IMPLICIT LEARNING OF TIMING INTERVALS IN A DUAL TASK SETTING

Bachelorproject

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Abstract: To find out if people are capable of implicit learning of a time interval, you cannot simply ask someone to press a button or ask them explicitly to asses the length of the interval. Previous research has not yet used eye movements in finding an implicit learning effect. By measuring eye movements in the direction of a stimulus with a hidden temporal structure, it is possible to establish implicit learning. We wanted to know if people are capable of implicit learning of a time interval in a dual task setting. We also wanted to know if the temporal structure of the secondary task has an influence on how well the time interval is learned in the primary task. Our results provide us with partial evidence that supports the hypothesis that people are capable of implicit learning of a time interval in a dual task setting. We found no evidence to confirm our hypothesis that the temporal structure in the secondary task has influence on how well the time interval is learned in the primary task.

1. Introduction

The ability to estimate time intervals is of common use in everyday situations. An example is writing a text-message on a mobile phone. You might notice that for typing two successive letters, you sometimes need to press the same key twice. You will have to wait a moment before you can press the second key without overwriting the first letter. Another example is learning how long you have to press the 'on'-button on a television-remote control until the television switches on. If actions such as those described above are done often enough, you will get better in estimating the period of time you would have to wait before pressing the second key, or until your television is turned on. No one has to tell you explicitly how long the period of time you have to wait exactly is. In many cases in everyday life, people seem to be capable of implicit learning when it comes to the estimation of time intervals.

Skinner (1938) found that rats are capable of learning time intervals. In this study, rats were rewarded for the first response that was given after a fixed period of time had passed. Responses before the end of the time interval had no effect. A new interval began once a reinforcement was given.

Taatgen, van Rijn & Anderson (2007) studied the effects of attention in learning of time-intervals in a dual-task timing task (DTT). They performed two experiments. Both experiments were designed to mirror everyday situations in which people had to discover a temporal structure. In the experiment, participants had to perform two tasks simultaneously. These tasks were both hard or both easy to do. The hard task involved verifying additions, the easy task involved recognizing letters. The experiment consisted of four between-subject phases where each phase was a combination of three task sets. The individual phases were combinations of easy and/or hard tasks. For each correct response, points were awarded. Also, a time estimate had to be made as part of one of the tasks while performing the other task. In order to be successful at the task, participants had to divide their attention over the subtasks. One of the findings of the experiment was that the various levels of difficulty in the tasks did not produce any large shift in time estimation. Reber (1967) was the first to suggest that learning might be implicit. In his experiment, subjects were asked to memorize meaningless strings of letters that were generated by a simple set of rules. Subjects were asked reproduce the learned strings and were told which strings they had reproduced correctly or wrongly without being informed about the nature of their errors. A control group was asked to perform the same procedure, only with randomized strings of letters. After the memorization task, subjects were told that the strings they had learned followed the rules of a grammar and were asked to classify novel strings as being grammatical of not. Reber found that subjects in the experimental group performed significantly better than subjects in the control group in the classification task, though they experienced great difficulty in verbalizing what grammatical rules they had learned. This finding suggested that learning is implicit, because subjects were able to apply knowledge without being able to describe the knowledge itself or having the intention to learn.

Cohen et al. (1990) found that it is possible to learn a structured sequence while performing a distraction task. They also found that the structure of the task has influence on how well it is performed. Fu & Miller (2007) found that people could also learn a temporal sequence successfully in a visual monitoring task. People are also capable of learning several overlapping time intervals (see Van Rijn & Taatgen, 2008).

Current research on the estimation of time intervals often requires subjects to give an explicit response when a time-interval has ended or having to make a prediction of the start or end of an event. For example: In Taatgen, van Rijn & Anderson (2007), subjects were explicitly asked to estimate a time-interval as part of the experiment. In Fu & Miller (2007), time-estimation was not mentioned explicitly, still participants were asked to predict which of four gauges would travel into an alarm region within the next second.

