Do expected words enter consciousness faster under Continuous Flash Suppression? A direct and conceptual replication.

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Abstract

Cognition guides the detection and perception of stimuli in numerous ways. Stimuli that are in some way expected or relevant to us are detected and perceived more readily. To investigate whether this also means that expected stimuli enter consciousness faster, a direct replication was done of a Continuous Flash Suppression (CFS) study by Rochal (2017), in which it was found that expected words entered awareness faster than unexpected words. Subsequently, to explore the possibility that this expectancy effect was in fact due to perceptual priming, a conceptual replication was added in which the cue words were presented in capitals while the targets were kept in lower case. One-tailed paired-samples t-test analyses on standardized z-scores showed no significant expectancy effects in either the direct or the conceptual replication, and the analysis of variance did not reveal a significant difference in the expectancy effect between the direct and conceptual replication. However, the small effects that were found were in the same direction as in the original study, whereas the sample size (25 participants, of whom 11 male) was only half of what in advance was deemed necessary to arrive at a power of .80. Therefore, it was carefully concluded that expected words may enter consciousness faster, either as a result of perceptual priming or expectancy.

Introduction

Cognition guides the detection and perception of stimuli in numerous ways. Unlike newborns we do not see colored lines and shapes, but for example people and houses. Another example is that at parties we can hear a person across the room mentioning our name, even when we had not been listening to the conversation they were engaged in before. More generally put, stimuli that are in some way expected or relevant to us are detected and perceived more readily than they would have been otherwise (Kristjánsson & Campana, 2010). However, at least two questions remain. Is it possible that expected stimuli are perceived more readily because they enter consciousness faster? And if so, does this suggest preconscious processing of a higher order? To investigate these questions, we replicated a Continuous Flash Suppression (CFS) study by Rochal (2017) in which she found that words entered awareness faster when the participants were expecting to see them. Subsequently, to explore the possibility that this expectancy effect was due to perceptual priming, we conducted a conceptual replication of the original experiment. In this experiment the cue words were presented in capitals, while the targets were kept in lower case.

The fact that priming leads to faster processing can be well explained by the theory of predictive coding (e.g. Barrett, 2017). In this theory it is hypothesized that we have two sources of information for perception, the sensory information (bottom-up) and our prediction or simulation (top-down). In the case of priming, the ‘correct’ simulation, i.e. the representation that will enter awareness, is pre-activated by the prime, even before it is produced or activated by the stimulus. Therefore, the so-called prediction error for this simulation is minimized faster than it would be otherwise. As a result, it takes less time for the individual to become aware of the stimulus. This is why congruent information can be assumed to enter consciousness relatively fast.

Price and Devlin (2011) and Gagl et al. (2018) offer a predictive coding account for word recognition, based on fMRI studies on the left ventral occipitotemporal cortex (vOT), referred to by Dehaene and Cohen (2011) as the Visual Word Form Area (VWFA), as it appears to be the location of the visual lexicon. Price and Devlin propose that patterns of activation across vOT neurons that encode sensory information of words, can activate the neurons that encode semantics and phonology in higher order association regions, which provide recurrent inputs to vOT until the top-down predictions and bottom-up inputs are matched. As such, their account strongly resembles the connectionist model of Rumelhart and McClelland (1982), in which the letters a word consists of are processed in parallel, and the elements corresponding to features of letters activate letter elements, that in turn activate word elements, as well as the other way around. As evidence for this kind of automatic (i.e. non-strategic) top-down effects on word recognition, they point at the reduced activation in the VWFA when a word is primed by a masked picture or the same word in a different case (e.g. AGE–age). In this case, a reduced activation suggests ease of processing, as its activation is highest in unskilled readers, and lowest in people who can not read at all. Complementing the theory of Price and Devlin, Gagl et al. (2018) offer a similar predictive coding account for the recognition of individual letters.

The recognition of letters and individual words is a highly automatic processes, i.e. the prediction errors involved are not noticed by the individual (e.g. Gagl, 2018). Sometimes however, when an aspect of the situation is not just not expected, but in fact surprising, they are big and may require conscious effort to be resolved. In this case the anterior cingulate cortex is thought to provide surprise signals to a number of other brain regions, like the dorsolateral prefrontal cortex, which in turn provide information critical to explaining the causes of prediction error (Alexander & Brown, 2019). This is why, at least at a higher level of processing, incongruent information can be assumed to be attended to more than congruent information. However, since in this study the focus is on a different kind of (in)congruency, and also because it is important to distinguish between awareness and attention (Custers & Aarts, 2011), this is not at odds with our hypothesis.

