HOW DIFFERENT OCCLUSION INTERVALS AFFECT TOTAL SHUTTER OPEN TIME

Volvo Car Corporation

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Abstract

The involuntary occlusion technique for evaluating in-vehicle TICS is under investigation by the ISO to come up with a criterion for acceptable in-vehicle functions. So far no study has compared how different occlusion time intervals affect the TSOT. In this study four different occlusion intervals were used: 1 second, 3 seconds, 4 seconds and 6 seconds. No significant difference was found between these intervals. There was however a tendency for the 1-second condition to have a longer TSOT. This could be due to the fact that the subject has longer time to think or act during the close intervals. The computational interruptions might however be an even bigger contributing factor to the higher TSOT for the 1-second condition and also the static condition. Two other issues in the study were comparing our results to the ISO proposed criterion (TTToccl/(Static + Ttoccl)) and to investigate what the subjects feel about using the occlusion spectacles used in the experiment.

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Rikard Karlsson and Neil Fichtenberg

Volvo Car Corporation, August 2001

Introduction

The increased information flow in the driving situation induced by modern information technologies is something that concerns today's automotive industry. The Society of Automotive Engineers (SAE) and the International Organization for Standardization (ISO) are both working on criteria as to which kind of functions should be accessible while driving. Paul Green, who is one of the researchers for SAE, has proposed the so-called 15-second rule[1] (Green 1999), but this criterion was later seriously challenged by Tijerina, Johnston, Parmer, Winterbottom and Goodman (2000) who claimed that the 15-second rule "has diagnostic sensitivity not much better than chance guessing" (abstract). One of the arguments that Tijerina et al. have against the 15-second rule is that it does not take into account whether the task under evaluation is chunkable or not. In the ISO work group on "TICS on-board – MMI" (ISO TC 22/SC 13/WG 8), focus now lies on just this, i.e. to come up with an evaluation method that is sensitive to the chunkability of in-vehicle tasks. The evaluation method that the ISO work group is currently working with utilises an occlusion technique to accomplish the chunkability criterion.

Going through the literature available using "occlusion technique" as keyword it is possible to discern two very different applications of occlusion techniques that relate to driving. The first is the so-called *voluntary occlusion technique*. This technique's purpose is to figure out how much visual information is required to drive. The subjects can control how much their line of vision is occluded and the task for the subject is to have the line of vision occluded as much as possible without deteriorating driver performance. In this way it is possible to find out how much of the visual information a driver receives is redundant (Senders, J.W., Kristofferson, A. B., Levinson, W.H., Dietrich, C.W., & Ward, J.L. (1967)). However, this is not the occlusion technique that the ISO is interested in. They are interested in the *involuntary occlusion technique*. In this technique, the subject cannot control how much he sees; instead the close and open intervals are controlled by something else (usually a preprogrammed computer). The point is to simulate an on-the-road situation where the occluded phase simulates that the subject looks on the road and the open phase allows the subject to see the in-vehicle system being evaluated. In this way it is possible to evaluate which in-vehicle tasks induced by a Traffic Information and Control System (TICS) are chunkable. In the following, it is only the involuntary occlusion technique that is under consideration.

A validation study of the occlusion technique as a method to test chunkability was carried out by Keinath, Baumann, and Krems (2001) who found that the occlusion technique makes it possible to differentiate between chunkable and unchunkable tasks[2]. However, they did not investigate if different occlusion interval lengths had an effect on task performance. As Keinath et al. point out, "The effect of the length of the occlusion phase on task performance is generally not examined so far and should be studied in further experiments." Studies so far have included lengths ranging from 2 seconds (ISO, 1999) via 3 seconds (ISO, 2001), up to 5 seconds (Goujon, 2001 and Niiya, 2000). The first objective with this study is therefore to see how different occlusion times affect task performance.

The second objective is to compare results from our experiment with a proposed ISO criterion. The third, and final, objective is to investigate how people feel about doing the occlusion technique experiment using a self-report method.

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[1] The 15-second rule means that all functions accessible while driving shouldn't take more than 15 seconds to complete in a parked car.

[2] It should perhaps be pointed out that Keinath et al. did not use only typical TICS-induced tasks, like navigation system tasks, but used tasks like reading a text that was displayed in multiple short sections. Further, Keinath et al. focus on errors and not on completion time as this study does.