1.1. The present study

We have extended the previous studies on time estimation. We wanted to find out if people are capable of implicit learning of a time interval while performing in a dual-task setting. Since it is known that the structure of a task has influence on how well it is performed (see: Cohen et al. 1990), we also wanted to know if the temporal structure of a distractor-task influences the performance on implicit learning in the first task. One major difference between our experiment and earlier studies is the implicit presence of a time factor of which participants were not aware. Another major difference is that we used eye movements in order to see if participants had anticipated the appearing of a target-stimulus instead of only measuring reaction times after a target-stimulus appeared.

In our experiment, participants had to perform in a dual-task setting. The first task, which from now on will be called the middle-task, referring to the position of appearing stimuli on the screen, was responding to the appearance of the stimuli "4" in a sequence of random numbers from one to nine. The second task was located in the upper-right corner of the screen. In this task, participants had to respond to the changing of the word "BONEN" (the Dutch word for "beans") into the word "BONUS" (which has the same meaning in English). What participants did not know, was that the word "BONUS" always appeared eight seconds after the displaying of the target-word "BONEN". We made two conditions in the middle-task, where the appearance of the target "4" was either random or happened on a fixed moment. We expected participants to learn when the target-word in the upper-right corner would appear, in a similar fashion as the findings of Skinner (1938). Also, we expected that the participants in the second (fixed) condition would learn the temporal structure of the middle- task and therefore would perform better in the upper-right task (responding to "BONUS") than participants in the first (random) condition.

2. Method

2.1. Participants

45 students of the University of Groningen took part in this experiment. There were 31 male students. They were all between 17 and 50 years old. The mean age of the participants was 21.7 years old. 18 participants participated for research-participation credits. All participants had normal or correct-to-normal vision.

2.2. Materials

Eyetracking was performed using an EyeLink II CL v4.40 with an EyeLink CL Version 1.4 camera at 500 Hz. sample rate. All experiments were performed without head support for the participants. The experiment was presented full screen on a 20.1 inch Dell 2007FPb monitor with a 1600x1200 resolution, which was connected to a Mac Mini T7200 2.0GHz computer and Windows XP SP2 software. A Cherry G230 keyboard was used to register the participant's responses to the stimuli.

Participants were seated behind a desk with a distance of approximately 600 mm. to the eyetracker. The desk was equipped with the computer monitor placed directly behind the eyetracker, a Mac Mini computer, a mouse and a standard keyboard. The experiment was ran on Mathworks Matlab R2009b with the Psychtoolbox 3.0.8.-package.

During the experiment, participants and experimenter both sat behind separate desks, separated by a closed closet which functioned as a room divider. The experimenter's desk was equipped with a computer screen to monitor the experiment.

2.3. Design

We used a between-subject design by dividing two conditions over the participants. The participants were balanced over the conditions based on gender and on volunteers versus participants who participated for research-participation credits. In the first condition, the first target stimulus appeared after a random period between 600 and 2400 ms. Note that all stimuli appeared for 150 ms, so a target stimulus is always presented after a multiple of 150 ms (e.g. at 600, 750, 900 ms etcetera). The next target-stimulus appeared after a new random period between 600 and 2400 ms after the previous target stimulus, and is from here on referred to as the unstructured condition. The average interval between two target-stimuli is 1500 ms for each trial. In the second condition, the appearance of a target stimulus alternated between a fixed and a random timing-interval and is from now on referred to as the structured condition. The target stimulus first appeared after a fixed period of 1500 ms, and the next target stimulus was shown after a randomized period of time between 600 and 2400 ms, with an average of 1500 ms for each trial.

2.4. Procedure

Before the start of the experiment, the eyetracker was calibrated. Participants were asked to perform two tasks simultaneously. In the middle-task, stimuli were randomly drawn from the set [1,2,3,4,5,6,7,8,9] and presented on the screen. Here, *4* was the target-stimulus. When the target-stimulus *4* appeared, participants had to press the "z"-key on the keyboard.

