Increasing Attentional Blink Using a Strategy-Based Training

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Abstract

This study aims to find out whether it is possible to decrease the magnitude of the attentional blink (AB) by training on another task to test if cognitive strategies play a role in the processing of sequentially presented visual stimuli. Many models of the AB point to structural limitations as the cause for the phenomenon, either in memory consolidation processes or in executive control functions. That such an explanation might be problematic was shown by Choi et al., who showed that the attentional blink can be trained away using a color-salient training task. In the current study two different training tasks, based on the PRIMs model by Taatgen et al., are tested to see whether strategic difficulties are at the base of the AB. The results of the study did not provide any evidence that support a strategy-based approach. A few problems with the strategy-based approach will be discussed and a new training task is proposed in order to eliminate the flaws that this design showed.

Keywords: Attentional blink; Memory consolidation; PRIMs; Cognitive strategies; Brain training

Introduction

The attentional blink (AB) is a paradigm that is used for examining limitations in visual processing regarding memory consolidation and conscious report (Marois, Yi & Chun, 2004). It refers to a suboptimal performance often reported in a rapid-serial-visual-presentation (RSVP) task in which participants are asked to report two targets in a stream of distractor stimuli. When the second target (T2) is presented within 200-500 ms of the first target (T1), participants are severely impaired at reporting the second target (Raymond, Shapiro & Arnell, 1992). This deficit regarding the second target is due to the presence of T1, since participants have no trouble reporting T2 when T1 is absent (Raymond et al., 1992; Joseph, Chun & Nakayama, 1997). Early models of the the attentional blink mainly point to capacity limitations as being the cause for the phenomenon (Raymond et al., 1992; Chun & Potter, 1995), whereas later models think the problem lies in executive control functions. (Di Lollo, Kawahara, Shahab, Ghorashi, & Enns, 2004; Bowman, & Wyble, 2007; Olivers, & Meeter, 2008). These models will be briefly explained later in the introduction.

In a recent study, Choi, Chang, Shibata, Sasaki, & Watanabe (2012) proposed a training task designed to eliminate the AB. The researchers used a task, similar to the AB paradigm, in which the second target was presented in a salient color (red). After the training, the AB seemed to disappear. This did not happen in the control group, where they used a non-modified AB paradigm to train the participants. Using fMRI, they also found differences in dorsolateral perfrontal cortex activity, intraparietal sulcus activity and anterior cingular cortex activity between the pretest condition (before training) and the posttest condition (after training). This shift in activity suggests the improvement is attentional-based rather than processing-based, because processing-based improvement (the processing and consolidation of single items) would show similar BOLD-responses in pretest and posttest condition.

Taatgen, Damsma, Willems, Wierda & Martens argue that the results of the training by Choi et al. are problematic for models that explain the AB as a structural limitation. They suggest that even the more recent models regarding executive control implicitly consider the phenomen as a structural limitation, albeit in the executive control system. If the training can make the AB disappear after only one hour of training, structural limitations cannot be the right explanation.

In the paper, Taatgen et al. use the recently developed PRIMs theory (Taatgen, 2013), based on the ACT-R theory (Anderson, 2007), to provide a new explanation for the AB. The paper depicts AB as a task in which two strategies have to be combined, a target detection strategy and a memory consolidation strategy. The model attributes the AB to the wrong choice of consolidation strategy. It assumes that only a single element can be in the focal working memory at the same time (Anderson, 2007; Oberauer, 2002). The process of consolidating an element from focal WM to long-term memory takes about 200 ms, during which WM is temporarily unavailable (Nieuwenstein & Wyble, 2014). The first of two memory consolidation strategies described in the article is named the reactive strategy. In the *reactive* strategy, the system waits for T1, stores it in focal WM, waits for T2 and then combines T1 and T2 before it consolidates this chunk to long-term memory (LTM). The second, *proactive*, strategy also waits for T1 and stores it in WM, but then immediately moves it to LTM. Because the access to WM is now blocked, T2 cannot enter, thus producing AB. Both strategies are visualized in Figure 1.

In order to test the theory, they ran experiments on multiple variations of a task in which a stimulus was presented, quickly followed by a mask (Letter-mask training). Subjects then had to respond as quickly as possible with the stimulus that was shown. This meant that the stimulus had to be entered into focal WM, but did not need to be consolidated in order to give an appropriate response. This training task was effective in reducing AB, presumably by teaching the subject a reactive strategy.