Method

Equipment

The equipment used included a Volvo V70 XC, model year 2001, equipped with the Volvo navigation system, Road and Traffic Information (RTI) which is maneuvered by six buttons just behind the steering wheel and has a color visual display and audio display for route guidance. The only method for entering information into the system is by scrolling through lists of options and letters. Further, the PLATO occlusion spectacles (Milgram, 1987) were used. These occlusion spectacles are based on the cholesteric-nematic phase change effect and scatter light in the closed state, i.e. they do not block any light. This means that the subject's eyes do not have to readapt to light after opening. The spectacles were controlled with ToTaLcontrol, specifically developed software by Translucent Technologies, which was used on an IBM ThinkPad laptop computer. For timing purposes a stopwatch was used.

Figure 1. The PLATO occlusion spectacles

Subjects

Twenty-four subjects participated in the experiment, 18 males and 6 females. The subjects ranged in age from 24 to 59. The mean age was 36,4. All of the subjects are employed at Volvo Car Corporation, have different driving experiences, and have varying levels of experience using the RTI.

Procedure

Each subject was given a thorough training immediately before the start of the test, to make sure that they were able to operate the system without difficulty. It was necessary to get familiar with the controls and then to become familiar with how to complete each of the tasks that would later be tested. For example, the subject was given five street destination entry tasks for practice that were similar to the tasks they performed during the experiment. For destination entry tasks, a flash card with the address was presented to the subject and the subject had to say what was written on the card to make sure he or she had understood. Simpler tasks, such as adjusting the volume of the system, were also practiced, but only for three times each.

There were five destination entry tasks of varying amounts of letters that needed to be selected in order to complete. Adjusting the brightness of the screen, adjusting the volume of the system, and choosing an establishment from a list were the other tasks tested in this experiment. All tasks commenced with the main menu, on the same line of the screen.

There were five conditions in the experiment: one condition without the occlusion spectacles (the static condition) and four with the spectacles. All subjects did all of the tasks once in the static condition and the same tasks with four different occluded conditions divided on the same tasks, (two tasks per condition) which means that there were 16 trials altogether for each subject. The different occluded intervals were 1-second, 3-seconds, 4-seconds and 6-seconds and the open interval was always 1.5 seconds for the occluded conditions. In order to avoid any sort of training effect during the experiment the static condition was outbalanced vis-à-vis the occluded conditions i.e. half of the subjects started with the occlusion glasses and half without. Also, the order of the tasks was changed for each subject.

Time was the only dependent variable measured in connection to task completion. Errors were only recorded if they had a very big impact on completion time. During the static condition, the timing began when the subject pushed the first button on the control. For the occluded condition, the timing began as soon as the glasses were opened. In both cases, the timing ended when the correct visual feedback was obtained.

After the experiment was finished the subject filled out a subjective ratings form (a Swedish translation of the NASA Raw Task Load Index) where the subject had to indicate his or her opinion on how it was like to do the experiment with the occlusion glasses.

Results

Relationship between different occlusion time intervals

An ANOVA test revealed no significant difference in the mean Total Shutter Open Time (TSOT)[3] for the different tasks between the 1, 3, 4, and 6 seconds occlusion conditions $F(3, 28)=0.57$, $p>0.85$. It is however possible to see that there is a tendency for the 1-second occlusion condition to have a higher TSOT than the other occlusion conditions (see Figure 2 below).

The TSOT/Static ratio of this interval was a fairly high 0,88. The other three intervals of 3, 4, and 6 seconds resulted in TSOT/Static ratios of 0,66, 0,74, and 0,67 respectively. The overall ratio of TSOT/Static was 0,74 which is very similar to other research (Goujon, 2001).

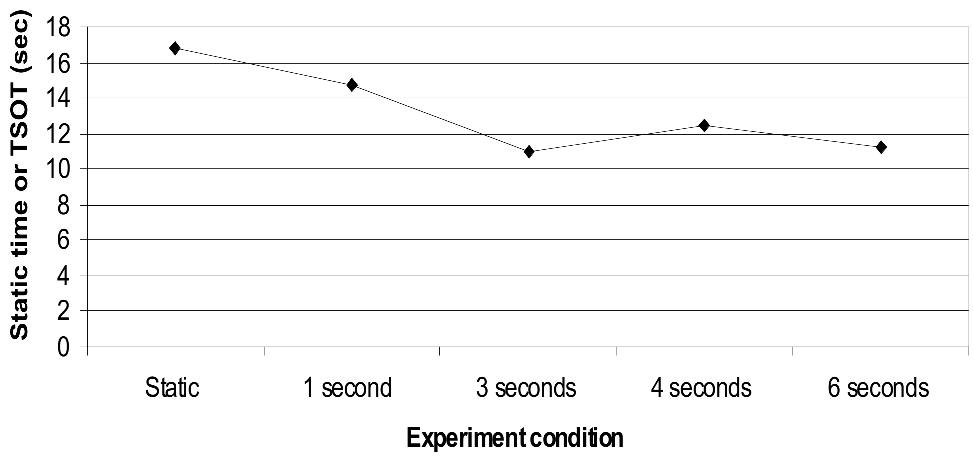


Figure 2. Static time or TSOT vs. occlusion interval time

Comparison to ISO criterion

Also calculated was the TTToccl/(Static + Ttoccl[4]). Table 1 contains these ratios for each task:

