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An aptitude-based influence on nonconscious arithmetic

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1 Introduction

One of the best known arguments in the field of artificial intelligence is based on the views of two of its best known founding fathers, Alan Turing and John Searle. Turing is in part famous for his idea that a computerprogram could be considered *intelligent* if people are unable to tell the difference between its behavior and that of their fellow humans (Turing, 1950). Searle disagreed strongly, presenting his Chinese Room Experiment to help him explain that simply *acting* intelligent is not enough to *be* intelligent. Searle based his argument on the fact that computers are unconscious while performing this seemingly intelligent behavior, and that a consciousness is a requisit for intelligence (Searle, 1980). This means that his argument rests (in part) on this difference in consciousness, which brings up the question: is there really a hard line we can draw between human consciousness and a machine's lack of it? This thesis shows an experiment focused on nonconscious processing in humans, which will show you that the destinction between man and program is not so simple as Searle would like you to believe.

1.1 An overview of subliminal processing

Subliminal processing is, in essence, the phenomenon of processing stimuli *nonconsciously*. In other words, when people process something subliminally they are not aware that this is happening, and often do not recall sensing the stimulus (Dehaene et al., 1998). This feature makes subliminal processing of a great interest to psychologists, in part because these hidden primes can have strong effects on our behavior, nudging us in one social direction or the other (Aarts, Custers, & Marien, 2008). In their 2001 paper, Bargh, Gollwitzer, Lee-Chai, Barndollar, and Trötschel (2001) have shown that by priming participants, they could be manipulated into working together or achieving selfish goals. Understanding the ideas behind such manipulation is obviously of a certain social importance, but there are also psychologists who believe that it could be used to examine patients suffering from major depressive disorder. These patients are often unable to correctly evaluate the emotions of others, making them unable to interact well with people around them. Subliminal processing of emotional faces indicates that sad faces are indeed given a lot more attention than happy ones (Sterzer et al., 2011).

If we want to research subliminal processing we have to objectively establish that stimuli are not consciously processed. Researching subliminal processing thus requires stimuli that are 'invisible' to our conscious mind (Costello, Jiang, Baartman, McGlennen, & He, 2009). Fortunately, this does not pose a problem.

When actively using our eyes, we humans are bombarded by an incredible large amount of stimuli that fall on our retina. Through *selective attention* we are able to focus on a tiny portion of these stimuli, enabling us to respond to the important bits of the external world while simply ignoring almost all irrelevant information (Duncan, 1984).In fact, we humans hardly realize that we do not perceive everything we sense: we are fooled into thinking that we are aware of most things we see. It is this property of vision that makes it well suited for research in subliminal processing. If the idea of subliminal processing is correct, then some information that falls outside of our selective attention is not alltogether lost. It could perhaps be processed without us knowing it, and might even affect our conscious processes.

To test if certain information is retained subliminally, Jiang, Costello, Fang, Huang, and He (2006) tested whether subliminally presented erotic images affected spatial attention. To make sure that stimuli were not consciously sensed, Jiang et al. cleverly exploited two properties of our visual system: *binocular rivalry* and *interocular suppression*. Interocular suppression is the phenomenon that when we focus with one eye, we suppress information from the other, preventing it from reaching our consciousness. This first phenomenon is the cause for the second, binocular rivalry, which states that our two eyes never show us a blurred combination of two images, but take turns in showing us their field of vision (Logothetis, Leopold, & Sheinberg, 1996). To make use of these properties of our visual system, Jiang et al. (2006) managed to delay the shifting of dominance between the eyes of their participants for a short while. During this time, they presented their participants with two sets of images: one for each eye. The dominant eye was presented with static: a rapidly changing image that kept the participants' attention but held no information. The recessive eye was presented with an erotic image.

In confirmation with Jiang et al's hypothesis, participants were quicker to shift eye dominance when erotic images were presented to their recessive eye than participants who had static presented to both eyes. Jiang et al. (2006) thus concluded that the unconsciously sensed erotic images were still processed and that the erotic content caused participants to shift their spatial attention. It was then theorized that this unconscious processing only occurs with stimuli that are evolutionary important, e.g. stimuli about sex, sources of danger, and food. These limitations aside, Jiang et al. have shown us that nonconscious information can affect our behavior.

Since 2006, many researchers investigating subliminal processing used methods very similar to Jiang et al's, using binocular rivalry and selective attention as their tools. However, results from later research differ in a very important way: they suggest that subliminal processing is restricted to evolutionary significant stimuli. A good example is the work done by Costello et al. (2009), which shows that the semantic meaning of words can also be subliminally processed. To account for these new discoveries, Lin and He (2009) proposed a framework called the *unconscious binding hypothesis*, which theorizes that many types of simple features can be unconsciously processed. According to the unconscious binding hypothesis, the binding of these simple features into complex features requires consciousness and thus cannot be done subliminally.

