Do People Use External Representations to Relief Their Problem State?

Bachelor's Thesis

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Abstract: The goal of this study is to find out whether people use information in their environment to diminish the interference in their problem state. Theories on multitasking focus on trying to predict when and why tasks interfere. In an earlier study Borst, Taatgen and Van Rijn (2010) showed the problem state caused interference in a dual task, consisting of a subtraction task and a text entry task, if both tasks needed the problem state module. We used an eyetracker to look how this interference influenced the eye movements made during this task and to find out if the interference will become less when there is information presented on the screen that represents the information that had to be kept in the problem state. Our results show that when the information is presented on the screen in a clear manner the response times and the fixations used to solve these tasks will decline. This suggests that people do use information in their environment to diminish the interference in their problem state..

1. Introduction

Walking down the streets in the city on a Saturday afternoon, you come across many examples of two interfering tasks. Business men who are trying to talk on the phone while driving, boys watching girls while riding their bikes and tourist trying to read a map while walking. This is a good example of the ability of human beings to do several tasks at once. While this capability works effortless in certain situations, like walking, talking and waving at a friend, there are other examples suggesting it is nearly impossible to execute two tasks at once (e.g. reading an article and watching television). Here we will discuss interference in working memory and the relation this has with eye movements.

1.1. Threaded Cognition

During multitasking several tasks have to be active in the brain at the same time. These different tasks result in different streams of information which have to be coordinated and distributed over the cognitive resources available. According to the theory of threaded cognition (Salvucci & Taatgen, 2008) interference between tasks occurs when multiple tasks require the same cognitive, perceptual or motor resources. These resources can operate in parallel but a single resource can only execute one operation at a time. The threaded cognition theory states that streams of thought are presented as threads through the brain. Although several threads can be active simultaneously, a resource cannot be used by multiple threads at the same time. Interference occurs when several threads have to use the same resource at the same time.

1.2. The Problem State: a Cognitive Bottleneck in Multitasking

One of the resources in which interference can occur is the problem state. The problem state, also known as the imaginal module, is the module which holds the current representation of the problem or task someone is working on. While solving the equation "3x – 5 = 7" one of the problem states could be "3x = 12" (Anderson, 2007).

Interference in the problem state resource is discussed by Borst, Taatgen & Van Rijn (2010). They define the problem state resource as the resource maintaining intermediate information that is necessary to perform a task. However, tasks in which no intermediate results have to be stored or tasks in which all relevant information is present in the environment do not need the problem state resource.

By conducting three experiments Borst et al. (2010) examined whether the problem state resource acts as a bottleneck when doing multiple tasks at the same time. When multiple tasks had to use the problem state resource to maintain information at the same time the amount of errors increased, while the response time increased. These results indicate that the problem state acts as a source of interference during multitasking. A cognitive model was developed to show that a problem state bottleneck can explain the data.

1.3. Minimal Control Principle and the Problem State

To find out if external information can relieve the task of the problem state we want to extrapolate the minimal control principle (Taatgen, 2007) to the problem state. Taatgen proposed the minimal control principle as a way to model cognitive tasks more flexible and realistic. The minimal control principle says that information from the environment is used to control the actions one takes. Top-down control, control from within, should be as minimal as possible. When information is presented on the screen this should relieve the brain of some of it's workload by not needing a control state anymore. In the case of the problem state this means that information about intermediate steps of a task are presented in the environment so there is no need to keep a problem state.

1.4. Eye Movements

We will look at the eye movements of our participants during a dual task to see whether information in the environment, in our case on the screen, is used instead of keeping a problem state.

Human vision can roughly be divided in two main activities: fixations and saccades. Fixations are moments on which the eyes are focused on one point, while saccades are the movements which redirect the eye to a new part of the environment (Land, 2006). In 1900 Dodge showed that information from the surroundings is absorbed during fixations. Activity in the visual cortex of the brain is the processing of this information. During saccades no information is taken in and no processing of visual information is needed.

Fixations give us therefore insight in the information needed and the information used to solve a problem or task. The fMRI experiment performed by Borst, Taatgen, Stocco and Van Rijn (in preparation) shows there is more visual activity when both tasks of the dual task are hard. This should correspond to more fixations during this condition.

1.5. Current Study

In this study we will continue to investigate the interference in the problem state and we want to find a way to overcome this interference. Therefore the question we ask in this paper is do people use information that is presented to them on the screen instead of keeping a problem state? We also want to support the model of Borst et al. (2010) by examining the eye movements participants make when doing the dual task.

To answer this question we constructed three variants of a dual task based on the first experiment of Borst, Taatgen and Van Rijn (2010). The typing task was the same for all variants. The subtraction task differed in the amount of information that was shown on the screen (Figure 1.1). The variant with one column resembles the original task the most and is also used in Borst, Taatgen, Stocco and Van Rijn (in preparation). In the variant with the signal the information that normally would need to be kept in the problem state is presented on the screen in a clear manner, no extra calculations are needed. This should

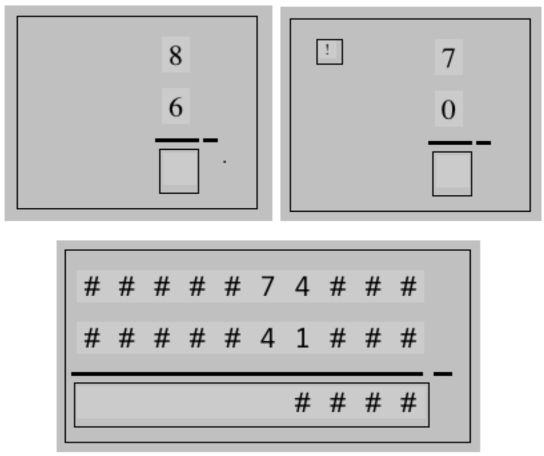

Figure 1.1: The three variants of the subtraction task. In the upper left corner the standard task is shown. In the upper right corner the variant with one column and a signal is shown. The lower panel shows the variant with the columns.

reduce the interference in the problem state. The task with two columns contains the same information by showing the previous subtraction. Except this time the effort of recalculating the previous subtraction is necessary to access this information. The typing task remained the same as the original task in all variants.