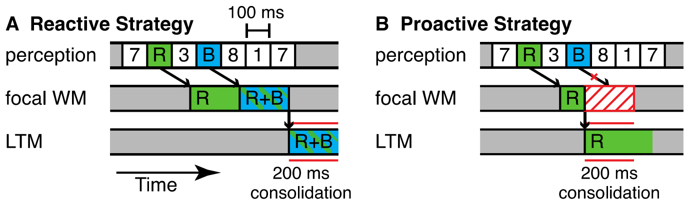

Figure 1. **(A)** The reactive strategy wait for both target items to enter the focal WM, before consolidating them as a single memory chunk. **(B)** The proactive strategy consolidates the first target immediately, shutting down access to the WM for approximately 200 ms. From Taatgen et al. (2015)

The results of this training task used by Taatgen et al. were the inspiration for the current study. If strategies are indeed the cause for the attentional blink and teaching subjects the better strategy improves performance, teaching subjects the suboptimal performance supposedly lowers performance in the AB task. To see whether this strategy-based approach might indeed be the right way to look at the attentional blink, this study aims to teach subjects the suboptimal proactive strategy.

Recalling the PRIMs explanation of a proactive strategy, the training must incentivize consolidation of T1 as soon as it is entered in focal WM. This is done by giving subjects a task that asks the subject to memorize a letter and then presenting them with a task that requires the use of the working memory, thus having to consolidate the first letter before starting on the task. After completion of the task, the subjects are asked to respond with the letter. One would not expect a change in performance for subjects that already utilize a proactive strategy. However, if subjects that normally use a reactive strategy in the attentional blink paradigm change to a proactive strategy, the PRIMs model would predict a drop in performance.

Before further methods of the experiment will be explained, some more detail will be given on the other models that were mentioned before.

First of all, Raymond et al. discovered the phenomenon in 1992. They attributed the attentional blink to confusion at the identification phase. The researchers argue that the salience of T1 in the stream is detected preattentively and an identification process (attentional episode) is initiated. Due to the speed of the RSVP, the features of T1 and the features of the item at T1+1 will be processed alongside each other and provide the identification mechanism with confusing information regarding physical features of T1+1 and the identity of T1. The system notices the potential confusion and initiates a suppressive mechanism to keep any new attentional episodes from starting and to prevent further confusion. This suppressive mechanism blocks incoming stimuli from entering the working memory, consequently causing the AB by keeping T2 from being processed.

In 1995, researchers came up with an alternative model to better fit their recent findings regarding the occurrence of an AB when targets were defined conceptually, rather than perceptually (e.g. black targets amongst black distractors) (Chun & Potter, 1995). This bottleneck model, referred to as a two-staged model of the attentional blink, describes two stages stimuli pass through in order to be memorized. Stage 1 occurs rapidly and involves the activation of conceptual representations by stimuli. Information about the identity of stimuli is available in this stage, but is susceptible to decay or masking by following stimuli. To avoid this loss of information, stimuli undergo stage 2. Identification of a relevant target initiates a transient attentional response that leads to memory consolidation to working memory. The attentional blink is addressed to a capacity limit in this second stage. Because of this limitation, T2 cannot be encoded into working memory while T1 is undergoing stage 2 processing. While T2 is waiting to enter working memory, it is susceptible to decay or interruption from other items and can therefore be missed.

More recent models shifted away from this capacity limited view on AB and directed their attention towards cognitive control as being the cause for AB (Dux & Marois, 2009)). The TLC model (Di Lollo et al., 2004) describes a central processor that can only attend one task at a time. When a target is detected at the early filter phase, the central processor moves from controlling the filter to monitoring consolidation processes. This leaves the filter under exogenous control, possibly causing the configuration of the filter to change and leaving targets susceptible to interference and masking by distractors.

The Boost and Bounce theory (Olivers, & Meeter, 2008) is comparable to the model by Raymond et al., it describes an input filter that can give an attentional boost (Boost) or attentional suppression (Bounce) to incoming stimuli. Due to the speed of the stimuli, T1+1 can receive part of the boost that was meant for T1, resulting in a similar interference as in the confusion model by Raymond et al. This interference causes an attentional suppression that lasts for a few hundreds of millisecond, keeping T2 from entering memory consolidation.

The eSTST theory (Bowman, & Wyble, 2007) refers in many ways back to the two-staged model by Chun and Potter. The AB is explained by describing an unconscious strategy used to overcome capacity-limitations in episodic registration. This strategy entails that until T1 is consolidated, no other target can be processed, thus causing the AB.