Lin & He's framework proved to be short-lived. In a 2011 paper, Sklar and Hassin presented evidence that arithmetic of increasing difficulty can be done non-consciously. They presented the results of experiments done with *contin-*

uous flash suppression, a technique commonly used in research on subliminal effects. Continuous flash suppression delays the switching of eye dominance by presenting noise in the form of quickly changing visual material. While the dominant eye keeps trying to focus on these stimuli, interocular suppression keeps our attention from attending what the recessive eye sees. Using CFS, Sklar and Hassin presented arithmetic equations of different difficulties to their participants recessive eye. The results of their experiment clearly show that participants could not only be succesfully primed with the smallest units of meaning (in this case the numbers), but were also able to interpret and solve the equations nonconsciously. This shows that the complex features that Costello et al. (2009) discarded, were in fact nonconsciously solvable. One year after Sklar and Hassin presented their results, Sklar et al. (2012) presented a second paper with nine different experiments designed to discover the limits of subliminal processing. Half of their experiments further explored subliminal arithmetic, while the rest were designed to experiment with other types of complex features. Results form this last group showed that strings of multiple words could also be nonconsciously processed.

1.2 Recent findings

As a conclusion of Sklar et al's 2012 paper, it seems that we are once again unsure about the limits of subliminal processing. In light of these new discoveries, some psychologists have voiced a radically different view on subliminal processes. In his 2013 paper *'Yes It Can, on the Functional Abilities of the Human Unconscious'*, Hassin presents us with an overview of the different categories of cognitive ability and how research has shown that all of them are able to work nonconsciously to a certain extent. Hassin then goes on to propose that earlier paradigms, including the *unconscious binding hypothesis*, may be wrong. He believes that the categorical difference between cognitive abilities that can, and those that cannot be done unconsciously, does not exist at all. Building on the foundation of earlier work, Hassin (2013) thus concludes that all cognitive abilities can be used unconsciously. Of course, this does not mean that they are *always* used unconsciously, or even most of the time. Hassin proposes that the likelihood for a cognitive function to be used unconsciously is based on three important factors.

1. *Practice*. The more an ability is practiced, the more likely it is to be performed automatically and unconsciously.

2. *Motivation*. If a person desires or likes certain things or tasks, it is more likely that they will solve them automatically. For example, if a person enjoys language and prides herself with punctuality, she will be more likely to unconsciously recognize a wrong use of (her) language.

3. *Ability*. Smarter people will be able to perform more difficult tasks automatically. Stronger people might be able to perform heavier physical tasks automatically. *Ability* could perhaps be compared with talent or insight.

Hassin (2013) suggests that the factors mentioned above explain some of the difficulties in earlier research. For example, the difficulty in finding the line between easy tasks and difficult ones in the arithmetic tests done by Sklar and Hassin (2011), can be explained bij different levels in ability or practice. Note that the ability of participants was not taken into consideration in these tasks, though they probably lie close together since alle participants were students at university level.

1.3 Testing the hypothesis

Hassin's three factors of unconscious processing-likelihood form a plausible explanation for earlier problems. However, little research has been done to test his hypothesis. The present study is designed to do just that. We have designed it to prove our hypothesis, which is that persons with a better developed arithmetic ability will be able to use subliminal arithmetic primes much more effectively than less developed persons. We have chosen for this focus on subliminal arithmetic because it has already been extensively researched. To find evidence for our hypothesis, we have split our experiment into four tasks.

The first task is a version of the subliminal experiments done by Sklar et al. (2012) and Sklar and Hassin (2011). We have named this task the *subliminal arithmetic task*. We will use continuous flash suppression to present participants with 'invisible' equations, and then examine if their reaction times on correctly primed target equations is better than for other equations. The effects of this task have already been shown by many researchers, but replicating their succes is crucial for our experiment.

After the subliminal arithmetic task, participants will take part in two objective tasks that test wether they have performed the first task correctly. These tasks are designed to give us a objective tool with which we can be certain that participants performed as intended. The tasks will help determine whether participants see the hidden primes, or whether these primes are so well hidden that they cannot affect the participants at all.

The fourth and final task is where Hassins' factors come into play. This task is designed to give us a measure of ability, motivation and/or practice of arithmetic for participants. Because we are not strictly interested in which of these factors play a role, we have decided to use the term *aptitude* to denote all three of them. Simply put, a person with a higher aptitude at equations is better at them than a person with a lower aptitude. To research the influence of aptitude on performance in the subliminal arithmetic task, we have designed the fourth task to be a simple (time based) arithmetic task. Participants will be timed while they fill in a form consisting of fifty eqautions. Since solving arithmetic quickly is obviously related to either practice, motivation or ability, it is no stretch to say that fast participants will have a higher aptitude for arithmetic than slower participants.