All tasks had an easy variant, in which it was not necessary to maintain a problem state and a hard variant, in which a problem state could be used to maintain the intermediate results of the task. For the subtraction task this meant that the number of carries varied. In the easy variant there were no carries, while in the hard variant there were six carries. In the easy text entry task only one letter at a time had to be entered, in the hard text entry task a word had to be memorized at the start of the task and the participant had to remember what letter it had to typ in next.

We expect that the interaction effect of the reaction times between subtraction difficulty and text entry difficulty found in the original experiments (Borst et al., 2010; Borst et al., in preparation) will be present in the variant with one column because a problem state has to be kept when both tasks are hard. According to the results of Borst et al. (in preparation) the visual activity also shows an interaction effect between subtraction difficulty and text entry difficulty. We expect to see this interaction effect in the number of fixations. In the variant with two columns it is not necessary to keep a problem state but due to the costs in time and effort to recalculate the previous subtraction it may be easier to store the representation in the problem state. Here more information is present on the screen and therefore more fixations will be needed. Therefore, here too an interaction effect is expected but overall the reaction times and the fixations will be higher than in the variant with only one column. In the variant with a signal there is no need to keep a problem state in the hard condition because all the information needed is presented on the screen. We therefore hypothesize that we will find no difference between the condition where both tasks are hard and the condition where only the subtraction task is hard. The hard condition will take some extra time and fixations in comparison to the easy condition because you have to look at the signal to find out whether a carry is in progress.

Because the only task that varied was the subtraction task, we expect to find the differences between the variants in the subtraction task and not in the typing task.

To support the model we looked at the number of fixations that were needed to do one column of the subtraction.

2. Methods

2.1. Participants

Sixteen students from the University of Groningen (Groningen, the Netherlands), in the age range from 19 to 28 (mean age: 22.7), participated in our experiment. Seven of the participants were female. All participants had normal or corrected-to-normal vision. Before testing informed consent was obtained as was approved by the Ethical Committee Psychology of the University of Groningen.

2.2. Apparatus

The eye tracker used in the experiment was the EyeLink 1000 (SR-Research). For better accuracy we applied a chin rest. A 20 inch monitor was used to present the stimuli to the participant.

2.3. Tasks and Stimuli

The experiment consisted of two tasks which had to be carried out concurrently. To achieve this participants had to alternate between parts of the task until the task was done. The two tasks were a subtraction task and a text entry task.

The Subtraction Task. Every trial of the subtraction task represented a ten column subtraction. Not all ten columns where shown at the same time. Participants were told, however, to treat the single or double columns shown as if they belonged to a ten digit subtraction. The subtraction could be easy or hard. When the subtraction was easy the upper term was always larger than the lower term. When the subtraction was hard the upper term was smaller than the lower term in six of the ten columns, when this happened one power of ten had to be borrowed from the digit to the left of the upper term. Because of the possibility of a borrowing in the hard condition, participants had to remember whether the previous subtraction caused a borrowing. They could use their problem state or the information on the screen (signal, previous column) for this.

There were three different variants of the subtraction task (Figure 1.1). The first variant was the single column subtraction in which participants saw one column of the subtraction at a time. The second variant was the double column subtraction. Two columns at a time were visible in this variant. It was possible to look back to the previous column to see whether the previous column caused a borrowing. The third variant was the single column condition with signal. Here, only one column at a time was shown to the participants. When the previous column caused a borrowing, an exclamation mark appeared in a box in the upper left corner of the subtraction pane. When the previous subtraction did not cause a borrowing, a dash appeared in the upper left corner. Participants had to clearly look away from the column to see the signal, but because of the signal it was not necessary to keep in their problem state whether there was a borrowing in progress.

The Text Entry Task. The text entry task was also presented in an easy condition and a hard condition. There were no different variants of the text entry task. In the easy condition a letter appeared on the screen. Participants had to enter the correct letter. No information had to be remembered. In the hard condition a ten letter word was shown on the first time the typing task was enabled. After the first letter was entered no word or letters were shown anymore, participants had to remember the word and the next letter they had to enter. Every trial consisted of ten letters that had to be entered.