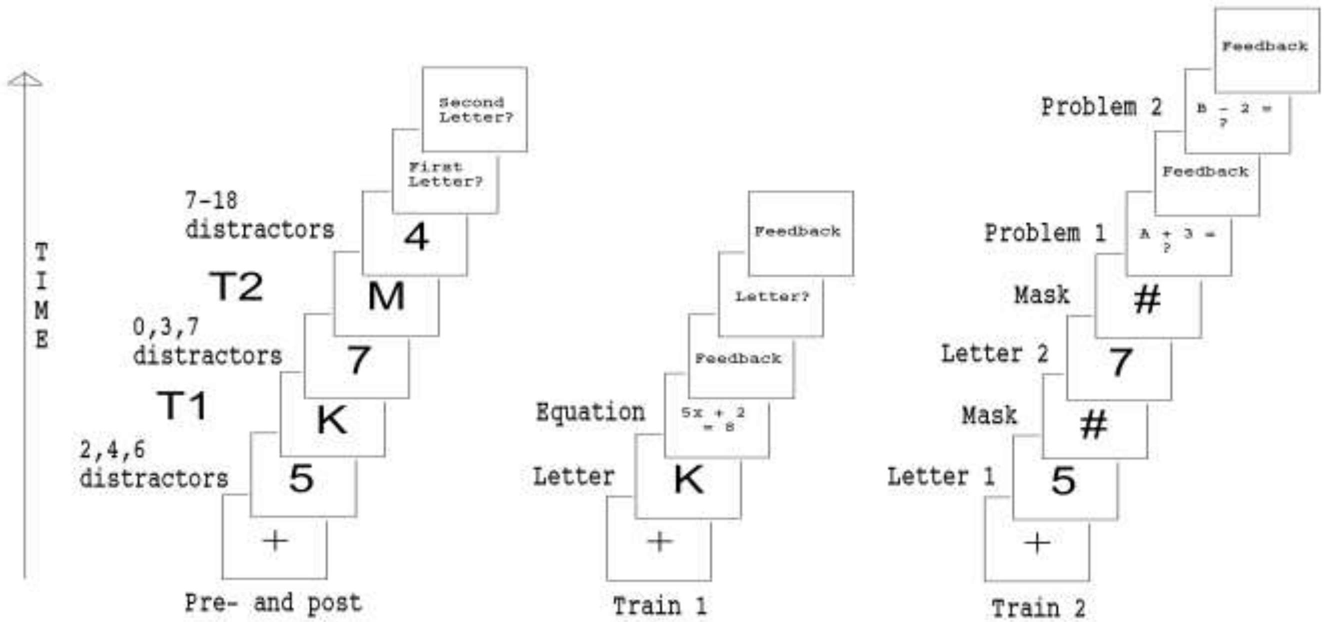

Figure 2. The task designs for the pre- and post-test tasks, the first training task and the second training task.

Concluding, Taatgen et al. argue that the results from the training by Choi et al. are problematic for models that attribute the AB to structural limitations, whether they are in the memory consolidation stage or in executive control functions. They proposed a new strategy-based model, in which the attentional blink is due to the wrong choice of memory consolidation strategy. This study aims to find out whether strategic difficulties are indeed at the basis of the attentional blink by seeing if teaching the subjects a suboptimal consolidation strategy results in a worse performance on the attentional blink task. In the remainder of this paper, the methods of the experiment will be shown and the results, as well as their relation to the strategy-based approach, will be discussed.

Experiment 1

Methods

Participants Thirteen research participants were paid 15 euros as a reward for their participation. All had either normal vision or their vision had been corrected to normal using glasses or contacts. The data of two participants were incomplete as they took longer than two and a half hours to complete the experiment. Another participant's experiment crashed during the pre-training trials and was also excluded from the dataset. In the end, the data of ten participants was used to compute the statistics. Participants gave written informed consent before the start of the experiment.

Stimuli/Materials The experiment was displayed on 24-inch computer monitors that have a refresh rate of 60 Hz. In order to execute and generate the experiment, E-prime 2.0.10.353 was used. The target stimuli were randomly selected from a list containing the uppercase consonants, excluding Q, V and Y. The distractor stimuli were single digits, excluding 1 and 0. All stream items were black, 18-point Courier New and presented on a white background.

Procedure The experiment consisted of a pre-test task, a training task and a post-test task. The pre-test and the post-test tasks were the same standard AB task, the only difference being the absence of a practice block in the post-training task. In the training task, participants were asked to remember a letter while solving an algebraic equation. The letter was presented before the equation for a short period of time. The complete experiment took approximately 130 minutes to finish. Written instructions explaining both pre- and posttest tasks and the training task were given prior to the experiment. T

Pre- and posttest task The trials each started with a fixation cross that lasted for 1000 ms. After this cross, a stream of 22 items was presented in the middle of the screen, 100 ms per item. After having presented the participants with such a stream of characters, they were asked to identify the first target. After doing so, subjects were asked to identify the second target. The positions of T1 and T2 in the stream were represented by the variables Jitter and Lag. The Jitter represents the position of T1 and was assigned three, five or seven at the start of each trial (i.e. T1 was either the third, fifth or seventh item in the stream). The Lag represents the position of T2 relative to T1 and was assigned one, three or eight (i.e. T2 was either the first, third or eight item to follow T1). Together these two variables made up nine trial conditions (three times three). The different conditions were randomly intermixed. The pre- and post-test task consisted of four blocks of 90 trials (10 replications per condition). In the pre-test task, this was preceded by a practice block of 9 trials.

