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Multitasking in work-related situations and its relevance for occupational health and safety: Effects on performance, subjective strain and physiological parameters

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Abstract
In the area of occupational health and safety multitasking becomes more and more important. Studies have shown that multitasking leads to a decrease in performance. However, studies often try to identify underlying mental mechanisms. Multitasking and its consequences for occupational health and safety are rarely considered. In this study, the effects of multitasking were investigated using two work-related scenarios. Changes were assessed in relation to three areas: performance values, subjective strain and physiological parameters. Data was also analyzed with respect to possible gender and age differences. Due to a focus on people of working age, the participants were aged between 21 and 60 years old. Multitasking led to reduced performance and increased levels of subjective strain. Changes in physiological parameters appear to be dependent on the type of task. There were no gender and virtually no age differences regarding the single-task compared to the multitasking condition. Overall, the data suggests that multitasking in the workplace should be minimized, at least for certain tasks, in order to prevent mistakes and potential accidents as well as mental strain. Further research should be carried out to investigate the long-term effects of multitasking on performance and health.

Keywords: multi-tasking, occupational health and safety, work-related scenarios, gender differences, age differences.

Introduction

Multitasking is considered to be a constitutive characteristic of modern work (Freude & Ullsperger, 2010). For the area of occupational health and safety multitasking might be relevant for several reasons: To what kind of mental strain, mistakes or even accidents might multitasking lead? Can women multitask better and therefore experience less strain? Does the ability for multitasking decrease with increasing age? Up to now there seems to be a lack of studies within the area of occupational health and safety especially regarding the effects of multitasking on mental strain. According to the International Standard ISO10075 "mental strain" is defined as the immediate effect of mental stress within the individual. Usually effects are described on a physiological, an emotional (subjective) and a behavioral level. The aim of the present study was to investigate the effects of multitasking on these three levels of mental strain. To this end, two different work-related settings were used. Differences in gender and age were also tested with a focus on people of working age, that is, between the ages of 20 and 60. The objective is to find out whether multitasking should be considered to a greater extent in the area of occupational health and safety. If negative effects regarding mental strain are observed prevention facilities should be discussed.

Investigating the effects of simultaneously performing two tasks has often been carried out as part of basic research within the area of attention research. This has shown that performance generally decreases when two tasks are carried out concurrently: the reaction time to a second stimulus is significantly longer when it is presented (very) quickly after the first stimulus (Koch, 2008). "Dual-task interference" is the term used to describe such interference when it occurs. The consequences of such performance decrements for the area of occupational health and safety have rather been neglected until recently. Basic research is rather interested in the causes of this interference. It is assumed that there is a bottleneck between perceptual and motor processing (Pashler, 1994). The exact location of this bottleneck has not yet been conclusively determined. It is likely that both input processes (perceptual encoding) and output-related processes (reaction selection and initiation) are affected (Koch, 2008). Studies have shown that the delay which results from performing tasks simultaneously can be reduced through practice (van Selst & Jolicoeur, 1997, van Selst, Ruthruff & Johnston, 1999). However, as a rule, even after intensive training a delay effect remains. The strength of the practicing effect is dependent on the type of task and on the participants themselves. Other than basic research on the causes of dual-task interference, according to Kiefer et al. (2006) there have been relatively few systematic studies of work-related multitasking situations and its effect on occupational health and safety. One of the few everyday situations which has been studied more often and is relevant for the working population is the situation of driving and simultaneously talking on the phone (cf. McCartt, Hellinga & Braitman, 2006) or carrying out another kind of task (cf. Kiefer et al., 2006). In a study by Strayer and Johnston (2001) for example, participants took part in a simulated driving task in which at the same time, a telephone conversation was conducted. During the telephone call mistakes increased and reaction times were considerably longer. In a second study participants either had to repeat words that were read out to them or they had to think up their own words regarding a certain rule. Here it could be seen that driving performance suffered significantly during the task of generating new words but not for the task of repeating words. The studies described above show that multitasking may have huge effects regarding road safety. Another study which used a rather work-related scenario was done by Ophir, Nass and Wagner (2009). They studied "media multitaskers", that is, people that use more than one medium at the same time. Participants were selected based on whether they were heavy media multitaskers or light media multitaskers. Participants were tested for their "cognitive control", that is, how well they could actively attend to certain elements while filtering out unimportant elements. It was shown that heavy media multitaskers (HMMs) were worse at filtering out irrelevant stimuli than light media multitaskers (LMMs). In a further experiment, it was shown that HMMs performed worse on task switching than LMMs. This suggests that LMMs are better able to focus their attention on particular information even if they are distracted by other things. It is not yet clear whether the poor performance of HMMs is a result of multitasking or whether people who generally have difficulties concentrating on one thing are inclined towards media multitasking. If it is proven that poor performance is a result of multitasking then this means that, in the future, people will be even less able to concentrate on what is important.