Table 1

Means and ratios for the different tasks

Task	Static	TTToccl	TSOT	TSOT/Static	TTToccl/ (Static + Ttoccl)
Destination: Byvädersgången	16,7	40,7	13,0	0,78	0,92
Choose establishm. from list	14,6	34,2	11,1	0,76	0,91
Destination: Pumpgatan 1	25,9	49,8	15,6	0,60	0,83
Adjust the Volume	5,6	14,9	5,3	0,93	0,98
Destination: Ugglegården	18,7	40,0	13,0	0,70	0,88
Adjust brightness	1,7	3,7	1,9	1,11	1,05

[3] TSOT is the total task time during an occluded condition that the vision is not occluded.

[4] Ttoccl is the total time that the vision is occluded.

Destination: Klostergången 1	26,1	54,2	18,3	0,70	0,87
Destination: Kastellgatan 1	24,6	59,1	20,4	0,83	0,93

In Figure 3, the TSOT has been plotted against the static time. A very high correlation (r=0.97) was found between the two.

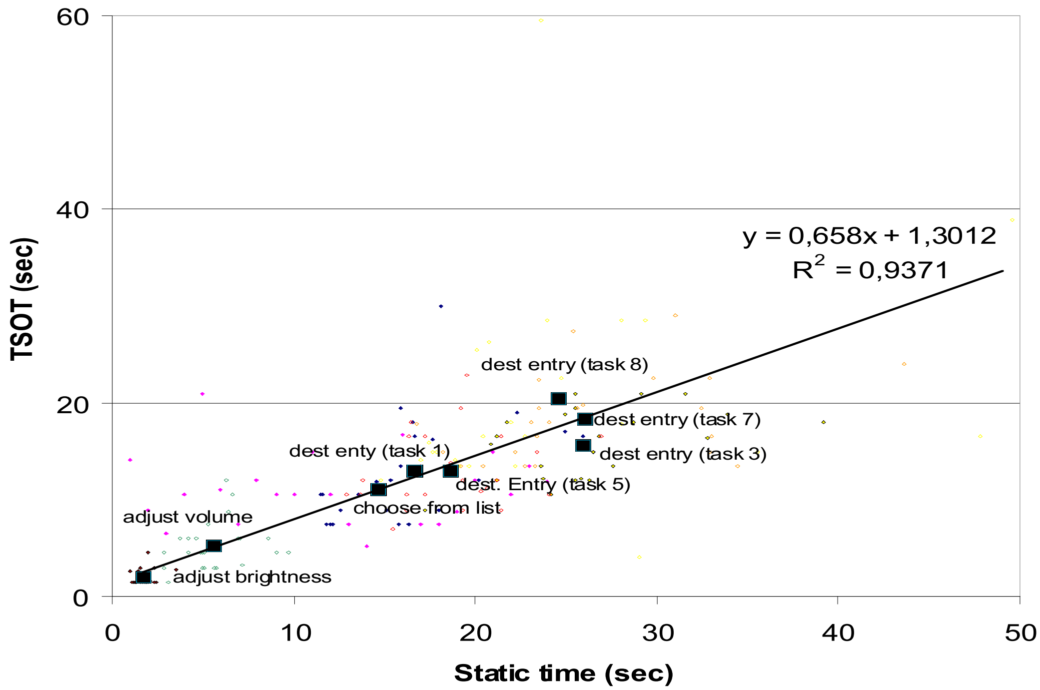
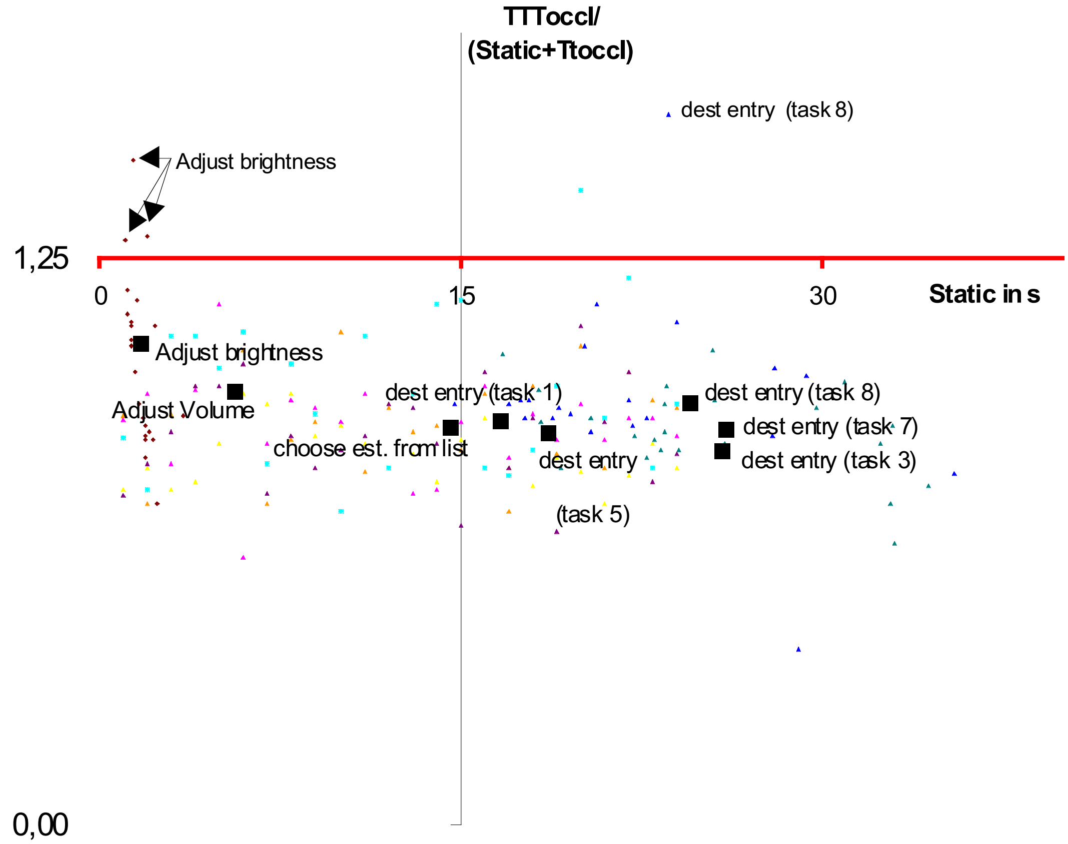