2 Method

2.1 Participants

27 participants, all native Dutch university-level students, attended and completed all four tasks. The participants' age ranged from 19 to 25 with an average of 22. 12 of the participants were female. Participants with glasses or contact lenses were allowed to perform the tasks if they had no problem focusing on the fixation cross. Two additional persons offered to participate but were excluded due to them being unable to see well with one of their eyes.

2.2 Determining eye dominance

Before starting the first task, all participants were checked for preferred-eye dominance. Determining eye dominance is not an exact matter and is sometimes hard to pinpoint, but by combining two different tests we could be reasonably sure.

The first test, called the *Miles Test*, is done by having participants extend both arms and place their hands together to form a small hole. Participants then alternately close their eyes to determine which eye is actively viewing the scenery behind the hole. When the image 'shifts' when one eye is closed, this means that the other eye has taken over. The closed eye thus appears to be dominant (Laby, Kirschen, Rosenbaum, Mellman, et al., 1998).

The second test is called the *Porta Test*. In the Porta test, a participant stands about five meters from an experimenter in front of them, and looks at the experimenters' nose. The participant would then alternately extend his arms and point at the nose of the experimenter. When doing this, the participant unknowingly places the finger of his extended hand between his dominant eye and the experimenters' nose. When the fingers of both arms are placed in line with the same eye (Figure 1), then according to the Porta test that eye is the

Figure 1: *The Porta test. People place their fingers in front of the same eye*

dominant one (Roth, Lora, & Heilman, 2002). This test provides a somewhat more objective result because it does not depend on a participant's judgement and was thus preferred when the Miles test seemed to disagree.

2.3 Apparatus and stimuli

Stimuli were presented using two linearized Philips Brilliance 202 P7 monitors. White stimuli were presented at a luminance of 90 cd/m2. Black stimuli at 1.2 cd/m2. Display resolution was set at 2048x768, and a refresh rate of 85Hz was used. Everything was presented using MATLAB with the Psychtoolbox extensions. The background in all experiments was a standard gray color, with a luminance of around 44.7 cd/m2. Participants viewed both monitors at a distance of 75 cm using a mirror-stereoscope, which caused dichoptic presentation. Figure 2 shows a picture of our setup. All equation-stimuli that used this setup were presented using the standard Helvetica font. All stimuli used in our computer tasks were presented in a fuse rectangle of 160 by 160 pixels, or 6.5 by 6.5 cm. The background of the rectangle was the same color and brightness as the rest. The visual angle of the fuse rectangle was 85 degrees. The purpose of these rectangles was to give participants two very similar images that their eyes could easily fuse together.

The first three tasks employed computer-based stimuli with the system described above. The fourth task used equations printed on paper. For this last task, a stopwatch was used.

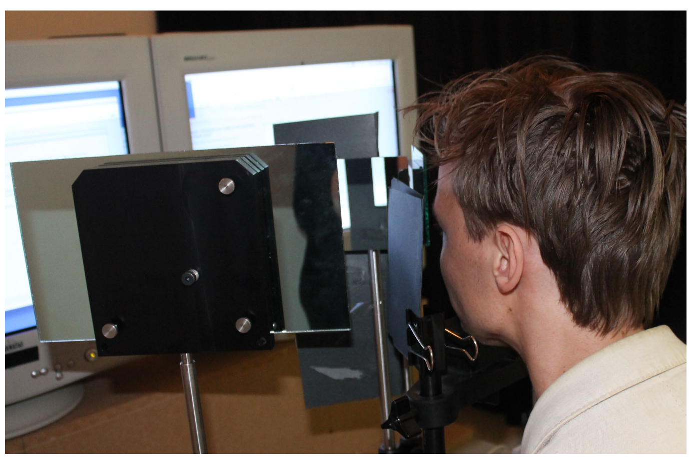

Figure 2: *Our setup, consisting of the stereoscope and two monitors*

2.3.1 Stimuli used in the subliminal arithmetic task

The first task used three main stimuli (Figure 3). During 700 ms, the participants' dominant eye was presented with the first stimulus, a static-like black and white mondrian-esque mask that rapidly changed at a speed of 10 Hz. These stimuli filled the entire fuse rectangle. Meanwhile, the recessive eye was shown the second (prime) stimulus: a single addition equation of the form A + B = C, such that A and B were two single digit positive numbers and C was their sum. The prime was presented during the same time as the mask. The prime started out as almost undistinguishable from the background, at a luminance of 45.5 cd/m2. During the 700 ms of presentation, the prime grew brighter in seven steps of 1.75 cd/m2 per 100 ms. This means that at its brightest, the prime was presented at about 57.8 cd/m2. After prime and mask had been presented, a black fixation cross was shown to both eyes for 200 ms. The third set of stimuli presented during the first task consisted of supraliminal (plainly visible) equations. These equations had the same size and form as the prime equations, but were plain white (90 cd/m2) and thus easily visible on the gray background. These stimuli remained on the screen for as long as participants needed to answer their current trial.