Stimuli. For the subtraction task we

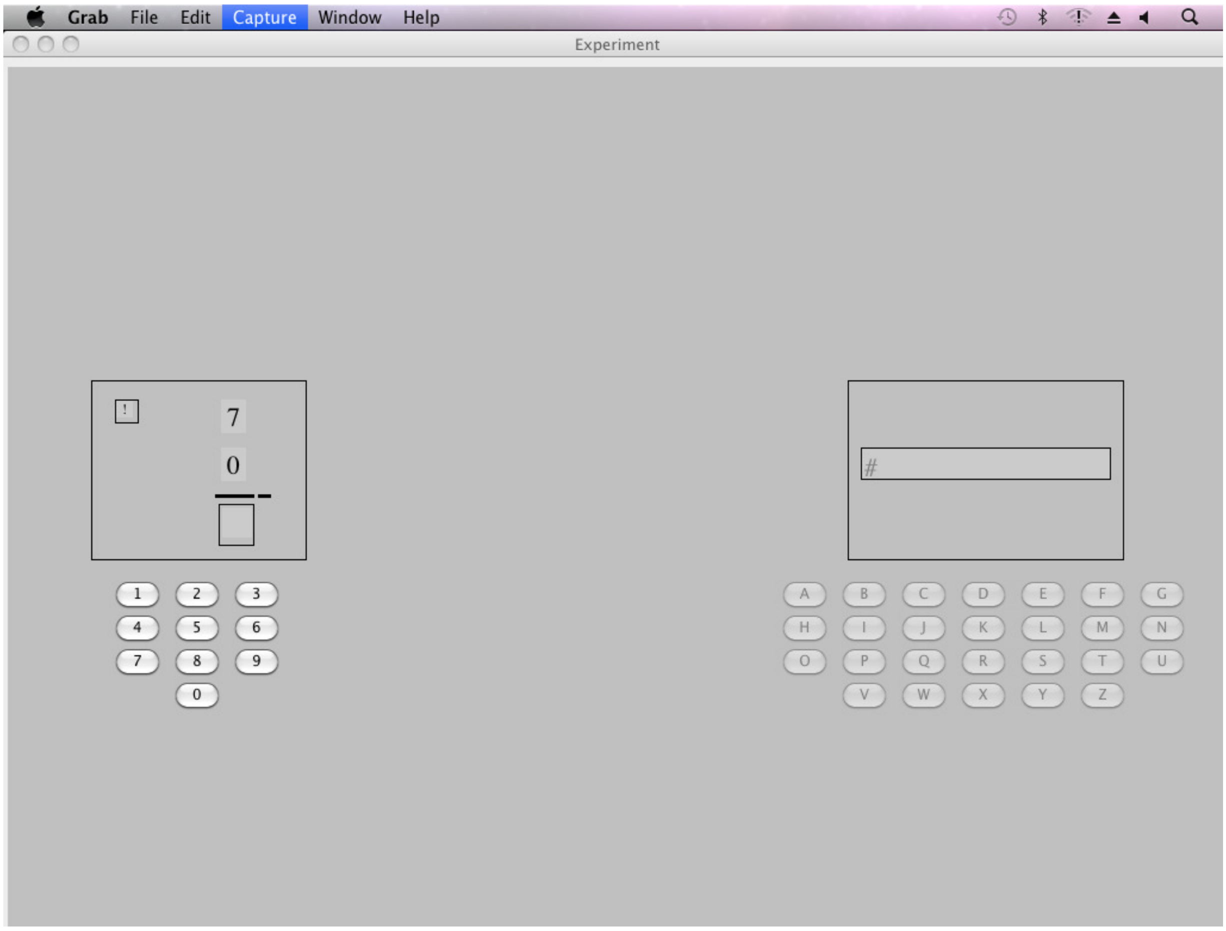

Figure 2.1: Screenshot of the experiment while the subtraction task is active. The variant shown here is the variant with signal.

used two random generated ten digit numbers which had to be subtracted. In the easy condition the upper number contained no digits which were smaller than the corresponding lower digit. In the hard variant the upper number contained six digits which were smaller than the corresponding lower digit so the participant had to borrow from the next digit.

The stimulus for the text entry task was a ten letter word. The words were selected from the most frequent ten letter words from the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993). It was made sure that the words selected were not too similar to eachother. For the easy variant the words were scrambled and the letters were presented in a meaningless order.

The experiment was presented full screen. The subtraction task was located on the left of the screen, the text entry task on the right side of the screen (see Figure 2.1). The text entry panel was 9 cm wide. The width of the subtraction panel varied for the different variants. With one column (with or without signal) the width was 7 cm. With two columns the width of the panel was 12 cm. The height of all panels was 6 cm. The space between the subtraction panel and the text entry panel was 18 cm for the one column variants and 13 cm for the two columns variant. The distance from the signal to the subtraction was 2.7 cm. Participants were sitting at a normal viewing distance, approximately 75 cm from the screen.

2.4. Design and Procedure

Before the experiment started, participants had to complete 12 practice trials. The eye tracker was not used during this practicing. These trials consisted of two easy and two hard typing trials and eight easy and eight hard subtraction trials. As each trial started a fixation cross appeared on the screen for two seconds after this two circles where shown on the screen, one on the left, representing the subtraction task, and one on the right, representing the text entry task. Each circle had a green fill if the task at hand was easy and a red fill if the task was hard.

Participants first practiced with a ten column subtraction task, after which they were presented the three versions of the subtraction task (two column, one column with signal, one column without signal, in that order). The final practice trial consists of the typing task. Each of these trials was practiced twice in each of the conditions (easy/hard), except for the variant with the signal which was only practiced in the hard condition as the easy condition is the same as in the variant with one coulumn. At the end of each trial, in the practice trials as well as the experimental trials, feedback was shown to the participants which let them know how many mistakes they made. After the first practice trials, the eye tracker was calibrated.

Then the actual experiment started. It consisted of three parts, one for each variant. The order of the variants was counterbalanced over participants. The eyetracker had to be recalibrated before every variant. For each variant they had to complete four practice trials and sixteen experimental trials. The conditions of the practice trials were in a fixed order (subtraction/typing: easy/easy, easy/hard, hard/easy, hard/hard) and let the participants practice the subtraction task of the concerning variant in combination with the typing task. The experimental trials were divided in four blocks of four trials. In each block the participants were presented with all the different combinations of conditions in a randomized order. In between trials there was some time to take a break.