The studies described above concentrated on performance changes, but psycho-physiological changes during multitasking have also sometimes been considered. Some data is available in relation to driving tasks. For example, Haigney, Taylor and Westerman (2000) found in a simulator study that speed was significantly lower during a cell phone call, whereas heart rate increased. There were no differences in heart rate between handheld and hands-free phones. Dey et al. (2006) investigated the effects of music on driving behavior during simulated driving. As the participants were driving they listened to upbeat music, relaxing music or no music at all. In addition to performance measures the authors also measured heart rate. It was shown that compared to the control condition, music led to a significant increase in heart rate. This was true for both the relaxing music as well as the upbeat music. Reaction time also increased under the music condition and significantly so with the relaxing music. Other studies using psycho-physiological parameters, like event-related brain potentials tried to find out the underlying mechanisms of multi-task processing and were not interested in mental strain from an occupational health perspective (see Kramer & Parasuraman, 2007).

Possible gender and age differences might be useful to know from an occupational health and safety perspective regarding an adequate job design in order to protect employees from mistakes and mental strain. Up to now, there has been no conclusive evidence for gender differences in multitasking. It is possible that gender differences manifest themselves depending on the type of task. In a study by Saucier, Bowman and Elias (2003), participants performed a navigation task on a two-dimensional matrix with symbols. Participants were either given landmark-based or Euclidean-based instructions for navigation within the matrix. They had to simultaneously perform an articulatory task (naming days of the week) or a visuo-spatial task (tapping a pattern on the table). The ability of men and women to navigate under the four conditions was compared. This showed that the best performance was achieved when the women were given landmark-based instruction with a simultaneous visuo-spatial task. The worst performance was also shown in the women but this time with Euclidean-based instruction and a simultaneous articulatory task. Studies on age differences generally show that performance during multitasking deteriorates with age. The degree of impairment depends on the type of task. For example, impairment in automatic processes is less than in tasks with difficult motor components (Riby, Perfect & Stollery, 2004).

However, many studies on the effects of age only compare two groups; one group with predominantly 20-30 year olds and the other group with mainly over-70 year olds (e.g. Voelcker-Rehage & Alberts, 2007, Priest, Salamon & Hollman, 2008). But even studies which compare more than two age groups show deterioration with age. Crossley and Hiscock (1992) studied three age groups in a tapping task where the participants had to alternatively push one of two reaction buttons as fast as possible. The participants were aged 20-40, 41-65 and 66-90 years old. In the second task they had to read silently, speak or follow a maze with their eyes. Each of the extra tasks had two difficulty levels. As expected, the tapping rate worsened when two tasks had to be carried out simultaneously, particularly for the higher difficulty level. For all three of the extra tasks, there was a drop in tapping performance with age. The authors came to the conclusion that it is harder for older people to allocate attention to different tasks. Crook, West and Larrabee (1993) also reported impairment in dual tasks in older people. They studied five age groups ranging from 18 to 85 in a driving task. The second task was a memory task. A comparison of the youngest group (18-39) with the oldest group (70-85) showed a significant impairment in performance in both driving and remembering. The authors came to the conclusion that the ability to perform tasks simultaneously deteriorates by 5-12% for every decade of life. However, this deterioration does not always manifest itself in the middle years between 40 and 60, but rather appears to depend on the type of performance. On average, working population is aged beween 20 and 60 years. So, these age goups should be considered when effects of multitasking on occupational health and safety are studied.

On the whole it can be stated, that multitasking generally leads to a deterioration in performance which can only be partially compensated for with practice. The degree of impairment is, however, dependent on the type of task. Age differences manifest themselves from a relatively high age of around 70 years old and gender differences were hardly investigated. The effects of multitasking regarding occupational health and safety have been rather neglected until recently. If there were negative effects on mental strain prevention strategies should be focused.