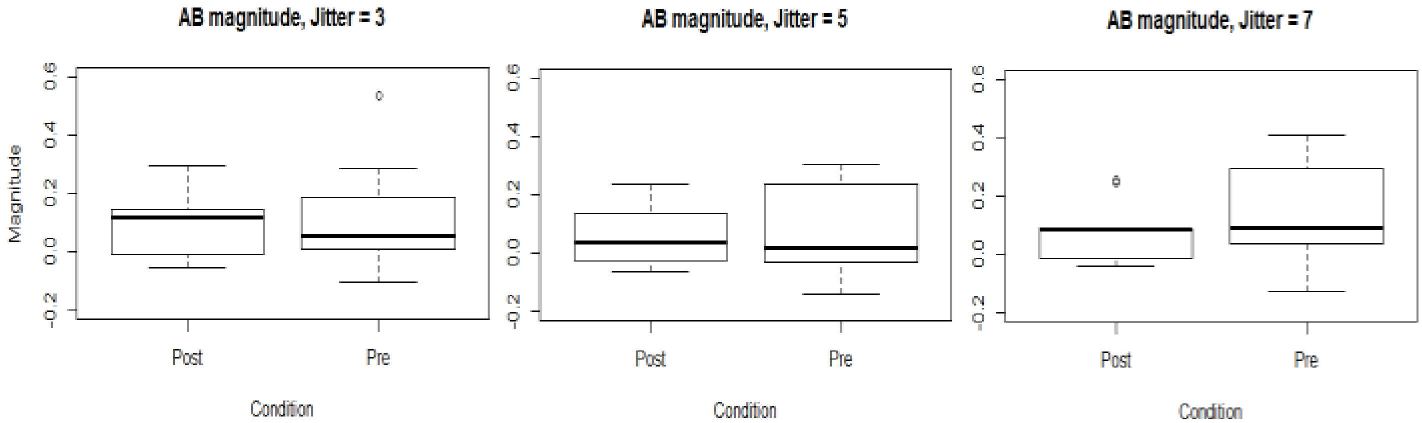

Figure 3. Boxplot of the AB magnitude for experiment 1 on all Jitter conditions

Training task The algebraic training task was composed of one block of nine trials, followed by four blocks of 126 trials. Again, each trial starts with a fixation cross. The fixation cross was presented for varying times. There was a random selection before each trial, choosing between 600, 800, 1000 or 1200 ms delay lengths. After the fixation cross, a letter target stimulus was presented. As in the pre- and posttraining tasks, the letter was randomly chosen from a set containing all consonants except Q, V and Y. The target letter was always presented for 100 ms.

Directly after the letter followed an algebraic equation of the form ax + b = c. The sum was generated at the start of each trial. This was done by choosing a random number from the set 4 – 7 and assigning it to a. Then, c was assigned a random value between 4 * a and 7 * a and b was calculated using the modulus of c and a (c mod a). Using integer division, x was calculated for checking the response of the subject.

The equation was presented until the participants responds with an answer. Then, a 1000 ms feedback display was presented indicating either “+5 points” or “incorrect” and also showing the overall score. After the feedback display, the participant was asked to repeat the letter from the start of the trial. It was followed by the same feedback display of 1000 ms, this time for the letter response. Total score was stored and displayed at every feedback display.

Results

For the pre-test and post-test data, the magnitude of the AB was calculated using the data of T1 accuracy and T2 accuracy. The AB magnitude represents the size of the attentional blink and was computed by subtracting T2|T1 on lag-3 from the T2|T1 on lag-1 and lag-8 divided by two. T2|T1 is the mean accuracy on T2, for the subset of the data in which T1 was answered correctly. The magnitude was used as the dependent variable, because it shows the relative size (performance on lag-3 in relationship to baseline performance) of the blink better than analysis of regular T2 accuracy would.

For an insight in the size of the attentional blink in pre- and post-test conditions, boxplots were made for all Jitter conditions. The plots are shown in figure 3.

R(R Core team, 2015) and lme4(Bates D, Maechler M, Bolker B & Walker S, 2014) were used to construct a linear mixed effects model regarding the relationship between AB magnitude as a dependent variable and Test-condition (pre-test, post-test) and Jitter (location of T1 in stream) as independent variables. Test-condition and Jitter were entered as fixed effects. As random effects, there was an intercept for subjects. To inspect the residuals, a QQ-plot as well as a residual plot was used. Both plots showed no obvious signs of heteroscedasticity or deviation from a normal distribution. Likelihood ratio tests using a full model containing the variable of interest against a model without the variable of interest were used to obtain the necessary p-values.