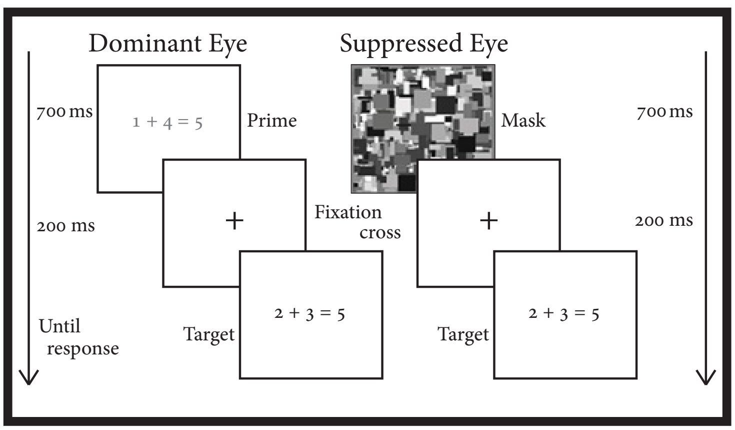

Figure 3: *A representation of type and durance of the stimuli in the first task*

The target stimuli came in four different combinations with the prime stimuli: congruent, incongruent, false A and false B. Congruent stimuli were correctly answered equations with the same result as the prime. Incongruent target stimuli were correctly answered but with a different result. False A targets were incorrectly answered equations but with the same answer as the prime, and false B stimuli were incorrectly answered and also had a different answer. The stimuli used in this experiment can be found in appendix A. This shows the 24 primes in combination with the four types of target stimuli. Every combination was presented twice, leading to a total of 192 trials in this task.

2.3.2 Stimuli used in the maskless objective task

The second task used just one type of stimulus, which was identical in font, contrast and presentation-time to the prime stimulus in the first task. However, in this task the prime stimulus did not have an answer to the equation filled in. Also unlike in the first task, this stimulus was easier to spot because it was not hindered by the mask stimuli.

2.3.3 Stimuli used in the masked objective task

The third task used two types of stimuli, exactly identical to the prime stimulus in the second task, and the mask stimuli described in the first task.

2.3.4 Stimuli used in the arithmetic aptitude task

The last task used a piece of paper with fifty unsolved addition equations. Appendix B shows these equations exactly as participants received them. These equations were all of the form 'A + B =', where A and B were single digit positive numbers. The equations were divided into two columns of 25 each. As a precaution, the equations used were not copied from the list of equations used in our first task. This was done to avoid equations being 'primed' by equations seen in earlier tasks. All equations were printed in the Arial font at size 10.

2.4 Procedure

2.4.1 Task 1, the subliminal arithmetic task

As explained in the introduction, the subliminal arithmetic task was closely based on one of the subliminal tasks carried out by Sklar et al. (2012). Therefore, a lot of procedural details are similar to their work.
Observers were seated in a dimly lit room with their head kept steady on a chin rest. Through the use of the mirror-stereoscope and dual monitors mentioned above, both eyes of the observer were directed to the center of different monitors. Before starting the task, participants were told that they were participating in an arithmetic-based experiment which would tell us something about their eyes. We informed participants that the estimated time for the entire experiment (all four tasks) was around thirty minutes, based on how fast they performed. Participants were then asked if they could succesfully fuse the two empty fuse rectangles. We asked this to make sure that participants were not afflicted with a disorder called *strabismus* in which a persons eye is not aligned properly (Graham, 1974). Though 4 percent of people have strabismus, most of them do not know this because their brain has adapted to this situation. However, if one of their eyes was not properly aligned, the participant was not suited for this experiment. After this initial test was succesfully completed (all 27 participants succeeded), participants were told that throughout the experiment they were required to focus on the fixation cross, except when a (supraliminal) arithmetic equation was presented (the target-stimulus, not the prime). They were then

told that each trial consists of a burst of static lasting for about one second, followed by an already solved equation. Participants then were explained that they were to judge the viewed equations and decide, with the left and right arrow key, whether or not these equations were correct. Note that, even though participants viewed the mask with only their dominant eye, we do not tell them this. After being told that they would see static, participants automatically assumed that the static was seen with both eyes. Because of this, participants were clueless as to what we were researching until after the experiment.
When the task was finished, participants were told about the existence of the prime equation presented to their recessive eye, and directly asked whether or not they saw the prime equation during the task. This last step was simply an extra check, since the objective tasks (task 2 and 3) were also designed to make sure participants did not see these primes.

