1	Factor 2	Factor 3	Sum score
2 N=8	U=24.5 p=.694	U=**3.5** **p<.01**	U=12.5 p=.072	U=13.0 p<.094
3 N=7	U=**8.5** **p<.05**	U=**4.0** **p<.01**	U=13.0 p=.165	U=**2.5** **p<.01**
4 N=8	U=14.0 p=.121	U=**6.5** **p<.01**	U=15.5 p=.152	U=**7.0** **p<.05**
5 N=8	U=19.5 p=.336	U=**7.0** **p<.05**	U=13.5 p=.094	U=**9.0** **p<.05**

Table 4 Results of Mann-Whitney-Tests – different groups compared with group 1 (N=7)

As can be seen in table 4 group 1 (2D freeze) and 3 (3D freeze) also differed significantly in factor 1. Involvement is significantly higher in group 1 compared to group 3.

Finally, the sum score over all factors of presence showed significant disagreement in conditions 3, 4 and 5 compared to group 1 (2D freeze). Overall presence seemed to be higher in 2D freeze.

4.3. 2D vs. 3D

Conditions of the same dimensionality were subsumed in one group except group 5, which participants had the possibility to interact during exploration phase and differed from all other conditions with regard to this characteristic.

Again, a Mann-Whitney-test was computed. The result indicated that the two-dimensional visualization condition had higher values in factor 1 (involvement) (U=67.5; p = .061) and also in the overall presence score (U=64.5; p<.05).

4.4. Mental demand

4.4.1. Different forms of visualization According to point 4.2. we compared the different groups with regard to the NASA-TLX ratings by means of an ANOVA. The results showed a significant difference in mental demand (F=4.779; p<.01). A Bonferroni-test was used to look at the significant differences between single groups. The 2D freeze (group 1) achieved a higher mental demand than 3D slider (p=.056) and the 2D slider group (group 2) a significant higher mental demand than the 3D slider group (p<.01). Compared to 3D slider the condition of 3D slider with interaction (group 5), however, showed also a significant higher mental demand (p<.05). The remained conditions were not significant.

4.4.2. 2D vs. 3D To compare the dimensionalities we combined groups with the same dimensionality and analyzed the differences in their ratings by means of a t-test. Again, group 5 (3D slider with interaction) was not considered.

The results revealed that mental demand (t=3.385; p<.01), time pressure (t=2,597; p<.05) and the sum score of overall workload judgments (t=2.351; p<.05) were significant different. Participants who worked with 2D displays perceived the task as more demanding than participants in 3D groups.

4.4.3. Workload and presence The next step was to investigate the relation between the perceived mental workload during the task and the degree of presence experienced by the participants. Therefore, we calculated a Pearson correlation of both, the overall workload score and the scores for the single types of workload with the different presence scores (the overall presence score and the factor specific presence scores). We found two significant positive correlations for the second presence factor (*realness/control*). There was a significant relation to the overall workload score (r=.344, p<.05) and the mental demand score (r=.324, p<.05).

All other correlations were not significant but predominantly positive. The correlation between the frustration score and the third presence factor (*action alignment*) was negative. One interesting result was that almost all correlations between the first presence factor (*involvement*) and the different workload scores (effort, mental demand, visual demand and temporal demand) were negative, except the frustration score (r=.122). The lowest correlations were found for the third presence factor (r<-.01 with one exception for the frustration score).

Conclusions

At first, the results of this study may be surprising. Those participants who worked with 2D displays (group 1 and 2) rated presence referring to items concerning involvement, realness/control and action alignment higher than participants who worked with 3D displays. We have expected it the other way around. If we take a closer look on the results, we see that the 2D freeze group (group 1) rated highest on the items referring to the factor realness/control. Items attributed to this factor comprised perceived realistic appearance and control of the simulation.

At second, the results on presence are in line with our findings on mental load. The 2D visualization with freeze training was the most difficult requirement. For participants who took part in this condition, information during problem exploration was only presented in two or three pictures at different points in time. In contrast to the 3D display conditions (group 3 to 5) participants furthermore had to integrate different information that were presented separately. On closer examination of results, we assume that participants in 2D groups grappled more with the data visualization because in this condition it was more difficult to monitor the process.

At third, there is a significant positive correlation for the presence factor realness/control and the sum score with the overall work load ratings and a general positive correlation for the presence factor involvement with the overall work load ratings. These findings support the view that the more the participants feel a sense of control and appearance of realness during the task the more workload they experience. Participants in the 2D freeze condition feel more strained in performing the task and more mentally demanded.

At this point, we have to ask what we at all have measured with the employed presence questionnaire. Of course, one might say that it is possible to have an experience of being there even if the environment is restricted. If we have measured the sense of being in the experimental room and taking part in an experiment, we must admit that we did not operationalize the task well enough. However, in this case it is implausible that there are differences between 2D and 3D groups at all. We intended to measure the participants' experience with the thermo-hydraulic process.

The already mentioned difficulties for participants in the 2D groups might serve as another explanation for the results in presence ratings. As stated above we assume and mental work load data support this view that participants in 2D groups grappled more with the data visualization. Maybe 3D presentation allowed participants digressing from the task and returning without a reorientation and therefore rated presence lower than participants in 2D groups. To investigate this assumption further we should also regard the findings on self-efficacy. From the literature on self-efficacy [20, 21] it is well known that more demanding tasks can lead to higher ratings on self-efficacy. Furthermore, self-efficacy might also be related to the perception of presence if we regard the presence factor involvement. However, the results for the perceived demand when participants feel involved are contradicting this view.