Method

In order to investigate the effects of multitasking, two tasks were used. These were a driving simulation and a task similar to that found in an office environment.

Procedure

The Lane-Change-Task (LCT, Mattes, 2003) was used for the driving task. This involves a driving simulation done on a PC with a three-lane road where participants must change lanes when prompted by road signs (Figure 1). Participants could practice the LCT before the actual task for as long as it took to master the controls. Then the participants had to drive once for three minutes without additional tasks and then once for three minutes with additional tasks. The participants had to simultaneously drive and perform the following tasks consecutively: dial a number on a cell phone, pull a tissue out of its packet, pull an exact amount of change out of a coin-purse, and read out directions.

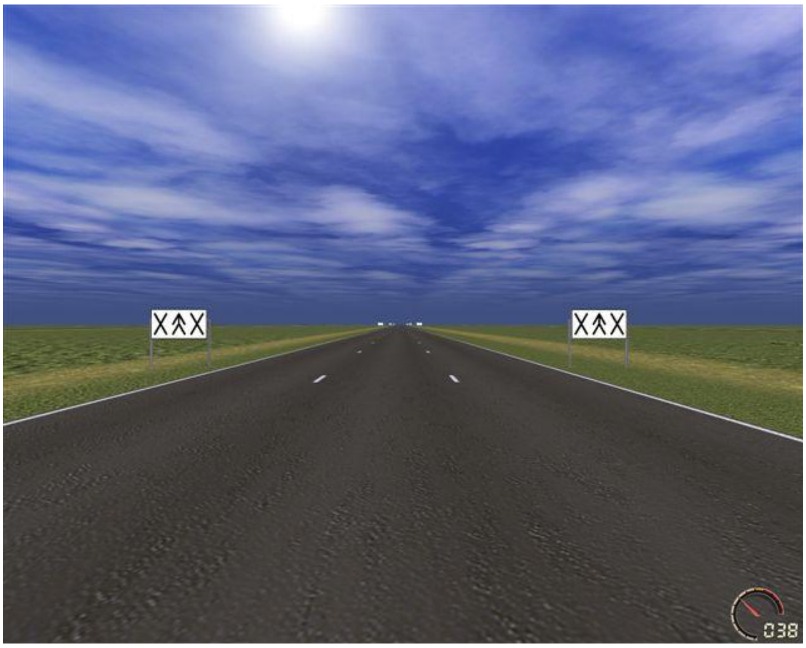

Figure 1: Simulated road with three lanes. According to the sign, the driver has to change to the center lane.

In the office task, participants were shown a word on the screen and they had to decide if the word had zero, one or two spelling mistakes (Figure 2). The participants were allowed to have ten practice trials. Participants then had to do two consecutive blocks of words consisting of 70 words each. In one of the blocks, the participants had to perform a secondary task. They listened to a text being read to them through headphones. They were instructed to listen carefully to the text as they would be asked questions about it at the end of the block.

The participant's heart rate was recorded during the task. Subjective experience was determined with the help of a scale from "relaxed" to "stressed" after each of the task blocks. The sequence of the tasks and the blocks within a task were counterbalanced across participants.

Figure 2: Screen with a word and reaction panel.

Apparatus and materials

For both tasks, a regular consumer PC with a 17" LCD monitor was used. Additionally, a steering wheel was used for the LCT (see Mattes, 2003 for detailed description). The following materials were used for the secondary tasks of the LCT: a cell phone, a coin purse, a pack of tissues, and a short set of printed directions which were to be read out. In the office task, a Schuhfried reaction panel with different colored reaction buttons was used. Stereo headphones (Sony, MDR-CD 780) were used for the listening task. The text was about a shopping situation and lasted 70 seconds. Questions were asked about this text. Preliminary investigation had shown that on average, 7 of the 9 questions could be answered correctly when someone listened to the text only. Heart rate was recorded using a chest monitor (Physiologger from med-NATIC). Subjective mental stress was quantified on a simple sliding scale ranging from "relaxed" to "stressed". A corresponding numeric value ranging from 0 to 10 could be read off the back of the scale.