2.4.2 Task 2, the maskless objective task

As with the first task, participants were placed behind the stereoscope and monitors, and placed their chin in the chin rest. Before starting this task, participants were told that this task was designed to prove that they could succesfully see and distinguish prime equations with the same intensity and contrast as in the first task. In this task the prime equation was again presented to the participants' recessive eye. However, no mask was shown to the dominant eye. This task is an important check because it showed us that the prime stimuli were not *so* difficult to see that they could not have had effect in the first task. If participants were unable to distinguish the prime *without* the mask, then surely they could not have used the information when the mask *was* used.
After explaining what this task is designed for, participants were told what to do next. In this task, the prime equation was shown the same length of time as in the last task. However, this time the prime was an equation that did not have its answer filled in. Participants were asked to remain vigilant for when the prime appeared, mentally solve the equation, and then answer with the left and right arrow keys whether the answer to the prime was an even or an odd number. If participants did not see the prime, they were asked to randomly guess odd or even. This task was a lot shorter than the last one, since we were not interested in reaction time but simply in whether the participants saw the prime or not.

2.4.3 Task 3, the masked objective task

The third task was almost identical to the second one, except for the fact that the mask was again added. Like in the second task, participants were asked whether they could spot the (now hidden) prime equation and decide whether its answer was an even or an odd number. The importance of this task was to find out whether participants could actively force themselves to see the prime equation, or if they still could not see it. Of course, an important difference with the first task was that participants were now aware of the prime's existance. It could be argued that partcipants who could see the prime in *this* task, would not have necessarily seen the prime in the first one. However, since the invisibility of the prime equations is very important for the entire experiment, we had nevertheless decided to omit participants who saw the primes (in the first task) from data analysis. Note that if participants could not see the prime even when *knowing* it was there, then it is extremely unlikely that they could have seen the primes in the subliminal arithmetic task. Another thing to note is that participants, should they fail to see the primes, were asked to always 'guess' with the same arrow key. This way, it would be easy to pick out participants who did not see the stimuli (because their answers were always the same). We made sure however, that participants were not lead to believe that we *wanted* them to not see the prime.

2.4.4 Task 4, the arithmetic aptitude task

As mentioned in the first section of this paper, the first three tasks were all designed to accurately replicate the work done by Sklar et al. (2012). The fourth experiment however, is where the three factors from Hassin's hypothesis came in (2013). The arithmetic aptitude task was a simple list of fifty addition equations. After finishing the third task, participants were asked to sit behind a desk with pen in hand. They were told that they were to solve fifty equations as fast as possible, while giving the highest priority to accuracy (not making any mistakes). When participants were ready, we started a timer and removed the sheets of paper covering the equations. As soon as participants finished the equations, the timer was stopped and their timescore was noted. After completing this task, participants had finished all requirements for the entire experiment and were given the oppertunity to ask questions and recieve their well-deserved cookie! Any remarks or criticism on the tasks were of course noted and considered in the following sections of this paper.

3 Results

Before we used the results of our 27 participants to find an influence of any significance, we examined each participant based on whether they met the conditions set for the tasks. In this section, we will briefly present the results of the tasks, as well as any criticism or remarks the participants had.

Before we started our first task, participants used the Porta test and Miles test to determine eye dominance. Nineteen participants appeared to have a dominant right eye, leaving eight participants with a dominant left eye. These results are in accordance with research stating that 2/3rd of all people are right eye dominant (Chaurasia & Mathur, 2008).

3.1 Passing the objective tasks

The objective tasks (tasks 2 and 3) were designed specifically to determine whether participants could see the prime stimulus without the mask (task 2) and if the prime stimulus remained invisible with the mask, regardless of the participants' awareness of its existence (task 3).

Since there was no mask hiding the primes in the second task, we accepted the (subjective) confirmation of the participants themselves as evidence. Of the 27 participants, five were unable to see the prime stimulus in this task, and were thus excluded from analysis. All remaining 22 participants stated that they could see the primes. However, most participants pointed out that they failed to see the first two or three primes, which they credited to the primes' rapid presentation and disappearance. Since participants *did* manage to see the primes in the rest of the cases, we decided to further continue the analysis of their results.

For the third task, which included a mask, the subjective opinion of participants was not enough to include or exclude them from analysis. Instead, we viewed the results on the odd/even task they performed, and excluded from analysis two participants that performed better than chance. Recall that before performing this task, participants were asked to always guess with the same arrow key if they never saw the hidden prime. Due to this fact, seventeen participants were easily identified as having not seen the prime, since their answer was the same in every trial. The final three participants stated that they saw small parts of letters or numbers in a few trials. However, since these participants subjectively stated that they had not seen enough to correctly influence their answers, and since they still did not perform better than chance on the task, they were included in analysis.