The effect of expectancies and other forms of top down influences on information processing has long been studied using various techniques, such as ambiguous pictures (Mooney, 1957), lexical decision tasks (Meyer & Schvaneveldt, 1971), and dichotic listening tasks (Cherry, 1953). However, these techniques offer no indication of the time it takes for a stimulus to enter consciousness and thus make it difficult to dissociate detection from attention. For instance, in a lexical decision task, Aarts, Dijksterhuis, and De Vries (2001) found that participants who were thirsty responded faster to drinking-related items, but this cannot be seen as evidence that these items were perceived faster, since what is measured is categorization and not perception. Therefore, Rochal (2017) used a relatively new technique that makes it possible to study the timing of conscious awareness in a more direct manner, the breaking Continuous Flash Suppression technique.

Continuous flash suppression. Continuous Flash Suppression (CFS) is an adapted version of the original Flash Suppression method. In this method, an image presented to one eye is suppressed by the flash of another image in the other eye. In CFS, one eye is presented with a series of rapidly changing patterns, while the other eye is presented with a static image, like a face, object or word (Tsuchiya & Koch, 2005). CFS gives a longer duration of suppression than the original Flash Suppression (Tsuchiya, Koch, Gilroy, & Blake, 2006). Other advantages of CFS are that it can suppress images presented at the fovea and suppress images with success in every trial, because there is no adaptation (Lin & He, 2009). The series of rapidly changing patterns presented in one eye are usually a series of Mondrian patterns, which often consist of white, grey, and black, or colorful overlapping squares.

CFS is a useful tool for scientists to study conscious and nonconscious visual processing. In a CFS experiment, the time it takes for a stimulus to break through the suppression is measured. This time is often referred to as the 'time to emerge' (TTE). TTE is considered to be the interval in which the stimulus enters conscious awareness. When comparing the TTE's of, for example, an emotional salient face and a neutral salient face, Stein and Sterzer (2012) found that the TTE is lower for an emotional salient face. The conclusion that can be drawn from this, is that there must be some kind of preprocessing of the stimulus before it enters your conscious awareness. However, there is some debate about the extent to which TTE really reflects conscious awareness. In their review of experiments with CFS, Gayet, Van der Stigchel, and Paffen (2014) stress the need for a distinction between high-level and low-level processing. They elaborate this via an example from Lupyan and Ward (2013): when participants are cued with the word 'square', the stimulus will break through suppression faster if the target is indeed a square. This does not necessarily indicate that high-level semantic processing took place, it could just be that the visual representation of a square is activated and that is why it breaks through faster.

CFS, congruency and words. There have been several studies that investigated the effect of expectancies using CFS. In a small number of studies a shorter TTE was found in the case of incongruency (or surprise). Mudrik, Breska, Lamy, and Deouell (2011) for instance used CFS to suppress the awareness of complex scenes that were either congruent, for example a basketball player holding a basketball, or incongruent, for example a basketball player holding a melon. They found that incongruent scenes emerged into awareness earlier and further concluded that visual awareness is not required in order to integrate the object and background. However, in a replication of this study, Moors, Boelens, van Overwalle, and Wagemans (2016) did not find a significant effect of congruency. The effect they did find was in the other direction, i.e. the congruent scenes broke suppression faster, and in the sequential analysis they performed, they found that p-values fluctuate strongly. In contrast, they found a significant effect of inversion, a condition they added themselves, i.e. inverted pictures broke suppression later. They concluded that higher level processing during CFS was unlikely. Similarly, Rabagliati, Robertson and Carmel (2018) aimed to replicate Sklar et al. (2012), who reported that sentences broke into awareness more rapidly when their meanings were more unusual or more emotionally negative, even though processing the sentences' meaning required unconsciously combining each word's meaning. Instead, across 10 high-powered studies, they found no evidence that the meaning of a phrase or word could be understood without awareness, and therefore concluded that only low-level perceptual features, such as sentence length, could be processed unconsciously.