Figure 3. TSOT vs. Static time

The ISO proposed criterion TTToccl<1,25*(Static + Ttoccl) was calculated, with the results in Figure 4.

All of the tasks in this experiment passed the proposed criterion, and the mean value of every destination entry task was well below the 1,25 mark. The highest values actually came from the tasks of adjusting brightness and volume, which are the two least complex tasks in terms of menu screens viewed and entries required by the user. A few individual cases of these simpler tasks were above 1,25, along with one case for one of the destination entry tasks (task 8).

Figure 4. How the tasks meet the ISO criterion.



All the destination entry tasks have nearly the same TTToccl/(Static + Ttoccl) values regardless of their complexity[5], along with 'choosing an establishment from a list', which is supposed to be a simpler task.

There did not appear to be any difference between the ISO proposed criterion and looking at the TSOT/Static ratio directly, except for a few more individual tasks that had ratio's above 1,25.

It is also interesting to note that the three tasks of lesser complexity passed the 15-second rule criterion, while none of the five destination entry tasks did.

Subjective ratings

The different categories from the subjective ratings form and the overall mean results and mean result by different groupings is shown below in Table 2.

Table 2

Subjective Ratings

	Mental demand	Physical demand	Performance	Frustration

[5] The destination entry task numbers correlate with their complexity, with the higher numbers being more complex. Example: Destination entry task number 8 requires 5 letters entered while destination entry task number 3 requires only 3

Mean	**52**	**21**	**71**	**41**
female	49	32	63	50
male	53	17	74	38
familiar 4	73	69	76	24
familiar 1	73	31	52	56
birth yr<1961	67	31	62	35
birth yr>1971	45	14	78	59
males >1971	45	4	83	64

The minimum value is 0 and the maximum is 112. Familiar 4 means the subject had the highest level of familiarity to the Volvo navigation system (using it for years, only two subjects). Familiar 1 means that the subject had never seen the system before (three subjects).

Discussion

The main objective of this study, to determine how different occlusion interval times affect the TSOT, had mixed results. One possible explanation to the difference between the 1-second condition and the longer occlusion interval conditions is that the operator has more time to think and act during the occluded phase with the longer occlusion intervals. However, a greater factor contributing to this difference is probably the computational interruptions[6]. It was much more likely that the subject will encounter a computational interruption during the open phase when the interval was only 1 second. These interruptions were rarely more than 2 or 3 seconds, so the chances of encountering them with the longer occlusion intervals were much less.