The first results that we laid out in this paper should be regarded as preliminary tendency. They should be examined in further investigations, with a larger sample, and with an additional questionnaire on self-efficacy. A larger sample is also needed to examine the influential factors between *realness/control* on the one hand mental demands on the other hand. To the moment we, however, could not clarify if a decrease according to this factor could lead to a decrease of mental demand and if such a decrease could therefore be seen as a conductive factor.

Another question concerns the role of interaction in the study we reported. Since there was only one condition, which allowed interaction during exploration phase we could not interpret our results concerning this condition further. Hence, follow up investigations should vary the type of interaction employed in 3D Slider conditions.

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References

[1] R. Zeipelt, B. Vogel-Heuser. Nutzen der 3D-Prozessdatenvisualisierung in der industriellen Prozessführung. *atp - Automatisierungstechnische Praxis*, 45, 45-50. 2003.

[2] H. S. Smallman, M. St. John, H. M. Oonk. Information Availability in 2D and 3D Displays. *IEEE Computer Graphics and Applications*, 51-56. 2001.

[3] C. D. Wickens, A. D. Andre. Proximity Compatibility and Information Display: Effects of Color, Space, and Objectness on Information Integration, *Human Factors,* 32, 61-77. 1990.

[4] J. D. Baumann, S. I. Blanksteen, M. Dennehy. Recognition of Descending Airc-raft in a Perspective Naval Combat Display. *Journal of Virtual Environments*. 1997.

[5] G. Riva, F. Davide, W.A. IJsselsteijn, *Being There - Concepts, Effects and Measurements of User Presence in Synthetic Environments,* Amsterdam: IOS Press. 2003.

[6] B. G. Witmer, M. J. Singer. Measuring Presence in Virtual Environments: A Presence Questionnaire. *Presence*, 7, 225-240. 1998.

[7] T. Schubert, F. Friedmann, H. Regenbrecht. The experience of presence: Factor analytic insights. *Presence: Teleoperators and Virtual Environments*, 10, 266-281. 2001.

[8] M. Krauss, R. Scheuchenpflug, W. Piechulla, A. Zimmer,. Measurement of presence in virtual environments. In: A. Zimmer, K. Lange, K.-H. Bäuml, R. Loose, R. Scheuchenpflug, O. Tucha, H. Schnell & R. Findl (Eds.) *Experimentelle Psychologie*. Lengerich: Pabst Science Publishers. 2001.

[9] M. Slater. Measuring Presence: A Response to the Witmer and Singer Presence Questionnaire. *Presence: Teleoperators and Virtual Environments*, 8, 560-566. 1999.

[10] M. Slater, V. Linakis, M. Usoh, R. Kooper, & G. Street. Immersion, Presence, and Perfor-mance in Virtual Environments: An Experiment using Tri-Dimensional Chess. In M. Green (Hrsg.), *ACM Virtual Reality Software and Technology (VRST)*. Hong Kong. 1996.

[11] R. Ma, D. Kaber. Presence, workload and performance effects of synthetic environment design factors. *International Journal of Human Computer Studies*. 64, 541-552. 2006.

[12] J. Takatalo, G. Nyman, L. Laaksonen. Components of human experience in virtual environments. *Computers in Human Behavior*, 24, 1-15. 2008.

[13] G. Janzen, T. Herrmann, S. Katz, K. Schweizer. Obliqued angle intersections and barriers: Navigating through a virtual maze. In: C. Freksa, W. Brauer, C. Habel , K. F. Wender (Eds.), *Spatial cognition II*. Berlin: Springer. pp. 277-294 2000.

[14] C. M. Beuthel. Dreidimensionale Prozessvisualisierung zur Führung technischer Anlagen am Beispiel eines Kohlekraftwers. Dissertation, TU Clausthal. 1997

[15] S. M. Hoppe, G. R. Essenberg, D. A. Wiegmann, T. J. Overbye. Three-dimensional displays as an effective visualization technique for power systems. *Technical Report, University of Illinois*. 2004.

[16] D. Pantförder, B. Vogel-Heuser, K. Schweizer, Y. Fuchs, A. van Burgeler. Offline- und Onlineprozessdatenvisualisierung anhand von 3D-Pattern unter Berücksichtigung kognitionspsychologischer Aspekte. VDI/VDE-Berichte *Useware 2006: Nutzergerechte Gestaltung Technischer Systeme*, 1946, S. 147-157. 2006.

[17] P. Larsson, D. Västfjäll, M. Kleiner. The actor-observer effect in virtual reality presentations. *CyberPsychology and Behavior*, 4, 239-246. 2001.

[18] S. G. Hart, L. E. Staveland. Development of a NASA-TLX (Task load index): Results of empirical and theoretical research. In P. A. Hancock and N. Meshkati (Eds.), *Human Mental Workload*. Amsterdam, The Netherlands: Elsevier. pp. 139-183. 1988.

[19] E. E. Cureton, R. B. D'Agostino. *Factor analysis: an applied approach*. Mahwah, NJ: Lawrence Erlbaum Associates, pp. 389 f. 1983.

[20] A. Bandura. Self-efficacy. The exercise of control. New York: W.H. Freeman & Company. 1997.

[21] S. Cassidy & P. Eachus. Developing the computer self-efficacy (CSE) Scale: Investigating the relationship between CSE, gender and experience with computers. *Journal of Educational Computing Research*, 26, 135-153. 2002.