Other authors found a shorter TTE in the congruent condition. For example, Pinto, Van Gaal, De Lange, Lamme, and Seth (2015) used images of houses and faces as their cues and targets, and found a congruency effect on both detection and identification of the targets. In the second half of their study, they established that this effect was not caused by priming or attentional influences. In order to rule out the possibility of visual bottom-up priming, Stein and Peelen (2015) used categorical word cues. For instance, in the case the target picture was a car, the cue was the word 'car'. With five separate experiments, they showed that providing information about the category of the initially suppressed stimuli facilitates both localization and detection of these objects. The authors further established that this effect is not limited to more familiar objects, but is also present when participants are given orientation information for more simple, differently oriented stimuli.

Interestingly, Heyman and Moors (2014) found that, while the word frequency effect is one of the most robust findings in the psycholinguistic literature, word stimuli did not break CFS faster than their pseudo-word variants nor was suppression time modulated by word frequency. This suggests that CFS can (only) be used to study the earlier stage of word recognition, that is the perception phase, and not for the phases that involve the visual lexicon.

In conclusion, two related points of discussion keep coming up regarding CFS studies. One is that in these studies there is more than a normal variability in reaction times, allowing for more and larger false positives (Gayet & Stein, 2017). The other is the distinction between high and low-level processing. These points are related in that authors who stress the methodological issues of CFS, like Moors et al. (2016) and Rabagliati et al. (2018), tend to consider it unlikely that in this paradigm higher order processing is possible. This is also what makes the study by Rochal (2017) worth replicating. After all, if under CFS top-down processes were possible on a higher level, than surely they should be found on a lower level.

The present research. In the current paper, we will seek to replicate the experiment conducted by Rochal (2017) to see if cued words will break faster through CFS than words that are not cued. In this experiment, there were two conditions. A congruent condition, where the supraliminal word cue that was given before the subsequent CFS trial was the same word as the target used in that trial, and an incongruent condition, where the cue word did not correspond with the subsequent target word. In this experiment, the words in the congruent condition broke suppression faster than the words in the incongruent condition.

A replication of this study is warranted, because, as mentioned above, replications of other CFS experiments were not always successful. Also, because in the congruent condition the cue words were identical to the target words, it could be that the primed stimuli were perceived earlier simply because the simulation of the cue remained active in Visual Working Memory, as for instance Gayet, Paffen, and Van der Stigchel (2013) argue was the case with the colored patches they used in their experiments with CFS. It is important to consider this possibility, since according to Wiggs and Martin (1998) this kind of perceptual priming can have very strong effects. As an example, they discuss a study of Cave (1997), who reported effects in an object naming task 48 weeks after priming. This is why a conceptual replication is warranted as well.

In the conceptual replication we presented the cues in capitals, while keeping the targets in lower case. Dehaene et al. (2010) found that the VWFA can be activated in a top-down manner, for instance during speech processing, and Dehaene et al. (2001) found that in this area, masked repetition suppression was independent of whether the prime and target shared the same case. We therefore hypothesized that the cues in capitals would lead the participants to activate the case-independent word form in the visual lexicon, so that if there was a top-down influence on this level of the preconscious processing of the target, this should be reflected in faster TTE's in the congruent condition.

Methods

Participants. With the data obtained from Rochal's (2017) supervisor, we found a Cohens *dz* effect size of 0.35. This effect size was used in a power analysis to estimate the required sample size of our direct replication of Rochal's study, using G*Power (Faul, Erdfelder, Buchner, & Lang, 2009). The power analysis was conducted using a one-tailed, matched pairs t-test with two dependent means, an alpha level of 0.05 and a power of 0.80. Based on this power analysis, our current research required 51 participants.

Participants with a history of epilepsy were excluded beforehand and therefore could not participate in our experiment. Furthermore, it was important that the participants have (corrected to) normal vision. Due to a time limitation, we were unable to reach the number of participants required for our research. Therefore, only 28 participants were recruited for the experiment. Of these 28 participants, two were unable to complete the full experiment, due to technical difficulties and problems with perceiving the stimuli, and one was excluded due to a lazy eye which caused extremely deviating results. The remaining 25 participants (11 male and 14 female) were used for the analyses and had an average age of 23.08 years ($SD = 4.97$). No participants are colorblind or have letter synesthesia, but one participant has dyslexia. However, dyslexia was not put in as a covariate, because it didn't affect our results. The participants were further asked about their English language abilities, because English words were used as stimuli in the experiment. All participants had an intermediate English proficiency level or higher and one participant was a native English speaker.