Each trial started with the presentation of the subtraction task. When a digit for the subtraction task was entered, the subtraction panel became inactive and the corresponding keyboard was disabled, the text entry panel turned active and the corresponding keyboard was enabled. After a letter for the text entry task had been entered the text entry panel became inactive and the text entry keyboard was disabled, the subtraction panel turned active and the subtraction keyboard became enabled. In the hard conditions information about the task had to be kept for one task

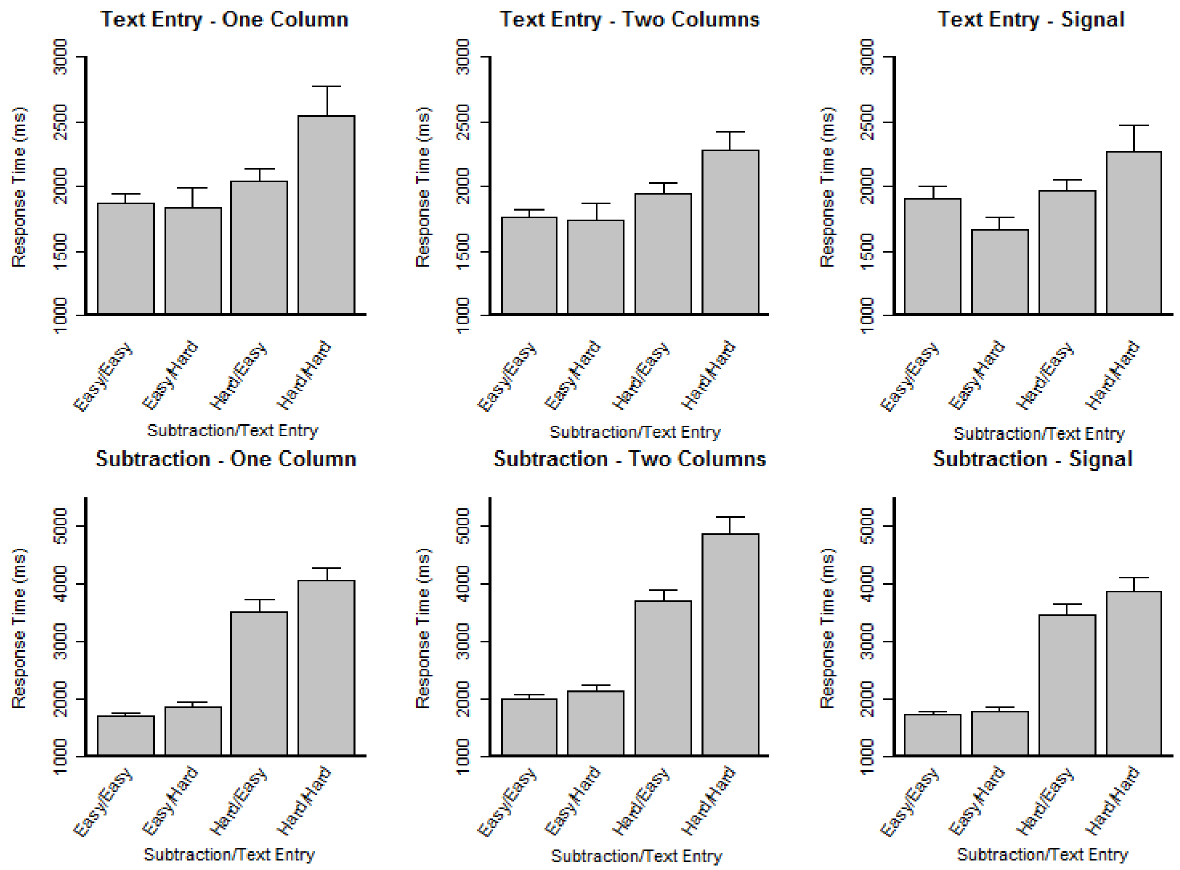

Figure 3.1: Response times on the textry entry task and the subtraction task.

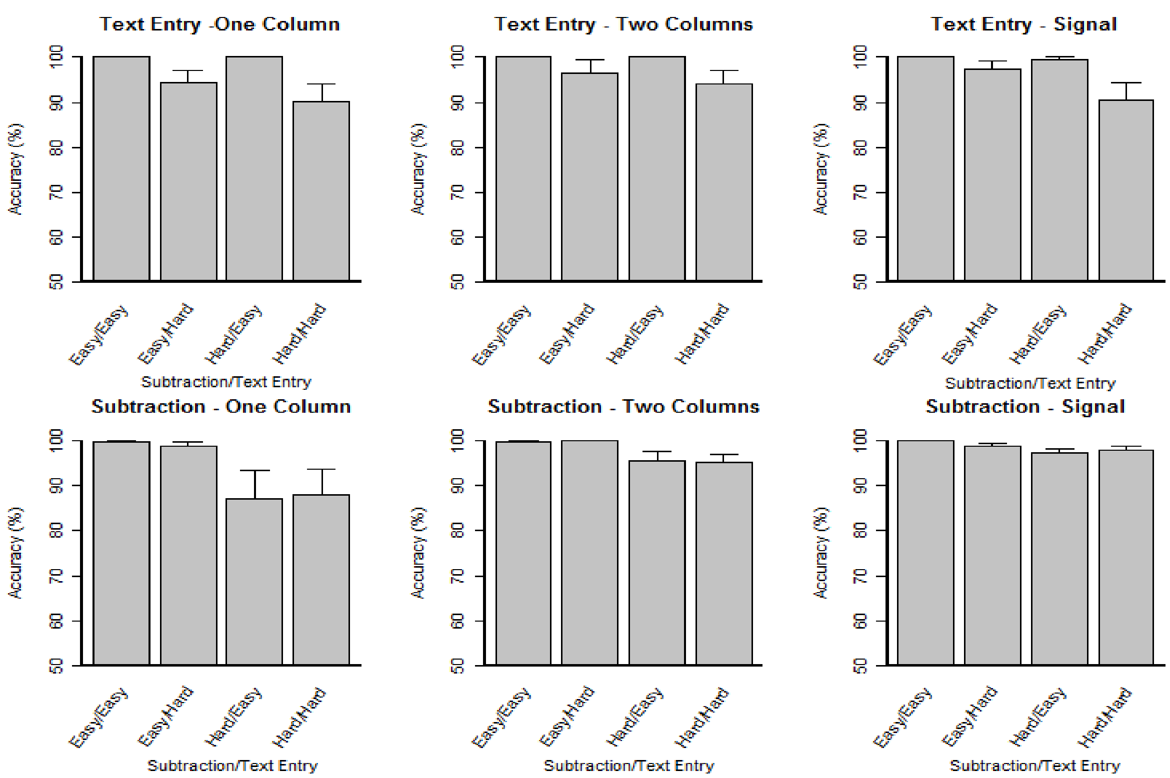

Figure 3.2: Accuracy on the text entry task and the subtraction task.

while doing the other task. This setup forced the participants to preserve the information to be kept in their problem state.