What is possible to say from our results is that since the static time-TSOT ratio always is 1:<1, the tasks implied by the Volvo navigation system are all chunkable, i.e. they can easily be broken into chunks by occlusion. Because of this there is no reason for there to be a difference in TSOT using different occlusion intervals. With another system however, implying tasks that are not chunkable, there might be a difference in TSOT between different close intervals. Tasks that are not chunkable are either those induced by a system that is more dynamic than the static Volvo system[7] or tasks that need restart time (restart time means that the driver needs time to restart the continuation of the task for each glance on the TICS). Restart time could be needed when there is a driving situation that demands much of the driver's attention. The attentional demand of the driving situation cannot be simulated using the occlusion technique, therefore it is beyond the scope of the occlusion technique method to study restart time due to attentional demand of the driving situation. There might as well be other reasons for restart time, so this should be studied in further research.

The result of the overall TSOT/Static ratio was very similar to that of the study done by Goujon (2001). We would agree that "an isolated criterion based on the ratio of Total Shutter Open Time or Total Task Time with occlusion on Total Task Time, as it is essentially sensitive to the value of TTT[8], is not appropriate to determine the visual distraction induced by the use of a system by the driver" (p.5). It seems that it would be very difficult for a task that does not have an incredibly small static time to fail the ISO proposed criterion. As seen in Graph 3, only once did one of the destination entry tasks not meet the criterion, and that particular instance was the result of the subject needing to start over in the middle of the task. All the other individual destination task plots are well below the criterion, along with the means. Perhaps a better criterion would be one that is based only on the occlusion experiment.

[6] A computational interruption is when the system is doing a calculation and it is not possible to input anything to the system.

[7] In the AI-literature this categorization of static and dynamic systems are very frequent see e.g. Russell, S. & Norvig, P. (1995). *Artificial Intelligence, A Modern Approach*. Englewood Cliffs, NJ: Prentice Hall.

[8] TTT is equivalent to Static time

An area of study that could help determine a better criterion would be to study the relationship between TSOT and the total glance time in a real driving situation. An experiment conducted by Kenji Niiya (2000) for Toyota determined that the TSOT was in fact almost equal to the total glance duration time while the vehicle is in motion. This would indicate that the occlusion method could be a possible evaluation method for the total glance duration.

From the self-report forms the following can be concluded:

- There is a difference in "Physical Demand" between males and females. This probably has to do with that for people with small hands it is hard to reach the controls behind the steering wheel.
- Older people felt that it was less frustrating using the occlusion spectacles than young people. This could be due to a general eagerness amongst the younger.

General comments inform us on that there is often a high level of frustration combined with using the occlusion spectacles in the first trials, but during the course of the experiment the frustration level decreases. Another observation is that 80% of the subjects (both left and right-handed) felt that the mapping of the left-right scrolling function was in the opposite of the expected direction. Some subjects said that a difference between the actual driving situation and using the occlusion spectacles is that in the driving situation it is possible to use peripheral vision.

Acknowledgement

This study was carried out as a five week summer project at the ergonomics group at Volvo Car Corporation, Göteborg. We would like to thank the members of the ergonomics group for their support and comments that helped us to complete this study. We would especially like to thank Martin Fagerström, our supervisor and Anders Hallén for giving us some of his valuable time to introduce us to the occlusion technique paradigm.

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Occlusion Experiment #2

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24 August, 2001

Abstract

This study is a follow up to the first occlusion experiment: *How different occlusion intervals affect total shutter open time*. That study determined that there was no difference between different occlusion interval times for tasks that were easy to chunk into small parts. Tasks that are considered less chunkable than those done in the first experiment are studied in this experiment. The tasks studied incorporate the need to keep track of where one is looking at the screen while counting. This becomes very difficult when using the occlusion spectacles, as it is very easy to lose one's point of focus on the screen when the glasses occlude. The results of the study indicate that for tasks that are difficult to chunk, the ability for a person to perform these tasks is negatively effected by increasing the occlusion interval time. The total shutter open time tends to increase with the increase in occlusion time while the accuracy decreases.