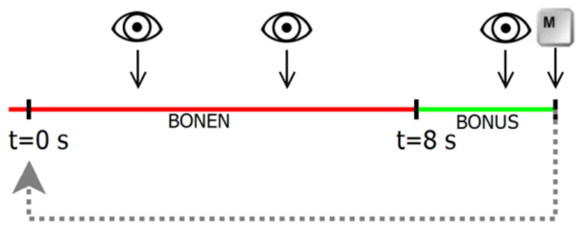
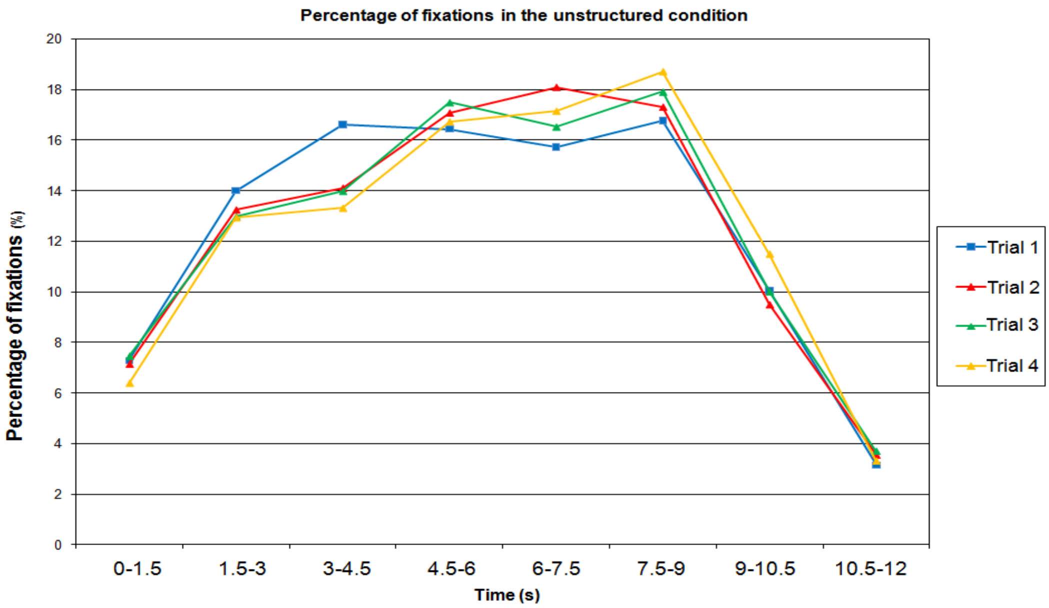


Figure 2.1: The temporal structure of the upper-right task. At t = 0 the stimulus "BONEN" is presented, after eight seconds it is replaced by target-stimulus "BONUS". When a response is given by pressing the m-key, the cycle restarts.

Participants were instructed to respond as fast as possible. Stimuli in the middle-task were shown in the center of the screen for 150 ms before the next stimulus appeared. A response was rated as correct when participants responded to a target-stimulus within 500 ms. When a correct response was given in the middle-task, it was awarded with 10 points and a beep sound was played as feedback. A false response resulted in the subtraction of 10 points and a horn-like sound was played as feedback. Simultaneously, the upper-right task was performed. At the start of the experiment, stimulus "BONEN" was presented. This is the start of a cycle, which is illustrated in figure 2.1. After 8000 ms, "BONEN" changed into target-stimulus "BONUS". When a response was given to the target, the target was replaced by "BONEN" and the cycle starts again. A response was rated as correct, when the "m"-key was pressed on the keyboard when the target-stimulus was visible. Here, a correct response was awarded with 50 points and a bell-sound was played as feedback. 50 points were subtracted when a false response was given on the upper-right task and a horn sound was player as feedback. Stimuli in the upper-right task were presented on the monitor on coordinates [1400,100]. An important feature in this experiment is that the screen flickers in both task every time a new stimulus is presented in the middle-task (every 150 ms). Without this feature it is fairly easy so see "BONEN" change into "BONUS" in the upper-right task. The flickering of the screen creates a necessity for participants to look in the upper-right corner of the screen in order to detect the appearance of the target-stimulus. The stimuli in center task and upper-right task were both presented in a bold 'Courier' font, size 32. The experiment consisted of five, four-minute trials. At the end of each trial, the gained number of points of the last trial and the total score were shown to the participants. A button on the keyboard had to be pressed to start the next trial.