3. Results

Due to technical difficulties only the data of the second and the fourth experimental blocks were analyzed. Three participants were removed from the data set. Responses faster than 250 ms were removed as well as responses slower than 10000 ms. In total 1.9 % of the data was removed. The reported F and p values are the result of repeated measures analyses of variance. All error bars represent standard errors. When the p-value of the results was below the 0.05 level the results were judged significant. For clarity the results of the main effects are not reported in the text.

3.1. Response Times

The response time is the time between entering a digit for the subtraction task and subsequently entering a letter for the typing task or vice versa. The first digit entered was not analyzed because it is the first response in each trial. So from every trial 19 (nine subtraction, ten text entry) responses are analyzed.

The reaction times for the subtraction task are shown in the upper panels of Figure 3.1. The interaction between subtraction difficulty and text entry difficulty did not differ between the three variants, $F(2,24) = 2.93$, $p = 0.07$, $\eta_p^2 = 0.20$. There were main effects of variant, subtraction difficulty and text entry difficulty. In both the variant with one column and the variant with two columns a significant interaction effect between subtraction difficulty and text entry difficulty was found in the subtraction task, $F(1,12) = 5.80$, $p = 0.03$, $\eta_p^2 = 0.33$ (one column), $F(1,12) = 19.19$, $p < 0.01$, $\eta_p^2 = 0.62$ (two columns). In the variant with the signal no significant interaction between subtraction difficulty and text entry difficulty was found, $F(1,12) = 2.53$, $p = 0.14$, $\eta_p^2 = 0.17$.

The reaction times for the text entry task are shown in the lower panels of Figure 3.1. In all variants there is a significant interaction effect, $F(1,12) = 11.13$, $p < 0.01$, $\eta_p^2 = 0.48$ (one column), $F(1,12) = 6.32$, $p = 0.03$, $\eta_p^2 = 0.34$ (two columns), $F(1,12) = 12.77$, $p < 0.01$, $\eta_p^2 = 0,51$ (one column with signal) and all variants show a main effect of subtraction difficulty but not of text entry difficulty. Overall there is no difference between the interaction effect for the different variants, $F(2,24) = 0.53$, $p = 0.59$, $\eta_p^2 = 0.04$. When the tasks were harder, the response times were higher and when both tasks were hard there was an additional increase in response time.

3.2. Accuracy

The accuracy represents the percentage of trials that is correctly executed. The upper panels in Figure 3.2 shows how accurate the participants were on the subtraction task. In the subtraction task there is a significant effect of subtraction difficulty, $F(1,12) = 8.10$, $p = 0.01$, $\eta_p^2 = 0.40$, but no interaction effect between subtraction difficulty and text entry was found, $F(1,12) = 1.11$, $p = 0.31$, $\eta_p^2 = 0.08$. Neither was there a difference between the three variants $F(2,24) = 1.57$, $p = 0.23$, $\eta_p^2 = 0.12$. The lower panels of Figure 3.2 depict the accuracy on the text entry task. There is only a significant effect of text entry difficulty $F(1,12) = 23.24$, $p < 0.01$, $\eta_p^2 = 0.66$. No interaction effect of subtraction and text entry difficulty was found $F(1,12) = 2.84$, $p = 0.11$, $\eta_p^2 = 0.19$ and there was no difference between the variants, $F(2,24) = 0.05$, $p > 0.5$, $\eta_p^2 < 0.01$.

3.3. Eye Tracking

Overall. The patterns observed in the reaction times can also be seen in the number of fixations. The number of fixations is the mean number of fixations on the whole screen during a trial. Figure 3.3 shows the mean number of fixations in all the different variants. There is a significant difference in the interaction effect between the three variants, $F(2,24) = 5.46$, $p = 0.01$, $\eta_p^2 = 0.31$, with main effects of variant and subtraction difficulty, but not off text entry difficulty. In both the variant with one column and the variant with two columns there is a significant interaction between subtraction difficulty and text entry difficulty, $F(1,12) = 12.29$, $p < 0.01$, $\eta_p^2 = 0.51$ (one column), $F(1,12) = 30.32$, $p < 0.01$, $\eta_p^2 =$

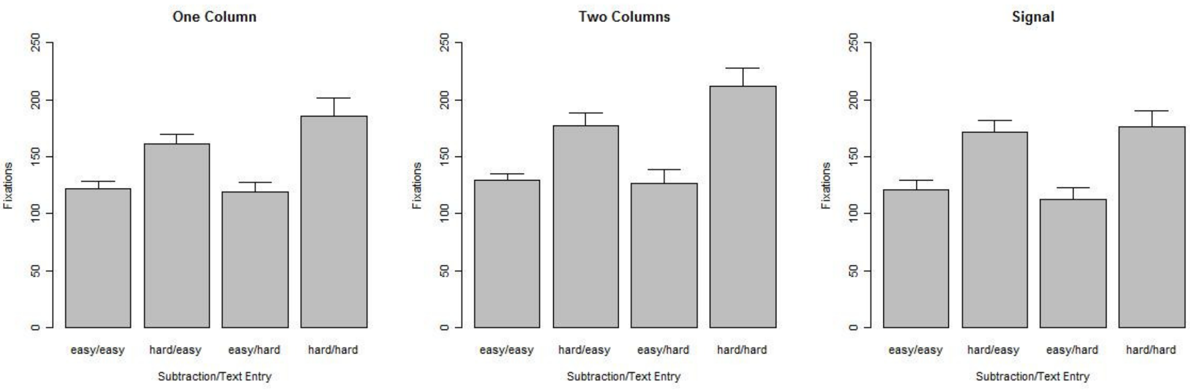

Figure 3.3: Average number of fixations for one trial on the whole screen.