Data analysis

The performance measure in the LCT was middle lane deviation and this was calculated for both the block with additional tasks and the block without. The simulated width of a lane was 3.85m. The performance measures for the office task were mean reaction time for the correct reaction as well as the total number of correct, incorrect and missed reactions; these were calculated for both blocks. In addition, the number of correct answers to the questions about the spoken text was calculated. Heart rate was recorded for the entire duration of the test. A marker was used to indicate the start and end of a block. Mean heart rate was determined for each of the blocks.

Across all participants, the differences between the conditions "without" and "with" additional task were tested using paired t-tests. Gender and age differences were examined by calculating the differences between the conditions "with" and "without" additional task for each of the dependent variables. This allowed, for example, the difference [lane deviation with additional task minus lane deviation without additional task] to be determined. The subtraction method ensured that absolute differences between the groups were not tested rather that only effects resulting from the dual-task versus single-task were compared. Differences then underwent variance analysis.

Participants

32 female and 32 male participants aged between 21 and 60 years took part in the study (mean age 39.8 yrs). They had different occupations like scientists, technical assistants or cleaners.

There were 4 age groups (21-30 yrs, 31-40 yrs, 41-50 yrs and 51-60 yrs). Therefore, each age group consisted of 4 male and 4 female participants.

Results

Lane change task

Performance and subjective strain

Lane deviation increased significantly from 0.76m without additional task to 1.2m with additional task ($t(63) = -7.4$, $p<.001$). Subjective strain also increased significantly on a 10-point scale from 2.9 to 4.8 ($t(63) = -8.8$, $p<.001$). Figure 3 shows the mean values with standard error for the conditions.

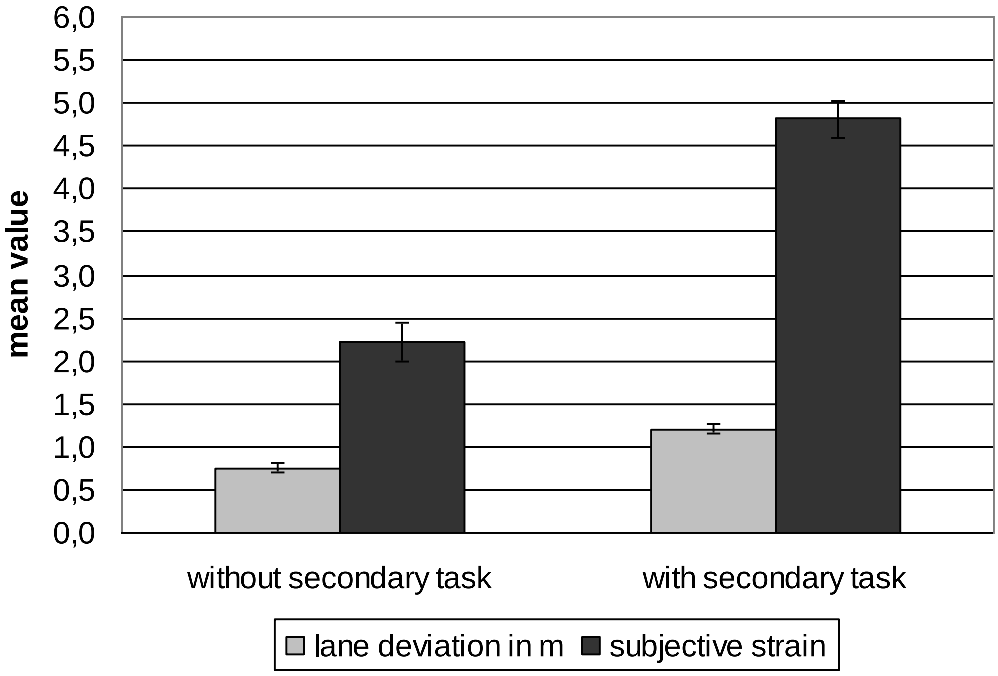

Figure 3: Mean lane deviation and mean subjective strain for the two conditions of the LCT with standard error of mean.

Physiological data

Heart rate differed significantly between the conditions. It increased from 80.5 beats per minute without secondary task to 86.1 beats per minute with secondary task. ($t(51) = -3.9$, $p<.001$).

Group differences

ANOVAs of the differences between the conditions revealed no significant gender or age effects (for all variables $p > .05$).