3.2 Errors in the written task

For the 20 participants still eligible for analysis, we viewed their time score and number of mistakes on the arithmetic aptitude task (task 4). We have excluded two participants who made more than one mistake, because there is

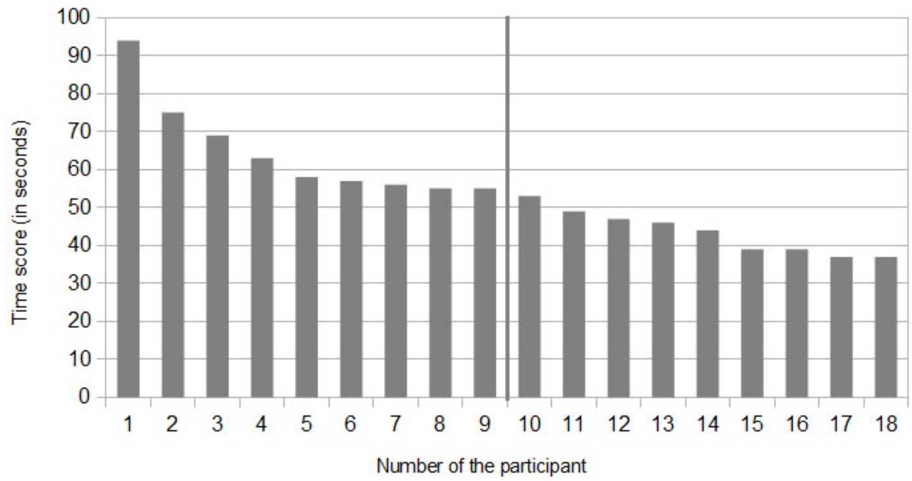

Figure 4: *Results (in seconds) of the arithmetic aptitude task, in order of slowest participant to fastest. The vertical line shows how the participants could be divided into two even groups, using a median split*

no non-abitrary time penalty we can award these mistakes. Figure 4 displays the results of the arithmetic aptitude task. Note that participants' time scores are given in rounded numbers. We have done this because the time score was measured with a stopwatch, and thus depended on the reaction time of the experimenter.

3.3 Results of the subliminal arithmetic task

Of the 27 participants that attended the experiment, a total of nine have been excluded from analysis. We examine the results of the subliminal arithmetic task (task 1) for the remaining 18. An interesting thing to note is that all nine excluded participants were right-eye dominant. When performing the task, participants were presented with four different types of (supraliminal) target equations. The incorrect equations (types false A and false B, see section 2.3.1) were only included in the task to keep participants occupied, and were not further examined in this analysis. Our main point of interest was the difference in reaction time between the congruent and incongruent types of equations. In Figure 5, you will find the median reaction times of congruent and incongruent cases, for each participant.

3.4 Preparing the results

It is this experiment's hypothesis that persons with a higher aptitude in arithmetic, would be better able to nonconsciously perform arithmetic. In our current

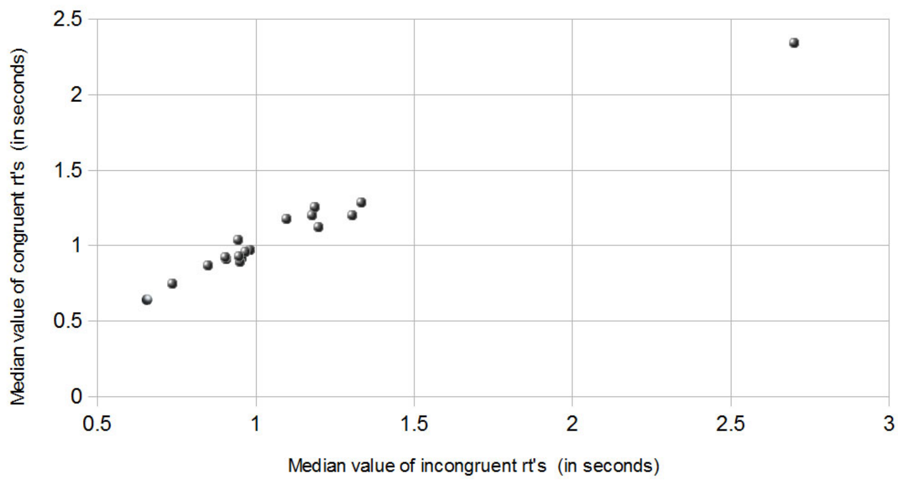

Figure 5: *Results of the subliminal arithmetic task for all eighteen participants. Compares the median reaction time for congruent cases with that of the incongruent case*

experiment, we therefore expected our results to show that faster participants had a (relatively) greater difference in reaction time between their congruent and incongruent cases. We expected that these participants had shorter reaction times in congruent cases, and that these differences were significantly larger than participants with lower arithmetic aptitude. If our results confirm this, then they will prove that participants with higher arithmetic aptitude are more affected by the hidden prime.

The first step in our analysis was to create two groups of participants that we could then compare to each other. The arithmetic aptitude task (task 4) was designed to test our participants for their skill at arithmetic. To examine whether participants with a higher aptitude performed better on the subliminal arithmetic task (task 1), we have devided our remaining eighteen participants into two even groups based on a median split of their time scores. The first group contains the nine participants that took the longest to complete the 50 equations. For simplicity we we will refer to this group as the 'slow' group. The second group is thus the 'fast' group. Figure 4 on the previous page presents an overview of these participants. The first nine participants form the slow group.