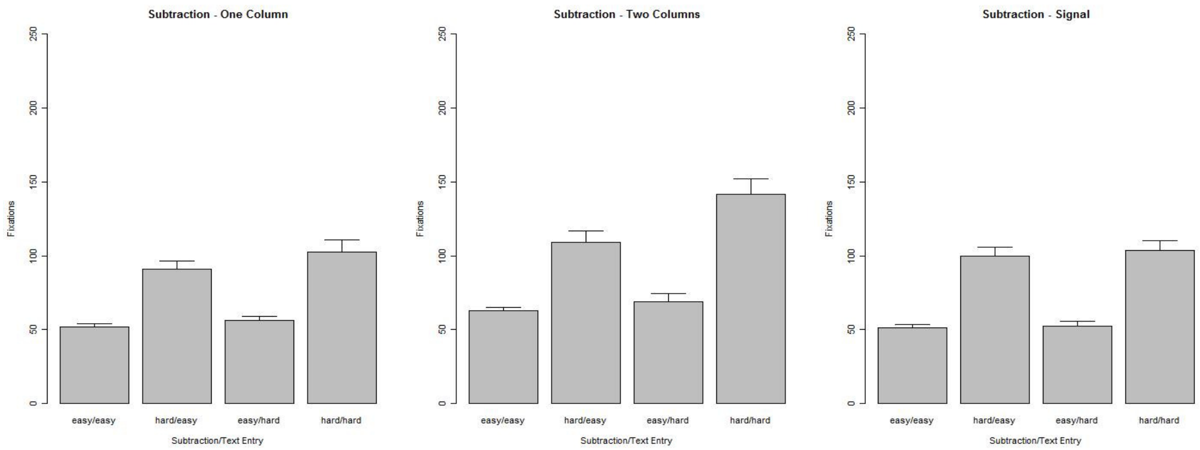

Figure 3.4: Average number of fixations for one trial on the left side of the screen (Subtraction)

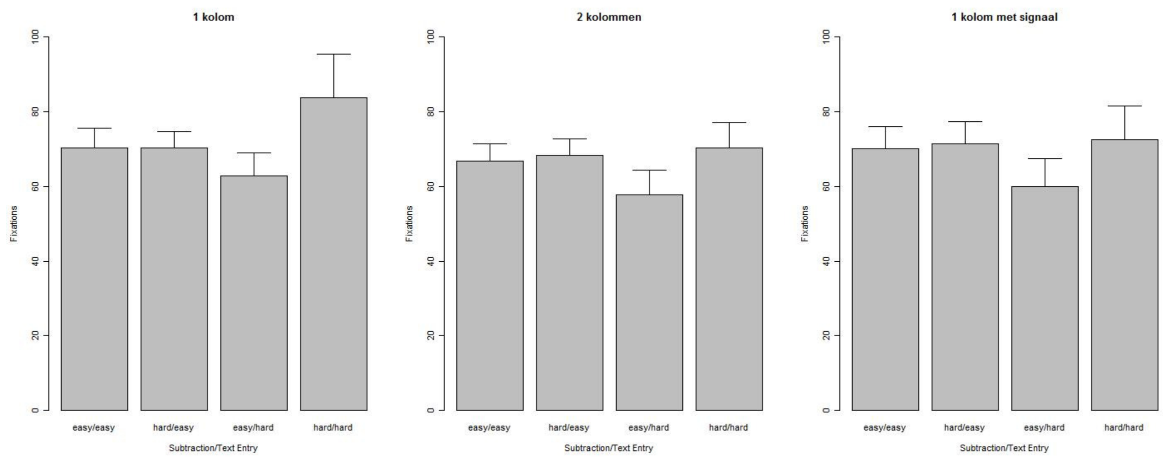

Figure 3.5: Average number of fixations for one trial on the right of the screen (Text Entry)

0.72 (two columns) and both variants show a main effect of subtraction difficulty but only the variant with two columns shows a main effect of text entry difficulty. The variant with one column and the signal also shows a small interaction effect, $F(1,12) = 6.19$, $p = 0.03$, $\eta_p^2 = 0.34$. This variant also shows only a main effect of subtraction difficulty, not of text entry difficulty. Harder tasks require more fixations and when both tasks are hard the number of fixations increases even more.

Subtraction. The fixations made on the left side of the screen (< 512 pixels) are counted as belonging to the subtraction task. Figure 3.4 shows the mean number of fixations per trial on the left side of the screen.

There is a difference in the interaction effect between the variants, $F(2,24) = 3.55$, $p = 0.04$, $\eta_p^2 = 0.23$, with main effects of variant, subtraction difficulty and text entry difficulty. In both the variant with one column and the variant with a signal there is no interaction effect of subtraction difficulty and text entry difficulty, $F(1,12) = 0.96$, $p = 0.35$, $\eta_p^2 = 0.07$ (one column), $F(1,12) = 0.23$, $p > 0.5$, $\eta_p^2 = 0.02$ (signal). Both variants show main effects of subtraction difficulty, but not of text entry difficulty. In the variant with two columns there is a significant interaction effect of text entry and subtraction difficulty, $F(1,12) = 8.98$, $p = 0.01$, $\eta_p^2 = 0.43$, there is a significant main effect of both text entry difficulty and subtraction difficulty.