Occlusion Experiment #2

Neil Fichtenberg
Volvo Car Corporation, August 2001

Introduction

The first occlusion experiment, *How different Occlusion Intervals Affect Total Shutter Open Time* (Karlsson & Fichtenberg, 2001) done for Volvo Car Corporation produced results that prompted the need for a second experiment. The objective remains the same, to determine how different occlusion interval times affect the total shutter open time (TSOT), but is done with tasks that are thought to be less chunkable than the tasks done in the previous experiment. It was concluded in the previous experiment that ”the tasks implied by the Volvo navigation system are all chunkable, i.e. they can easily be broken into chunks by occlusion. Because of this there is no reason for there to be a difference in TSOT using different occlusion intervals.” (Karlsson & Fichtenberg, 2001). If tasks are tested that are less chunkable than those done on the navigation system, Road and Traffic Information (RTI), perhaps there will be an effect on the TSOT.

Besides studying the effect on TSOT, this experiment also examines the effect on the accuracy of the subject. Since the tasks used involve counting, and there is not visual feedback obtained to indicate when the task has been completed, it is important to keep track of how accurate the subject is to determine that he or she is not just guessing or estimating. If a task is very difficult to chunk, or perhaps even impossible to chunk, then it would be more valuable to examine the accuracy of the subject rather than the time it takes to complete.

Method

Equipment

All tasks were performed while viewing certain Microsoft Word files on an IBM desktop computer. The PLATO occlusion spectacles (Milgram, 1987) were used, as in the previous experiment. These occlusion spectacles are based on the cholesteric-nematic phase change effect and scatter light in the closed state, i.e. they do not block any light. This means that the subject’s eyes do not have to readapt to light after opening. The spectacles were controlled with ToTaLcontrol, specifically developed software by Translucent Technologies, which was used on an IBM ThinkPad laptop computer. For timing purposes a stopwatch was used.

Subjects

Fifteen subjects participated in the experiment, 12 males and 3 females. The age range of the subjects was from 24 to 59. The mean age was 38,4. All of the subjects are employed at Volvo Car Corporation. Thirteen of the subjects had previously participated in the first occlusion experiment.

Procedure

Each subject was shown an example of the two types of tasks that were tested in the experiment, and had the opportunity to practice both types before the start of the testing. Since the tasks only involved counting, it was not necessary to have a thorough training as was done with the navigation system.

There were two types of tasks, and three tasks to be completed for each type, totaling six tasks with the occlusion spectacles. There were two tasks (one for both types) done without the spectacles, giving a total of eight tasks that were performed. The occlusion times used for the experiment were 1 second, 3,5 seconds, and 6 seconds. These were balanced so that each individual task was performed five times at every occlusion time. The open cycle was always 1,5 seconds. The order the tasks were done in was randomized.

The first type of task was called a ’matrix’ task. The subject was shown a matrix of approximately 150 random letters on the computer screen. The task was to count the number of times the letter ’A’ appeared in the matrix. The ’A’s were in different positions in each of the four matrices (3 occlusion and the static), so a pattern did not exist. The number of ’A’s was 22, 21, and 20 for the three different occlusion tests, and 21 for the static. Figure 1 below shows an example of a matrix task.

FSKDLKGJBAPOHVLKHHCVKJHK
SLAGJAÖLDSAGDAIFOABADFBAÖ
ASFLKJGÖLKFDAJÖIGHÖAIDHFA
XCVBMÖNJEBÖIJFBASNAÖOIANF
QOWIUAABDIFKLAGAKDLFNBD
JOIEJHIOKJBÖOIBNIONAVAIÖONC

Figure 1. Example of a matrix task.

The second type of task was known as a ’string’ task. The objective was to count how many ’A’s there were in a string of only the letter ’A’. The three occlusion tasks had 16, 17, and 18 ’A’s in the string. The static condition contained 17. The font style and size remained the same for all the tasks of both types. Figure 2 below shows an example of a string task.

A A A A A A A A A A A A A A A A A

Figure 2. Example of a string task.

The two dependant variables that were measured were task completion time and how accurate the subject was. For example, if a string contained 17 ’A’s and the subject counted 19, an error rate of 2 was recorded. It was also noted whether the count was over or under the actual number. For the occluded conditions, the timing began as soon as the glasses were opened and stopped when the subjects stated the number that they believed was correct. For the static condition, the timing commenced as soon as the file appeared on the screen. Both the opening of the glasses and files were controlled by the timer, who confirmed that the subject was ready immediately beforehand.

After the testing the subject was asked two questions about the experiment. The first question asked which of the two types of tasks was more difficult with the occlusion glasses. The second question asked whether the different occlusion times made a difference on either of the two types of tasks.

Results

Effect of different occlusion intervals on TSOT

The affect of the different occlusion intervals was different for the two types of tasks. Figure 3 below shows the average time for the static condition and TSOT of the occluded conditions for both tasks.