The analysis showed that Test-condition influenced the AB magnitude ($\chi^2(1)=4.4424$, $p=0.03506$), decreasing the AB magnitude in the post-training condition by about 0.05 ± 0.02 (standard errors). The analysis did not show a significant influence of Jitter on the AB magnitude ($\chi^2(1)=1.1792$, $p=0.2775$).

The mean score for the equation task in the training was 0.715 with a standard error of 0.08, the mean score for the letter memorization task in the training was 0.911 with a standard error of 0.02.

Discussion

In the introduction section was described how, using a specific training task, the magnitude of the AB could possibly be increased. In the training, early consolidation of T1 was promoted by presenting the participant with a task that requires the use of working memory. The hypothesis was that this early consolidation strategy would also be learned and used in the posttest task, shutting down the access to WM for T2.

The results of the experiment show that the AB magnitude decreased over test conditions, rather than increased as hypothesized in the introduction. No significant effect was found for the varying Jitter conditions. The general performance on the second target during the AB window (200-500 ms after T1) is remarkably high in the current set of participants. In the results of Raymond et al. and Chun and Potter, performance would drop to approximately 40 or 30 percent. In the current study, Lag-3 performance is somewhere around 80 percent. Looking closer at individual performances, six out of ten participants had Lag-3 scores higher than 80 percent in both pretest and posttest conditions.

The training might not have been enough to incentivize a quick consolidation of T1 in the posttest task. A possible explanation for this could be that the two task did not have enough similarity between them, thus making it hard to transfer learned skills from one to the other. In order to further enhance the skill-transfer between the training task and the AB task, a second training was designed, more similar to the AB tasks used in the pre- and post-test tasks.

Experiment 2

Methods

Participants Ten research participants were paid 15 euros as remuneration for their efforts. All of the participant had normal or corrected to normal vision. During two of the experiments, the computers ran into an unforeseen display error and the results of those experiments have been omitted from the dataset because they are incomplete. Thus, the data of eight participants was used in the analysis. Participants gave written informed consent before the start of the experiment.

Stimuli/Materials The second experiment was displayed using the same monitors and research environment as experiment one. This included a 24-inch monitor with a refresh rate of 60 Hz as well as the E-prime software 2.0.10.353 to execute and generate the experiment. The target stimuli were stochastically selected from the set of uppercase consonants, excluding Q, V and Y. The distractor stimuli could be single digits between 2 and 9. The stream items were all presented in an 18-point Courier New font. The letters were black and the background was white.

Procedure The second experiment was composed using the same pre- and post-test attentional blink task as the first experiment but differed in its training task. This training task had the participants remember two numbers after which they had to solve two easy sums involving those numbers. The experiment took about 120 minutes on average to finish. Written instruction, comparable to those in experiment one, were handed out before the experiment. The instructions explained both the pre- and post-test tasks as well as the training task.

Pre- and posttest task The pre-test task and the post-test were identical to the ones used in experiment 1.

The Double-Number task The Double-Number experiment also used 9 practice trials to get the participant acquainted with the experiment set-up. Another four blocks of 126 trials were used to train the participant. Each trial started with a fixation cross. This cross was presented for either 600, 800, 1000 or 1200 ms. After the fixation cross, a random number between zero and nine was presented for 100 ms, followed by a mask for 600 ms. This presentation of a number followed by a mask was then repeated using a different number.

After the second mask, the first question was presented. Question were presented in the form A + 4 = ? or B – 3 = ?. The A refers to the first number in the presentation phase, whereas the B refers to the second number that was presented. The number behind the operator was randomly chosen between 0 and 5. This number was added up with either A or B, dependent on whether it was the first or second question. If the outcome was greater than nine, the plus-sign was changed to a minus-sign. Therefore, the solution to the question could never be a number that required more than one key-press to answer.

Both questions were followed by a 1000 ms feedback display that showed whether the question was answered right or wrong. In case the participant managed to answer it right, it would also add 5 points to the total score. The total score was presented, as well as either “+5 points” or “incorrect”.

Results

Again, the magnitude of the AB was computed by substracting T2|T1 on lag-3 from the T2|T1 on lag-1 and lag-8 divided by two.

Boxplots of the AB magnitude were made for all different Jitter conditions. These are shown in figure 4.

A linear mixed effects model was constructed using R and the *lme4* package. The AB magnitude was used as a dependent variable and Test-condition and Jitter were used as independent variables. As fixed effects, Test-condition and Jitter were entered into the model. As random effects, there was an intercept for subjects. A QQ-plot and a residual plot were used to inspect any abnormalities in the residuals. Both plots showed no deviation from homoscedasticity and no deviation from a normal distribution. Likelihood ratio tests were used using a full model and a model without the variable of interest to obtain P-values.