Figure 3.6 shows the mean number of fixations per column in every variant. In the variant with one column the mean number of fixations needed to solve a column of the easy subtraction is 5.4, the mean number of fixations needed to solve a column of the hard subtraction is 9.66. For the variant with two columns these two numbers are respectively 6.58 and 12.55. For the variant with a signal the numbers are 5.18 and 10.18.

Text Entry. The fixations made on the right side of the screen (> 512 pixels) belong to the text entry task. Figure 3.5 shows the mean number of fixations per trial on the right side of the screen.

There is no significant difference in the interaction effect of subtraction difficulty and text entry difficulty, but there is a main effect of subtraction difficulty. No main effect of text entry difficulty or variant is present. There is an interaction effect of subtraction difficulty in the variant with one column and the variant with two columns $F(1,12) = 11.91$, $p < 0.01$, $\eta_p^2 = 0.50$ (one column), $F(1,12) = 12.57$, $p < 0.01$, $\eta_p^2 = 0.51$ this effect is not present in the variant with signal, $F(1,12) = 3.72$, $p = 0.08$, $\eta_p^2 = 0.24$. All three variants show main effects of subtraction difficulty, but not off text entry difficulty.

Time Independent. To make the number of the fixations independent from the different durations of the trials we divided the number of fixations by the time the trial took. The results of this are in Figure 3.7.

All the variants had a significant interaction effect of text entry difficulty and subtraction difficulty, $F(1,12) = 12,29$, $p < 0.01$,

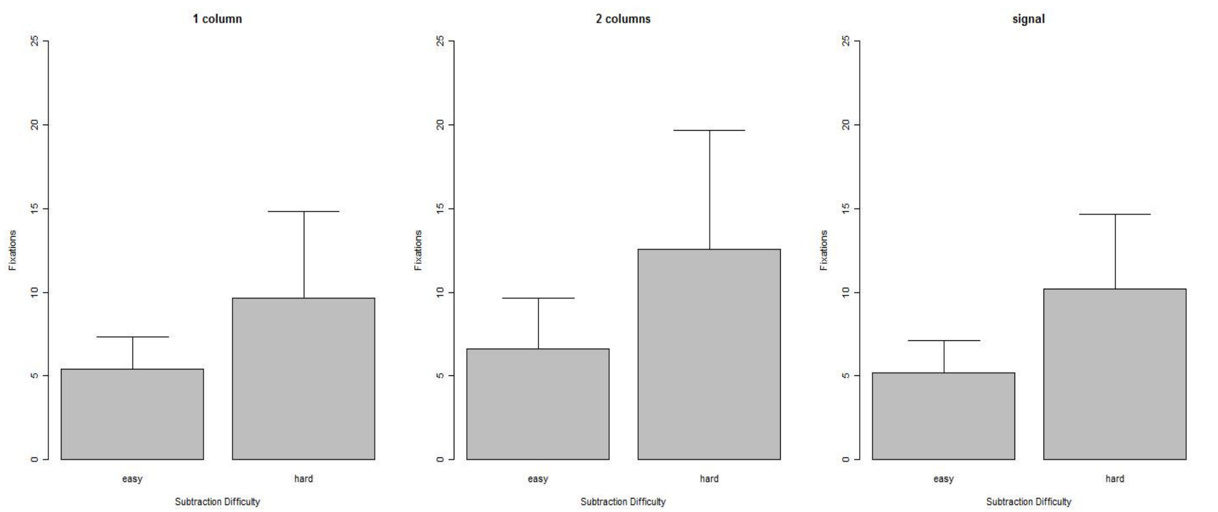

Figure 3.6: The mean number of fixations per column.

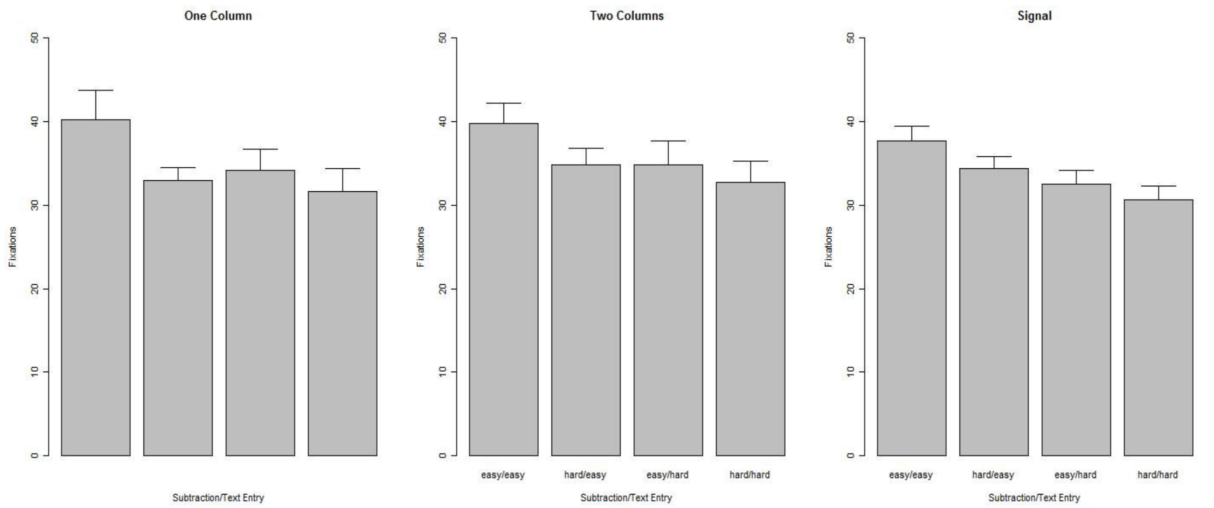

Figure 3.7: The mean number of fixations per trial, normalized for duration.