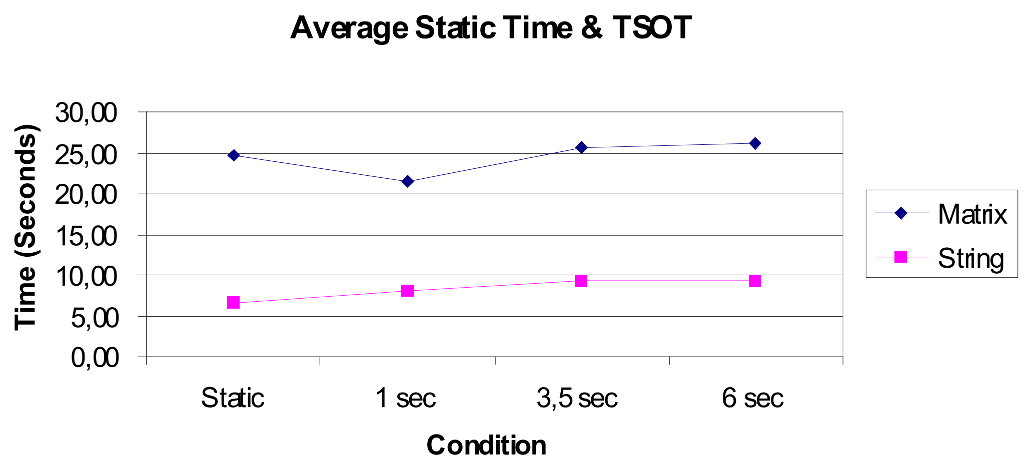

Figure 3. Average Static Time or TSOT vs. condition for both types of tasks.

Effect of different occlusion intervals on error rates

The effect on error rates was also different for the different types of tasks. For the string task, both an ANOVA test and t-test showed that there was a significant statistical difference between the error rate of the 1-second and 6-second occluded conditions. Figure 4 shows the rate of error for each condition for both types of tasks.

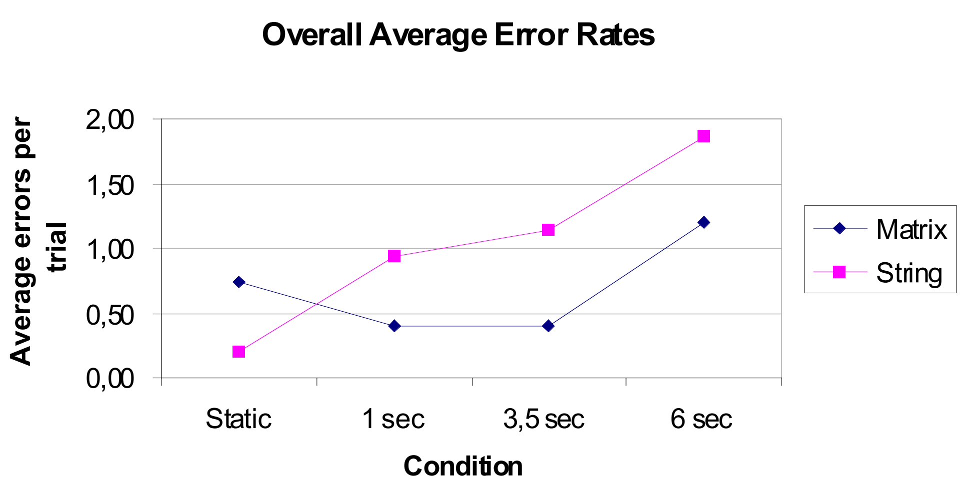

Figure 4. Error rates vs. Condition for both types of tasks.

Post-experiment questions

The following table contains the results from the post-experiment questions asked:

Question 1 Which of the tasks was more difficult with the occlusion spectacles?

Answer:	Matrix	String
Percent:	15,4	84,6

Question 2 Did the different occlusion intervals have any effect on either of the tasks?

Answer:	1	2	3
Percent:	7,7	76,9	15,4

Answer 1: There was no difference.
Answer 2: Longer occlusion intervals made both tasks more difficult.
Answer 3: Longer occlusion intervals made the string task more difficult, but had no effect on the matrix task.

Table 1. Answers to post-experiment questions.

Discussion

The two types of tasks used in this experiment had quite different results regarding how the different occlusion times affected both TSOT and the error rates. Thus both types of tasks, matrix and string, will be examined separately in the discussion section.