Office task

Performance

The number of correct, incorrect and missed reactions did not change between the two conditions in the spelling task. The respective means for the condition without secondary task versus the condition with secondary task were: 55.5 versus 55.3 correct reactions, 12.23 versus 12.34 incorrect reactions, and 2.42 versus 2.31 missed reactions. The reaction time for reacting correctly also remained constant. For the single task it was 2.645 ms and with secondary task it was 2.666 ms. However, only 2.27 of the 9 questions asked about the listening text were answered correctly. In a preliminary study with another sample, which consisted mainly of technical engineers only the text was given. Here the number of correct answers was 6.98 ($n = 40$). The difference is significant ($t(102) = 13.55$, $p<.001$, Figure 4).

Subjective strain

Subjective strain increased significantly on a 10-point scale from 3.4 without secondary task to 4.3 with secondary task (t(63) =-5,6, p<.001. Figure 4 shows the mean values with standard error for the two conditions.

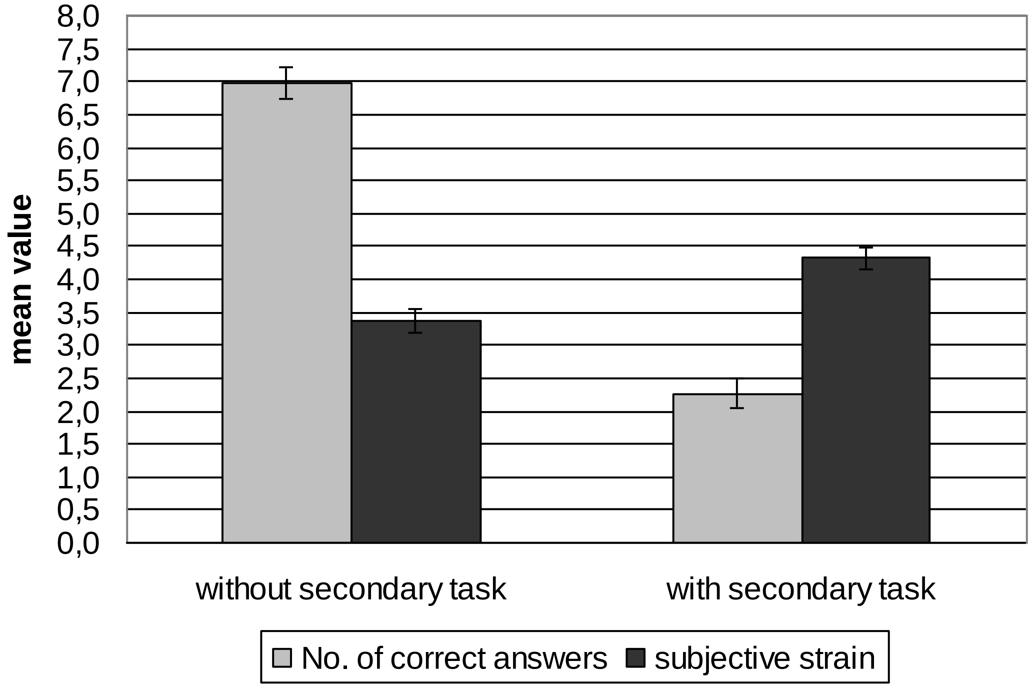

Figure 4: Average number of correct answers about the auditory text and subjective strain for the two conditions of the office task with standard error of mean (the number of correct answers are from different samples, see text).

Physiological data

Heart rate did not differ between the conditions. It was 82.54 beats per minute without secondary task and 82.24 beats per minute with secondary task.

Group differences

ANOVAs of the differences between the conditions revealed no gender effect and only one significant age effect in which the number of correct reactions differed ($F(3,60) = 2.8$, $p < .05$). Post hoc tests (LSD) revealed that the 41-50 year olds differed significantly from the 31-40 year olds and the 51-60 year olds. The 41-50 year olds had fewer correct reactions in the condition with secondary task compared to the condition without, whereas the performance of the other age groups remained virtually constant.

Discussion and conclusion

The aim of the present study was to find out whether there should be paid more attention to multitasking in the area of occupational health and safety. Therefore, by means of two work-related tasks it was investigated how performance, subjective strain and physiological measures change during multitasking. The participants had to perform two tasks with and without additional tasks. In addition to changes in the aforementioned three areas, gender and age differences were also tested.

It was shown that the multitasking condition in the driving task resulted in poorer driving performance as well as increased subjective strain. In addition, a significant increase in heart rate was seen which is also associated with increased stress. There were no gender or age differences between the conditions. In the office task, there was a significant deterioration in performance of the additional tasks as well as an increase in experienced strain. The physiological values did not change. There were no gender differences and no age differences other than for one value.