$\eta_p^2 = 0.51$ (one column), $F(1,12) = 30.318$, $p < 0.01$, $\eta_p^2 = 0.72$ (two columns), $F(1,12) = 6.19$, $p = 0.03$, $\eta_p^2 = 0.34$. All variants had a main effect of subtraction difficulty, but only the variant with two columns had also a main effect of text entry difficulty. There was a significant difference between the variants, $F(2,24) = 5.46$, $p = 0.01$, $\eta_p^2 = 0.31$ with main effects of subtraction difficulty and variant.

4. Discussion

We have investigated if people use their environment instead of their problem state for keeping intermediate information. We hypothesized that an overadditive interaction effect of subtraction difficulty and text entry difficulty is present when there is no information present on the screen (the variant with one column) but this effect is not seen when the information is clearly presented on the screen (the variant with a signal). No problem state has to be kept in the hard condition of the subtraction task with the signal, so there should be no overadditive increase in reaction times or fixations. In the two column variant there is more information presented on the screen. To process this information, more time and fixations should be needed than in the one column varian, but the interaction effect should still be present.

4.1. Behavioral Data

The same interaction effect in the response times as was was found in Borst et al. (2010) is present in our data of the variant with one column, which represented the original task the most. This provides additional proof for the problem state resource as a bottleneck (Borst et al., 2010). As we expected the variant with two columns also showed the interaction effect between subtraction difficulty and text entry difficulty and the response times for the subtraction task are overall higher than the response times for the variant with only one column. The cause of this is probably the screen that is more clogged up and if people use the previous column instead of keeping a problem state, they have to recalculate the previous subtraction. In the variant with a signal there is no significant interaction effect found, what could be expected because it is not needed to maintain a problem state in this case. Due to the information on the screen, the hard/hard condition became approximately the same as the hard/easy condition and so the interaction effect of text entry difficulty and subtraction difficulty disappeared. Overall the interaction effect did not differ significantly between the variants, although it had a trend towards significance. Our lack of participants and loss of the data could have caused this.

The reaction times for the text entry task did all show an interaction effect. This was expected in the case of the variant with one column and the variant with two columns, but in the variant with a signal it should not be necessary to keep a problem state and thus there should not be an overadditive effect of difficulty in the hard/hard condition. One explanation for this could be that participants did try to keep a representation for the subtraction task in their problem state, what caused interference in the text entry task, but as soon as they came back to the subtraction the information was clearly presented to them so they did not have to try to fetch the problem state of the previous problem but could go on with the problem at hand.

The accuracy data does not show the same pattern as in Borst et al. (2010) but it seems like less errors are made overall in the variant with the signal. Which shows that reducing the interference in the problem state can benefit task performance.

4.2. Eyetracking Data

The interaction between subtraction difficulty and text entry difficulty differed significantly in the three variants. Overall you can see that harder tasks require more fixations than easy tasks and in the variant with one or two columns without the signal there is an interaction between subtraction and text entry difficulty which results in more fixations. There are more fixations made in the variant with two columns than in the variant with one column, as you would expect because there are more tokens on the screen to look at. The variant with the signal did also shows a small interaction effect of text entry difficulty and subtraction difficulty. We expected to find no interaction effect here, because we hypothesized that no problem state had to be kept when there was a signal. An explanation for this could be that the strategie the participants used differed. Maybe some of them did use the signal instead of the problem state and others used their problem state although the information was present. When the fixations are split between the subtraction part of the screen and the text entry part of the screen there is no interaction effect in the variant with a signal, but also not in the variant with one column. In the text entry task the only variant that shows no interaction effect of text entry difficulty and subtraction difficulty is the variant with the signal. Although these results are not entirely convincing, this shows that in the variant with signal there is the least increase in fixations overall.

The division of the fixations in a subtraction part and a text entry part also shows that the differences between the variants stem mainly from the subtraction task.

When the fixations of a trial are divided by the time that trial took you can see that the easy/easy condition had the most fixations per time unit. It seems here that the variant with a signal had somewhat less fixations although these results are not that much different.

4.3. Conclusion

The additional variants we have tested provide new evidence for the minimal control principle (Taatgen, 2007). The increased reaction times and fixations suggest that the participants did use the information on the screen instead of keeping a problem state.

We have shown here that the problem state bottleneck as found by Borst et al. (2010) indeed exists and decreases the performance on this task. However, we also found that the problems that arise due to this bottleneck can be avoided when information is easily available. This can be of use in many situations where people are doing multiple tasks which need to maintain a problem state. As Taatgen (2007) put it, people use information from their environment to control tasks. This is not only true for the control state, but it holds for the problem state as well.

Our research question was: Do people use information on the screen instead of using a problem state? Our data shows that there is indeed less time needed for the variant with a signal and there are less fixations needed, even though there is a signal that can be looked at. This suggests that the information is indeed used to relief the problem state, but only when the information is presented in a clear way.

4.4. Further Research

To further investigate offloading the representations in the problem state to the environment more research should be done. As said before, this research only had a limited group of participants and half of the data could not be analyzed. As some of the graphs show large error bars, this small data set could not always be conclusive about the subject.

The regions of interest should be more specialized. Not only the left and right side of the screen should be discriminated, the signal should be a region of interest on it's own and if it is possible the columns of the variant with two columns should be divided in regions of interest so that it is possible to see whether people make use of the previous columns. To achieve this the interface should be more clearly designed so that there is a clearer distinction possible between the different columns. If this is possible it will also be easier to find out certain patterns in viewing habits of participants. This can help to present the information in a better way that is easier to use. These patterns or sequences of eye movements that return often can also give us insight in strategies used to deal with these tasks. It would also be interesting to find out if different people use the same or different strategies.

Further research could also be more applied, in that it applies our findings to the design of interfaces that are used in a multitasking environment. When the information is more clearly presented on the screen so that it does not have to be kept in the problem state there will be less interference so that tasks can be executed faster and more accurately.

5. References

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