3. Results

Due to a bug in our experiment, participants were not evenly divided over the two conditions. Data from six participants in the unstructured condition, and data from one participant in the structured condition, was not used in the



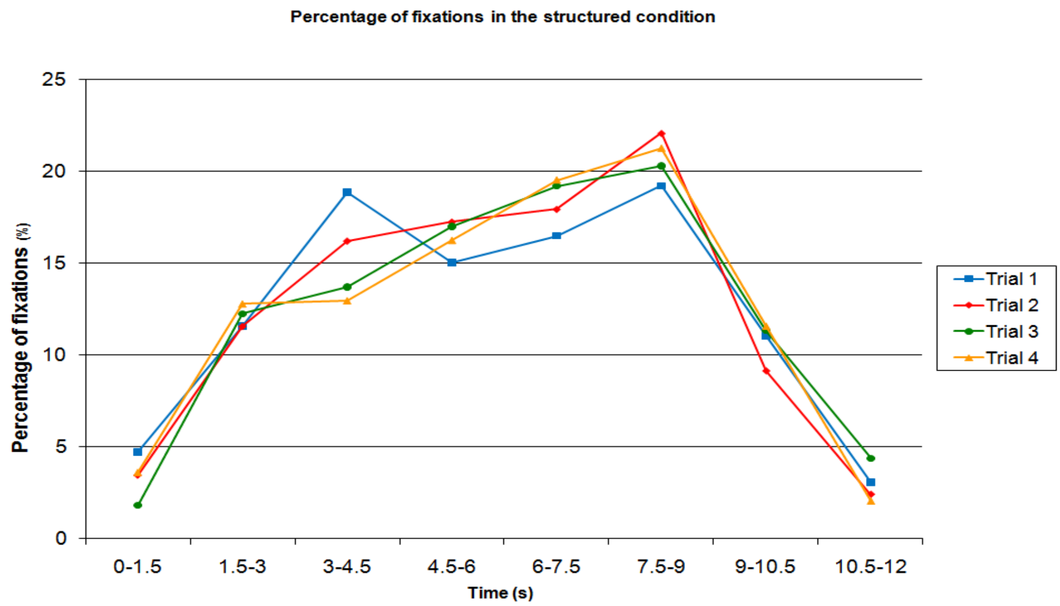


Figure 3.1: Percentage of fixations in the area of the upper-right task in the unstructured condition and in the structured condition. The horizontal axis is divided in bins of 1.5 seconds. Note that the time line starts at the moment where stimulus "BONEN" is presented and ends at the moment where participants responded to the target-stimulus. The graph of the unstructured condition represents eye tracker data from 28 participants. The graph of the structured condition was drawn using the data we collected from seven participants. The lines of each graph show fixations for each trial separately. Both graphs show a peak in fixations around 8 seconds (the moment when the target stimulus appeared).

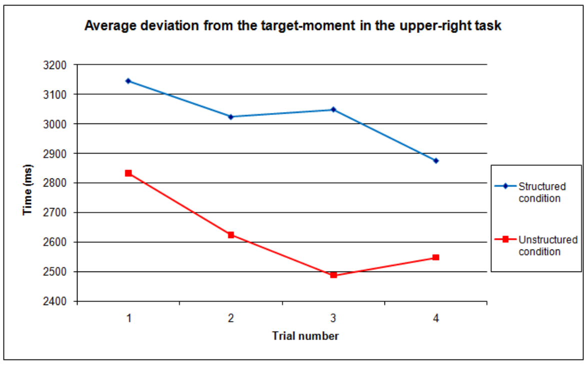


Figure 3.2: The average deviation between the eye fixation moments and the target-moment in the upper-right task area. This graph shows an overall decrease in the deviation in the unstructured and the structured condition. The blue line represents data from the seven participants in the structured condition, the red line represents data from the 28 participants in the unstructured condition.

analysis because these participants only responded to one of both tasks in the experiment. Data from three participants in the unstructured condition was not used for further analysis because of incomplete eyetracker data, caused by participants changing their body positions during the experiment. We finally used the data from 28 participants in the unstructured condition and data from seven participants in the structured condition for further analysys. Because of an overall decrease in performance due to fatigue in the fifth trial of the experiment, we chose only to analyse the data from the first four trials.