On the whole, the results show that multitasking in work-related situations leads to mistakes and to mental strain and is therefore of great importance for occupational health and safety. However, the exact effects are dependent on the actual task itself. For example, increased heart rate only occurred during the driving task and not during the office task. It seems likely that contrary to instructions, participants ignored the secondary task, that is, they did not listen to the text. This explains the poor performance in answering questions about the text. This means that, for the participants, the dual-task condition actually presented itself quasi as a single-task condition. This explains why there was no increase in heart rate during the entire task. Only when answering the questions did participants become aware that they had not been listening. This resulted in the increase in subjective strain which occurred afterwards.

An interesting finding of the study is that there were no gender differences. Up to now there has been almost no data concerning the question of gender differences. The finding shows that it cannot be categorically assumed that men and women differ in their ability to multitask. This can, of course, depend on the type of task and should be further investigated. If there were gender differences dependent on the type of task this should be considered in job design in order to prevent persons from strain.

The lack of any age differences in the age group studied (20-60 yrs) is also interesting. Previous findings have shown age effects for multitasking. Generally speaking, however, a drop in performance is only seen in people aged from around 70 years old. Looking at people of normal working age there are no clear changes as a result of age. In this experiment, an age difference in multitasking could only be seen in one of the performance measures. Post hoc tests showed that the effect was not in the oldest group but rather in the group aged 41-50. This confirms the finding of West and Larrabee (1993), that there is some variability in the middle years. The degree to which age differences are dependent on the type of task could also be investigated in further studies.

Multitasking in work-related situations, and presumably in real workplaces, can lead to mistakes and mental strain. Not only could this result in possible business losses, but it also has important implications for occupational health and safety. In real-world working conditions, these mistakes might not only result in reduced performance but also cause accidents and corresponding health consequences. Strain caused by continuous multitasking could also have a negative impact on the health of those involved. Multitasking also has possible long term consequences as suggested in the study of Ophir, Nass and Wagner (2009): If the ability to concentrate diminishes as a result of multitasking, this can lead to an even higher level of error rate in performance. On the other hand, basic research such as that done by van Selst, Ruthruff and Johnston (1999) has shown that multitasking can be practiced. It would be interesting to investigate whether sustained multitasking of real-world-like tasks has more of a negative effect in the long term or whether it results in practice effects. Presumably this depends on the type of task. If a task can be automated and therefore needs less attention after some exercise, it can be carried out simultaneously with another task. Realistically speaking it is probably impossible to completely eliminate multitasking from the workplace and so it makes sense to look closely at the situations in which multitasking is particularly critical. Two questions should be considered when deciding if multitasking should be prevented:

1. Can the task be automated?
2. What are the possible consequences of mistakes?

If the tasks cannot be automated, mistakes as well as mental strain will probably increase. If the consequences can be (fatal) accidents, multitasking might be dangerous. One example for such dangerous multitasking is cell phone usage while driving. As a consequence, companies should discuss the mentioned two questions for different types of tasks and define when multitasking has to be suppressed. It is also important to investigate how much multitasking can be reduced through measures either at the organizational or at the individual level. A study by Lehle, Steinhauser and Hübner (2009) is of particular interest in relation to this last point. They had participants perform reaction tasks either in parallel or in serial, and raised the subjectively experienced level of effort. Although the reaction times and the error rate during the parallel tasks were higher than during the serial tasks, the participants experienced more effort under the serial condition than under the parallel condition.

Performance and subjective strain, therefore, were not connected in this study. It is possible that the reason for this was that participants were under the illusion that they were faster when doing tasks in parallel even though this was not actually the case. The result suggests that simply asking people to do less multitasking will not have any effect. As long as people subjectively perceive multitasking as less stressful than performing tasks consecutively, they most likely will not change their behavior. However, whether this finding can be replicated in real-world-like situations should be further verified.

Anyhow, multitasking for critical tasks as described above should be prevented by a corresponding work organisation, e.g. to define certain hours in which e-mails are not read or answered. An appropriate corporate culture might also help, i.e. that multitasking is not appreciated as outstanding performance.