After creating two groups of participants to work with, our next step was to compare the median congruent and median incongruent reaction times between participants of both groups. We chose not to calculate the median incongruent RT minus the median congruent RT for each participant. Instead, we calculated the *percentual* differences between the median incongruent and median congruent reaction times. This is very important, because a difference of 0.2 seconds is a bigger deal for a person with a median of 0.7 seconds, than for a person with a median of 2.5 seconds. By using percentages we can now view the *relative* increase or decrease in reaction time. These results are presented in Figure 6.

Slow group			Mean		Fast group			Mean		Total mean
86.59	100.66	105.4			97.37	101.92	93.64			
96.18	109.42	92.01	99.41		93.86	98.52	101.28	98.36		98.88
101.54	106.86	96.03			101.98	98.85	97.79			

Figure 6: *The percentual differences between the RTs of the median incongruent and the median congruent cases. Also noted are the average differences for both groups, as well as for all participants*

Figure 6 shows a number of interesting things. First of all, it shows us that on average, participants were about 1.2 % faster at the congruent equations. Secondly, it shows us that members of the slow group had only a 0.6 % increase, while members of the fast group had an increase of about 1.7 %. For a complete overview of our relevant results, Figure 7 shows the median congruent and incongruent RT's of each participant, compared with their performance on the arithmetic aptitude task.

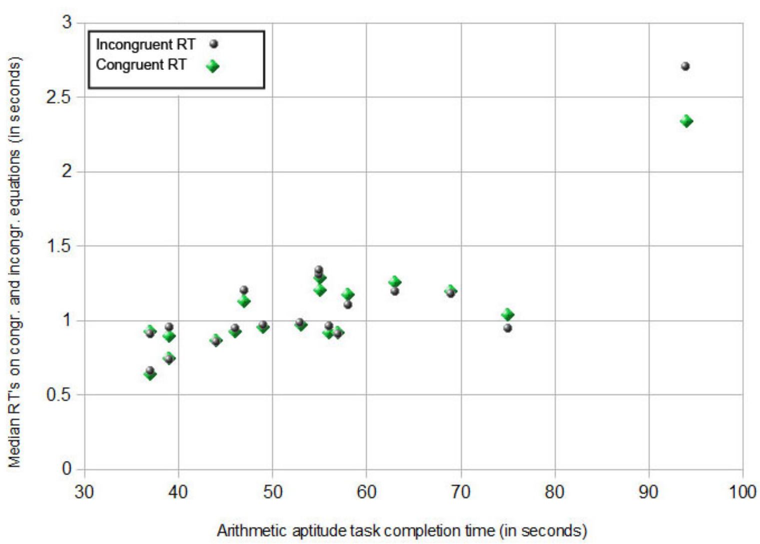

Figure 7: *An overview of our results. Participants' median reaction times for congruent and incongruent cases are set against their time scores in the arithmetic aptitude task*

3.5 The statistical analysis

To determine whether a significant influence exists, we have used the results displayed above in a unpaired t test. This statistical hypothesis test compares two groups of data (in this case, the results from both groups of participants) and calculates an estimated variance and estimated error of difference between the two means. For this experiment, we have set our 0-hypothesis to be that both groups of participants had the same effect of arithmetic aptitude on their reaction times in the first task. If the results show that our 0-hypothesis is significantly unlikely ($p < .05$) then we may legitimately conclude that there is indeed an aptitude-based influence. Our t test is called one-sided or one-tailed because we expect to find that the fast group performs better than the slow group. The other possiblity is very unlikely since the results show us that the slow group has seen a smaller percentual increase in RT than the fast group. Applying the t-test to our two groups, we found no significant effect for the aptitude-based influence, $t = 0.393$, $p = 0.350$. This means that the chance that our 0-hypothesis is correct is about 39%, a result that is not nearly significant enough to justify a confirmation of our experiments hypothesis.

4 Discussion

The results of our experiment are of course in every official sense a rejection of the hypothesis we set to this experiment. However, this does not necessarily mean that the hypothesis in general is untrue. After all, participants in our fast group still performed better at the subliminal arithmetic task than participants of the slow group. In the literature presented in the first section, many psychologists had access to larger groups of participants. Working with averages based on larger groups means that there is a smaller chance that a difference is based on chance. Another advantage of more participants is that they do not necessarily have to be split into two groups. In our current experiment, we found only small differences in reaction times between the slowest persons of the fast group and the fastest persons of the slow group. When working with a larger amount of participants, it would be possible to split them into three or four groups. Comparing the fastest and slowest groups will then likely result in larger differences, increasing the likelyhood of finding them significant.