The analysis showed no influence of Test-condition on the AB magnitude ($\chi^2(1)=1.0814$, $p=0.2984$. It also did not show a significant influence of Jitter on the AB magnitude ($\chi^2(1)=0.3977$, $p=0.5283$).

The mean score on the first sum in the training was 0.87 with a standard error of 0.04, the mean score for the second sum in the training was 0.86 with a standard error of 0.04.

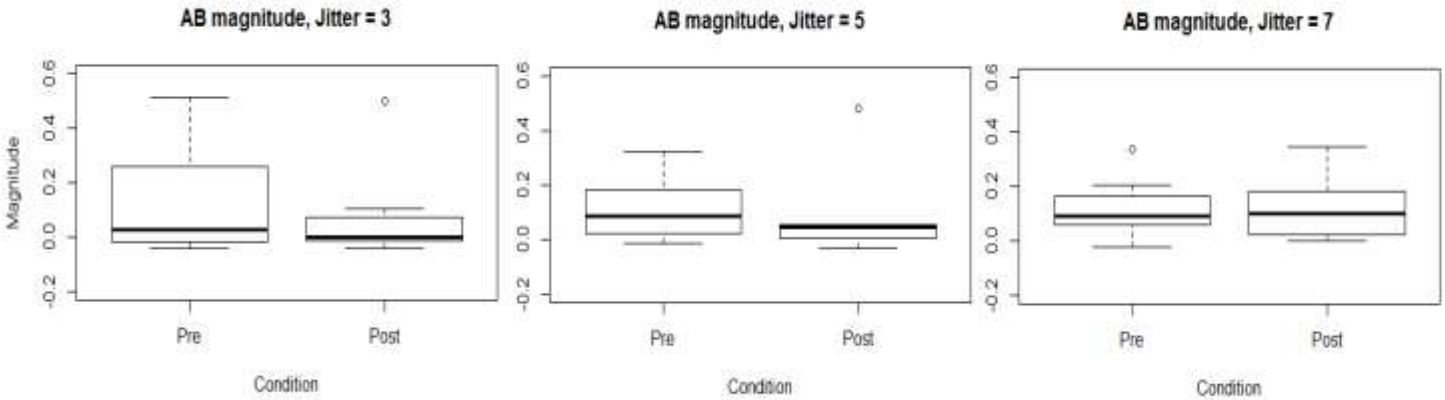

Figure 4. Boxplots of the AB magnitude for experiment 2 on all Jitter conditions

Discussion

The second experiment was designed to promote direct consolidation of T1 in the attentional blink paradigm. The results differ from the first experiment in that no significant effect of test condition was found. This means that the participant did not worsen in their performance. However, the participants also did not improve their performance.

The second experiment also showed a score similar to the first experiment in that the general performance on Lag-3 items was very high. Out of the eight participants, six had Lag-3 performances of over 80 percent.

General Discussion

Both experiments were designed to have subjects change their memory consolidation strategy. The hypothesis was that when subjects change to a proactive strategy, their performance will drop in the post-test task. Neither one of the experiments showed the expected results. In experiment 1, a significant difference between the performance in the pre-test condition and the post-test condition was found. However, the performance got better after the training.

There are a couple of explanations possible as to why the training tasks did not have the effected effect. First of all, it might be possible that the strategies that were learned in the training task did not transfer to the attentional blink task, but this seems rather unlikely. In the experiment by Taatgen et al., they used a training task that was also quite unsimilar to the attentional blink task. In this experiment, they found an influence of the training on the performance in the attentional blink task. If performance in one skill can change due to training on a different skill in the study by Taatgen et al., it should not be very different in the current study.

Taatgen et al. proposed in their PRIMs model that the wrong choice of memory consolidation strategy is the cause for the attentional blink. A second explanation might be that if the underlying causes for the AB are indeed strategy-based, promoting the use of a proactive strategy to participants that already utilize this strategy would give little effect.

But on the other hand, there is also a category of people that show no blink in their performance, the so called non-blinkers (Martens, Munneke, Smid & Johnson, 2006). Looking only at the PRIMs model, one would think that this group of people utilizes the reactive strategy. However, the results from Martens et al.'s EEG study on the attentional blink, and the difference between blinkers and non-blinkers in specific, seem to conflict with this notion. During the execution of the task, non-blinkers showed an earlier P3 peak, the component related to memory consolidation. This is the opposite of what you would expect when going by the PRIMs model. If non-blinkers use a reactive strategy their P3 peak would be expected later than for blinkers since the memory consolidation happens at a later moment in time than in the proactive strategy.