We were interested to see if the moment when participant's eye fixations focused on the upper-right task region, shifted towards the moment when the target stimulus "BONUS" appeared. This would indicate that participants were able to learn when the target stimulus would appear. We calculated the average deviation between the fixation moments and the moment when the target stimulus appeared (ADFT) in the upper-right task. The moment when a target stimulus appears will be called the target-moment from here on. Percentages of fixations in the upper-right corner of the screen are plotted in figure 3.1 for both conditions. The graphs show that in the first trial, the precentage of fixations in the 3 - 4.5 s interval is fairly high, but it decreases in the the later trials. In time, the percentages of eye fixations show a peak around the target-moment. Figure 3.2 shows that the ADFT decreases as the trials progress. We conducted a repeated measures ANOVA to see if the ADFT significantly decreased over time. We found a significant decrease in the ADFT between the four trials of the unstructured condition, $F(3, 81) = 2.83$, $p = 0.043$. Note that we used the data of 28 participants here. In the structured condition, this difference was not significant, $F(3, 18) = 2.53$, $p > 0.090$. Note that this result was based on the data of seven participants. We also compared the data of seven participants from both conditions, to see if the ADFT differed between-subjects above chance level. This ANOVA showed no significant difference between the two conditions in the ADFT, $F(1, 12) = 0.972$, $p = 0.34$.

To see if there was a significant difference between the two conditions in the middle task, we used the reaction times on the target-stimulus 4 for further analysis. We compared the reaction times of the same seven participants from both conditions as in the analysis of the upper-right task using a repeated measures ANOVA. There was no significant difference in the reaction times to the target stimulus in the middle-task between the two conditions, $F(1, 12) = 0.99$, $p = 0.76$.

4. Discussion

The results of our experiment suggest that participants in the unstructured condition were able to learn when the target-stimulus would appear in the upper-right task. However, this is not the case in the structured condition. A major difference in the analysis of both condition is the number of participants we compared to each other. Data from only seven participants in the structured condition was used for analysis, this may explain that we could not find a significant learning-effect in this condition. A larger number of participants in the structured condition could possibly make a difference in the results of the experiment. Our hypothesis was that people were able to learn the time interval in the upper-right task, this hypothesis is only partially confirmed. In figure 3.1, a peak is visible in the interval of the target-moment in both conditions. Figure 3.1 also shows that performance does improve as the trials proceed, though not significantly.

We also expected that participants in the structured condition would perform better in the upper-right task than participants in the unstructured condition. Our explanation was that participants would learn the structure of the middle-task. We found that the difference between the two conditions on the upper-right task was not significant. We could not find a significant difference in reaction times on the middle-task. The easiest explanation for this observation is that the structure in the middle-task was not learned by the participants in the structured condition. Maybe the structure is just too hard to learn. Because the structure is partially random, it would be interesting to experiment with easier structures. In an easier structure, the appearance of the target-stimulus could alternate between two fixed intervals instead of one fixed and one random interval. This may be easier to learn and may lead to learning two overlapping time intervals as seen in Van Rijn & Taatgen (2008). This may lead to better performance on the upper-right task.

In our analysis we left out the results of the fifth trial, because the performance of the participants decreased. Some participants reported that they suffered from fatigue due to the high speed of the experiment. Others reported having dry eyes which made them blink more than usual, causing missing eye tracker data. A possible follow up on this study could make use of shorter trials, this may increase performance by decreasing fatigue.

Can we conclude that eye movements are useful in establishing implicit learning? Our results do not provide us with enough evidence to answer to this question confidently. We have seen a certain learning effect in figure 3.1, from which one could conclude that eye movements are indeed usable for establishing implicit learning. Unfortunately we were not able to support this theory with significant results.

5. References

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