Of course one limitations of this study is, that it did not examine real word situations, but only related scenarios. One problem with real work situations are the real dangers the participants would be exposed to. Therefore, simulation studies are a possible research method. Furthermore subjective strain as well as physiological parameters could be examined by using more complex data collection. However, on the whole, the present study verified that multitasking is of great relevance for occupational health and safety and should be analyzed more detailed than it has been done until now. This might help to reduce mental strain as well as mistakes and possible accident.

References

Crossley, M. & Hiscock, M. (1992). Age-related differences in concurrent-task performance of normal adults: Evidence for a decline in processing resources. *Psychology and Aging, 7*, 499-506.

Crook, T. H., West, R. L. & Larrabee, G. L. (1993). The driving-reaction time test: assessing age declines in dual-task performance. *Developmental Neuropsychology, 9*, 31-39.

Dey, M., Gschwend, B., Baumgartner, T., Jäncke, P. & Jäncke, L. (2006). Effekte von Musik auf das Fahrverhalten. *Zeitschrift für Verkehrssicherheit, 1*, 32-36.

Freude, G. & Ulsperger, P. (2010). Unterbrechungen bei der Arbeit und Multitasking in der modernen Arbeitswelt – Konzepte, Auswirkungen und Implikationen für Arbeitsgestaltung und Forschung. *Zentralblatt für Arbeitsmedizin, 60*, 120 – 128.

Haigney, D.E., Taylor, R.G. & Westerman, S.J. (2000). Concurrent mobile (cellular) phone use and driving performance: Tasks demand characteristics and compensatory processes. *Transportation Research Part F, 3*, 113-121.

Kiefer, J., Schulz, M., Schulze-Kissing, D. & Urbas, L. (2006). Multitasking-Strategien in der Mensch-Maschine-Interaktion. *MMI-Interaktiv, 11*, 26-42.

Koch, I. (2008). Mechanismen der Interferenz in Doppelaufgaben. *Psychologische Rundschau, 59*, 24-32.

Kramer, A. F. & Parasuraman, R. (2007). Neuroergonomics: Application of neuroscience to human factor. In J. Cacioppo, L. Tassinary & G. Bertson, *Handbook of Psychophysiology*, 3rd edition. N.Y.: Cambridge University Press, 704-722.

Lehle, C., Steinhauser, M. & Hübner, R. (2009). Serial or parallel processing in dual tasks: What is more effortful? *Psychophysiology, 46*, 502-509.

Mattes, S. (2003). The Lane-Change-Task as a tool for driver distraction evaluation. In H. Strasser, K. Kluth, H. Rausch & H. Bubb (Eds.). *Quality of Work and Products in Enterprises of the Future* (pp. 57-60). Stuttgart: Ergonomia Verlag.

McCartt, A. T., Hellinga, L. A. & Braitman, K. A. (2006). Cell phones and driving: Review of research. *Traffic Injury Prevention, 7*, 89-106.

Pashler, H. (1994). Dual-task interference in simple tasks: Data and theory. *Psychological Bulletin, 116*, 220-244.

Ophir, E., Nass, C. & Wagner, A. D. (2009). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences, 106*, 15583-15587.

Priest, A. W., Salamon, K. B. & Hollman, J. H. (2008). Age-related differences in dual task walking: a cross sectional study. *Journal of NeuroEngineering and Rehabilitation, 14*, 29.

Riby, L. M., Perfect, T. J. & Stollery, B. T. (2004). The effects of age and task domain on dual task performance: A meta-analysis. *European Journal of Cognitive Psychology, 16*, 863-891.

Saucier, D., Bowman, M. & Elias, L. (2003). Sex differences in the effect of articulatory or spatial dual-task interference during navigation. *Brain and Cognition, 53*, 346-350.

Strayer, D. L. & Johnston, W. A. (2001). Driven to distraction: Dual-Task studies of simulated driving and conversing on a cellular telephone. *Psychological Science, 12*, 462-466.

van Selst, M. & Jolicoeur, P. (1997). Decision and response. *Cogntive Psychology, 33*, 266-307.

van Selst, M., Ruthruff, E. & Johnston, J. C. (1999). Can practice eliminate the psychological refractory period effect? *Journal of Experimental Psychology: Human Perception and Performance, 25*, 1268-1283.

Voelcker-Rehage, C. & Alberts, J. L. (2007). Effect of motor practice on dual-tasl performance in older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 62*, 141-148.

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