Perhaps a direct relation cannot be made between non-blinkers and the reactive strategy. It could be possible that non-blinkers are just fast processors and can perform well on the attentional blink task, even when using a proactive strategy. They could have consolidated T1 fast enough so that it will not block following stimuli. It could also be possible that there are more than just two strategies. Perhaps the non-blinkers use a different third strategy that allows them to consolidate the items as they come by, and still keep the second target from decaying or being overwritten. However, such a strategy does not seem possible in just the three modules that are used in the PRIMs model (Perception, focal WM and LTM) given the assumption that the consolidation process stops new items from entering the WM. So if the subjects that already show a blink in pre-test trials already use the proactive strategy, and the subjects that don't show a blink cannot be directly related to the use of a reactive strategy and are perhaps also using the proactive strategy, who is left to be trained? Perhaps Martens et al. show that the reactive strategy is not the correct underlying mechanic for good performers on the attentional blink.

Maybe the results of the current study show that a strategy-based approach does not fully cover the causes for the attentional blink. The ERP study by Martens et al. suggest that there is more going on that just the two strategies and that individual differences and consolidation speed play a role in the performance.

Furthermore, it is interesting that in the behavioral experiment by Taatgen et al. the attentional blink decreases, but does not completely disappear. If subjects change to a strategy that is able of processing T2 in such a fashion that it can always be consolidated as well as T1, you would expect that the difference between Lag-3 performance and non-blink (Lag-1, Lag-8) lags would disappear. However, there is still an observable blink after the training. Therefore the behavioral experiment might not be enough evidence to say that a strategy change is the cause for the improvement of the subjects' performances.

Another explanation as to why the experiment did not have the expected outcome can be found in the design of the training tasks. Perhaps both training tasks did not succeed in sufficiently incentivizing the change of strategy. In both training tasks, the same strategies would be needed as in the attentional blink paradigm, namely, a target detection strategy and a memory consolidation strategy. One would expect that if the proactive strategy is the default in the attentional blink paradigm for a specific person, the same strategy would be the default in the training task. Vice versa, if the reactive strategy is the default in one, it would probably be the default in the training task. Learning the novel training task means assembling a strategy from readily available task-general components, quite probably the same as in the attentional blink paradigm.

In the first training task the participants had to consolidate the letter before they could get started on solving the equation. A proactive strategy would detect the letter, move it to focal WM and consolidate to LTM immediately. The use of a reactive strategy in this task seems quite redundant. The reactive strategy would keep the letter in WM until a second item enters the WM. Directly after, the items will be chunked and consolidated to LTM. It might also be possible that due to the switching of tasks (memorizing a letter and solving an equation) the system recognizes that a memory chunk is not necessary. Whether the system chunks the letter with another item or consolidates it on its own, the WM will be shut down for about 200 ms, keeping the system from engaging in the second task.

The problem with this training might lay in the fact that the letter is presented for only 100 ms. Because of this short duration, the proactive strategy and the reactive strategy perform not as different from each other as in the attentional blink paradigm itself. The proactive strategy will consolidate as soon as it can, directly after perception. This starts at about 70 ms after the stimuli appeared (Taatgen et al., 2015) and finishes roughly 200 ms later. The reactive strategy will consolidate once a second item is entered into working memory. This happens at about 70 ms after the presentation of the equation, 170 ms after the stimulus itself. Consolidation of this target stimulus finishes at about 370 ms after the presentation. Thus, the proactive and the reactive strategy only differ by about 100 ms.

Furthermore, the equation was presented until a response was given. The delay caused by the reactive strategy can therefore not be an influence on the performance on the task. This means that the performance per trial is unrelated to the strategy applied, as is the feedback. Without any relationship between the feedback the participants receive per trial and the strategy that was applied, a shift in strategy might be unlikely to happen. However, in the letter mask training by Taatgen et al. (2015) there was no difference between the condition in which the task was to respond as fast as possible (speeded) and the condition in which no fast response was necessary (non-speeded). The researchers explain that the masking alone was effective for the strategy change, the speeded response was not necessary. An explanation could be that participants might not need an incentive to perform tasks quickly, because they provide themselves with an intrinsic incentive. Cognitive studies can take quite a while and it is possible that participants want to finish as soon as possible. This intrinsic incentive to perform a task fast might thus be enough to change strategies. However, in the first training task of this experiment the difference between the two strategies was only about 100 ms. Given that a single trial might take a few seconds, the 100 ms difference due to the strategies might go unnoticed in the temporal variance that is already present in the task.