A different area in which future research could deviate from this experiment, is in the intensity of their stimuli. In this experiment, to make sure that enough participants would pass the the objective tasks, the prime stimulus was created with a luminance that was very close to the background, and ramped up in a short amount of time. When working with more participants, it could perhaps be fruitfull to make the prime stimulus stand out more (have a higher contrast in luminance). This way, although more participants would be able to see the primes and thus be excluded from analysis, the participants that *would* pass would have had the prime presented more clearly to their recessive eye. Furthermore, in much of the research reviewed earlier, experimenters prepared multiple variations on their experiments, changing the length of presentation of their stimuli. Though our presentation of 700 ms was copied from the most succesfull variant of Sklar et al. (2012), it could nevertheless prove valuable to try different lengths of presentation.

Aside from these alterations of our experiment, we have also taken another look at Sklar et al's exact results to help determine *why* our results are off. Sklar et al's paper contains nine different experiments in total, four of which concentrated on arithmetic. One way in which these experiments differed from one another was the complexity of the subliminal and target stimuli. While our experiment is based on the Sklar et al's ninth experiment where stimuli were equations consisting of two single digit numbers, there was also a different experiment which used primes and targets consisting of three digits, i.e. of the form A + B + C = D. The difference between these two experiments is interesting, because it could perhaps be used as a different way to add aptitude to the mix. A different experiment to our own could be devised, in which the hidden primes could deviate in difficulty. By using primes of two, three and perhaps four numbers interchangebly, we could examine whether there are differences in how participants react to these changes. Perhaps in our current experiment, using primes consisting of two simple numbers is not challenging enough to require much aptitude. Comparing results on different levels of difficulty could give us insight into when the aptitude is stretched in nonconcious processing.

We conclude this experiment on a hopeful note: though this pilot study has not given sufficient proof for its hypothesis, it does further explore a still growing area of research and present a few new options for future research. While the possible variations described above are certainly worth investigating, there are many other avenues of subliminal research that we could take. Hassin (2013) claimed that subliminal processing would be possible to a certain extent for our every cognitive process. This means that there is no reason to limit ourselves to arithmetic, though perhaps it is the subject that has thus far been studied most extensively. The experiments on subliminal semantic priming discussed earlier are also an excellent choice to replicate.

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Appendix A

false statement B	false statement A	incongruent statement	Congruent statement	prime equation
13=4+6	7=5+4	9=5+4	7=3+4	2+5
14=3+9	8=3+7	10=3+7	8=3+5	2+6
11=8+5	9=7+5	12=7+5	9=3+6	2+7
8=3+7	11=8+5	13=8+5	11=3+8	2+9
11=5+9	7=2+8	10=2+8	7=5+2	4+3
12=6+8	9=3+8	11=3+8	9=7+2	4+5
9=7+5	11=6+2	8=6+2	11=9+2	4+7
15=4+8	8=7+4	11=7+4	8=6+2	5+3
9=3+8	12=6+8	14=6+8	12=3+9	5+7
11=7+2	13=9+6	15=9+6	13=7+6	5+8
12=7+8	9=3+4	7=3+4	9=5+4	6+3
12=3+6	10=5+2	7=5+2	10=2+8	6+4
9=3+4	11=7+2	9=7+2	11=7+4	6+5
10=3+5	13=4+6	10=4+6	13=4+9	6+7
8=7+4	15=4+8	12=4+8	15=7+8	6+9
13=9+6	10=3+5	8=3+5	10=4+6	7+3
15=4+9	10=7+6	13=7+6	10=3+7	8+2
7=5+4	11=5+9	14=5+9	11=5+6	8+3
14=9+2	12=3+6	9=3+6	12=7+5	8+4
10=5+2	14=9+2	11=9+2	14=5+9	8+6
13=5+6	15=4+9	13=4+9	15=9+6	8+7
10=7+6	12=7+8	15=7+8	12=4+8	9+3
11=6+2	13=5+6	11=5+6	13=8+5	9+4
7=2+8	14=3+9	12=3+9	14=6+8	9+5

Figure 8: *The equations used in the subliminal arithmetic task.*

Appendix B

5 + 3 =	9 + 4 =
7 + 3 =	3 + 3 =
8 + 3 =	7 + 7 =
4 + 6 =	7 + 8 =
1 + 6 =	3 + 4 =
3 + 5 =	5 + 4 =
4 + 3 =	6 + 1 =
9 + 5 =	2 + 7 =
3 + 2 =	8 + 4 =
3 + 8 =	3 + 5 =
3 + 1 =	9 + 7 =
3 + 6 =	8 + 8 =
6 + 9 =	1 + 2 =
9 + 2 =	5 + 2 =
4 + 2 =	3 + 7 =
4 + 4 =	9 + 3 =
7 + 2 =	4 + 6 =
7 + 6 =	9 + 9 =
4 + 5 =	1 + 7 =
5 + 1 =	2 + 5 =
2 + 8 =	6 + 3 =
2 + 3 =	5 + 6 =
1 + 4 =	2 + 2 =
5 + 5 =	8 + 5 =
7 + 4 =	1 + 1 =

Figure 9: *The equations used in the arithmetic aptitude task.*