Matrix results

As can be seen from figure 3, there is a big increase in the TSOT from the 1-second condition to the 3,5-second condition, of about 4,1 seconds. Figure 4 shows that for these two conditions, the error rate stays exactly the same. Therefore, it can be concluded that in order to maintain the same level of accuracy from the shorter to longer occlusion time, it is necessary to take more time. A possible explanation for this would be that it is easier to lose your point of focus on the computer screen when the occlusion interval becomes longer than 1 second. So when the glasses reopen it may be necessary to take a little more time in order find the correct place. The TSOT increases a very small amount, just over half a second, between the 3,5-second condition and the 6-second condition. However, the error rate triples. This could be because after a 6-second occlusion phase, it is more likely to completely lose one's place in the matrix. This would not necessarily increase the TSOT much, but it would certainly decrease the accuracy. One thing that is for certain is the overall performance decreases from the 1-second to the 6-second occlusion interval in terms of both time taken and accuracy. Approximately three-quarters of the subjects asked felt that the matrix task was more difficult when the occlusion interval was increased, as seen in Table 1.

Surprisingly, the static condition does not result in as good a performance as the 1-second occlusion interval. The average time taken for the static condition is closer to that of the 3,5-second occlusion condition. The error rate is much higher for the static, however that can be explained by one subject that must have missed an entire line in the matrix because there were more errors than any other matrix task. It would be more accurate to look at the percentage done without an error, as this would not put a great amount of weight on this single occurrence. The percentage for the static and 1-second are almost equal with the 1-second condition being slightly (0,7%) higher. Therefore the only difference between the static and 1-second condition is that the static took more time.

String results

Contrary to the matrix task, the TSOT for the string task did not increase for each increase in occlusion interval time. It increased a little more than one second from the 1-second to the 3,5-second condition, and then decreased going from the 3,5-second condition to the 6-

task, as 84,6 percent of the subjects felt. Many commented that it was impossible to chunk the string task, since there were only ‘A’s on the screen, there was no point of reference to start from every time the glasses reopened. Thus many of the subjects had to make estimates, as that was the best they could do. This seemed especially true for the 6-second occlusion condition, which could explain the decrease in TSOT from the 3,5-second occlusion condition and the major increase in the error rate, as seen in Figure 4. There is a huge increase in the error rate between the static condition and the 1-second condition, unlike the matrix, which coincides with the subjects’ feelings that the string task is virtually impossible to chunk. Therefore occluding the subjects’ view for even just one second decreases their performance dramatically. The following figure shows the percent done correctly for each of the occluded conditions.

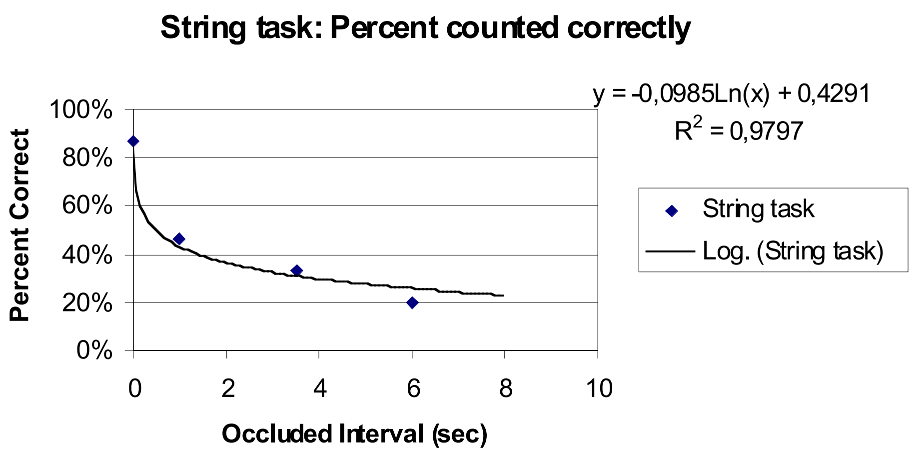

Figure 5. Percent of string tasks counted correctly vs. occluded interval time.

Summary

Though both tasks studied in this experiment are less chunkable than the tasks performed on the RTI system, the string task is much less chunkable than the matrix; it might even be considered an unchunkable task. This is based upon the results of the experiment and the subjects’ own input after completing the experiment. For the string task, there was an increase in TSOT from the static to the occluded condition in general, but there was no real correlation between the TSOT and the different occluded conditions. The accuracy decreased from the static to the occluded condition, and it continued to decrease through each increase in occluded interval time. The matrix task was possible, though very difficult, to chunk. Since there were other letters besides ‘A’s, it was possible to have a reference of where one was. Comparing the 1-second occlusion condition to the 6-second, there was a major increase in TSOT (about 22%) and a major decrease in accuracy (three times the error rate). So, for tasks that are considered less chunkable than those done on RTI, this experiment concludes that longer occlusion interval times will decrease the overall performance of a person’s ability to perform the task in terms of time and accuracy.

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