In the second training task that was tested in this study, the proactive strategy would detect the first number and move it to focal WM. Here, it would consolidate this item immediately. This consolidation process takes up about 200 ms, whereas the second target appears 700 ms after the first target (100 ms presentation, 600 ms mask). When the second target ultimately appears, the focal WM will be free and the second number can enter immediately. A reactive strategy would detect the first number, move it to focal WM and wait for the detection of the second number before it consolidates them together as a single memory chunk. During this consolidation period, the WM is blocked and the participant cannot get started on the task. However, the consolidation period of this chunk will be over when the subject starts on the first task. This means that a reactive strategy will, as in the first experiment, not have an effect on the performance on the questions. Furthermore will it not have an effect on the speed at which a trial will be performed. Thus, shifting to a proactive strategy will have no positive effect regarding performance or speed associated with it, making it very unlikely that participants will do so.

A different training task can perhaps be designed by changing the aspects that made the first training task not work. As described, the task gives very little differentiation between proactive and reactive strategy. Furthermore, the performance on the equation is not related to the memory consolidation strategy that is used. In this new task, letters are still presented for 100 ms, but a mask will follow that is presented for 500 ms, right before the equation starts. This makes is so that the proactive strategy will be ready to start on the task as soon as it is presented and the reactive strategy will have to wait until the consolidation process of the letter has finished. Because the temporal differences between the two strategies are now greater than in the first experiment, the expectation is that subjects will notice that the reactive strategy is slower and change to a proactive strategy. To further incentivize a strategy change, points could be assigned for a fast response, perhaps even in a gradual fashion. The proactive strategy will result in a higher score, because it starts on the second task directly after perception. The expectation is that subjects will want to shift to a proactive strategy in the training task. This change will carry through to the attentional blink task, thus another expectation is that AB magnitude will be increased in posttest trials.

Something might also have to be changed about the way subjects receive feedback in the pretest and posttest tasks. It is remarkable that people that use a suboptimal strategy continue to do so in future trials, without realizing that they are utilizing a suboptimal strategy. The AB task in this experiment uses multiple lag-conditions and the proactive strategy will not fail in all of them (it performs well on lag-1 and lag-8). Because participants do not receive feedback on their performance, they can only go by the number of targets they manage to report. Due to the variant nature of the conditions it can be hard to figure out that the current strategy is not the best one. Willems C, Damsma A, Wierda SM, Taatgen NA, Martens S. (2015) showed that when reducing this variety in conditions (only using Lag 2 trials), the performance of the subjects increased.

Apparently, when suboptimal performers of the AB task can gather sufficient evidence that a different strategy results in a better score, they will change strategies. The standard AB task does not seem to provide an environment in which this kind of evidence can be gathered. However, people that have switched from a reactive strategy to a proactive strategy due to a training task will have this evidence. This is because they have been utilizing the optimal strategy in the pretest condition and have had many trials, possibly enough to remember the performance of this strategy. When performing the posttest task with a proactive strategy, they will soon see that their performance has dropped compared to the pretest task and perhaps consider a change in strategy to the one they have been utilizing until the training task.

In order to prevent subjects from changing back to former strategy once a new strategy has been learned on the AB task, all feedback on this task must be absent. In the AB task used in this experiment, subjects could still indirectly receive feedback on their performance because they knew if they remembered a target when asked to report it. In order to prevent this from happening, an AB task must be used in which trials that contain no T2 can appear. When participants in this new task notice they did not remember seeing a T2, it can either be due to missing it or due to the absence of the target in the trial, thus giving no information about the performance of the subjects itself and the strategy they apply.

A final remark should be made about the data that ultimately entered the dataset. In the first experiment, the experiments of two participants were aborted because they took too long to finish the experiment. This reveals a certain bias in the selection of data that ultimately entered the dataset. Participants may be slow because they did not understand certain aspects of the experiment, were not involved enough in the experiment or because they are simply slower performers. In the latter case, this data could be quite interesting, especially in a study that involves training subjects to perform in a different way than they do by default.

Conclusion The experiment did not manage to enhance the attentional blink that participants show in the pretest condition. The ERP study by Martens et al. shows that good performance on the AB cannot be directly related to the use of a reactive strategy, thus making it hard to see which subset of people could actually be susceptible to a training like the one in this experiment. Furthermore, in the results from Taatgen et al. the blink did not completely disappear, indicating that a strategy-based might not fully cover the underlying causes for the AB.

Because of the design of the experiment and its possible flaws, the results of this study are probably no direct argument for or against a strategy-based approach. In the discussion, modifications to the training task were proposed. In this new training task, the use of a proactive strategy is promoted by giving out higher scores to faster responses on the second task (thus incentivizing immediate consolidation on the first task). Furthermore, adding trials to the AB tasks in which no T2 can be shown ensures that subjects are not able to receive any indirect feedback on their performance. If this training task again shows no results, more conclusions can be made about the role of cognitive strategies in the processing of sequentially presented visual stimuli.

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