Design. In the current research, a 2 (congruency: congruent and incongruent) x 2 (case: lowercase and capitals) within subjects design was used. This was similar to the design in Rochal (2017), except for the fact that we manipulated case in the second block instead of having two identical blocks. The experiment started with the direct replication, where cue words were presented in lower case. The second part was the conceptual replication, where the cue words were presented in capitals. For the first part of the experiment to be an exact replication, the order of the two parts was kept constant. The target words were either congruent or incongruent with the cue, which means that trials can be classified as congruent or incongruent. The 'time to emerge' (TTE) was used as the dependent variable.

Analysis. Before the analysis could be performed, the data had to be checked on predetermined exclusion criteria, based on Rochal's study (2017). For each participant, each eye was inspected separately. Data from single eyes were excluded from the data set if the participant responded correctly on less than 80% of the trials or if their average reaction time was below 600 milliseconds or above 30,000 milliseconds. Data from trials were excluded individually if the participant scored incorrect on corresponding trial.

After the data-check, standardized z-scores were created for each participant on each trial, to control for the effect of eye-dominance. For the first two analyses, the two-tailed paired samples t-tests, the z-scores were calculated separately for both replications. A separate mean and standard deviation were used for separate eyes. For the third analysis, the repeated measures ANOVA, the z-scores were calculated for both replications together by taking the mean and standard deviation of all trials presented to the left and right eye separately, across the two parts of the experiment. After creating the z-scores, two new variables were created by averaging the z-scores on all congruent trials and all incongruent trials, for both the direct and conceptual replication. These variables were used in the analyses. Data was analyzed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., 2017).

Because one of the stimulus words ('sock') was in high case perceptually almost the same as in low case, an additional repeated measures ANOVA was performed to see if in the congruent condition of the conceptual replication this word was perceived faster than the other words. If that were the case, this would suggest that a congruency effect was at least in part the result of perceptual priming. In this analysis the first factor was experiment (direct vs conceptual) and the second factor was 'sockness' (sock vs other words). The dependent variable was the same z-scored TTE as in the first ANOVA, though in this case only the congruent trials were included.

Stimuli. In the current study, the same words have been used as in the original study by Rochal (2017), which were 'tune', 'sock', 'nest', 'crab', and 'seal'. In Rochal's study, all words were matched on frequency, number of letters, and pixel count, to make sure the stimuli presented are as similar as possible. In the conceptual replication in the second part of the experiment, the cue words were presented in capitals. Because the words in capitals were cue words, it was not necessary to match these on pixel count as well.

Mondrian patterns were used as a mask. In total there were always 700 rectangle figures making up this mask, changing in size and color. The length of each side of a rectangle can be between 1 and 35 pixels and is determined randomly. Like Rochal, we chose to allow only five different color outcomes, that is, there could only be full red (255, 0, 0), green (0, 255, 0), blue (0, 0, 255), black (0, 0, 0) or white (255, 255, 255) rectangles.

Apparatus. For this experiment E-prime (Psychology Software Tools, Inc, 2016), a programme also used by Rochal (2017), was used to present the stimuli on a 27 inch Asus monitor with an Intel Core i7-6700 CPU. The resolution of this monitor was 2560 x 1440 pixels and the monitor had a refresh rate of 59 Hz. The participants had to rest their heads on a chinrest, which was placed at 57 cm distance from the monitor. The participants had to look through a mirror stereoscope, which allowed presenting different stimuli to each eye, as seen in figure 1. First, the participants were presented with a cue word in both eyes. After this, the participants were presented with Mondrian patterns that serve as a Continuous Flash Suppression (CFS) mask in one eye, while target stimuli faded in, in the other eye. The stimuli were presented on a grey background on both sides of the screen, within a white frame (8.03° x 8.03° visual angle) to facilitate binocular fusion. The target stimuli were either presented above or under the center of the white frame, in Arial 32 point font (height 0.29° to

0.48°, width 2.39° to 5.24° visual angle). The mask (5.52° x 5.52° visual angle) was presented at the center of the white frame

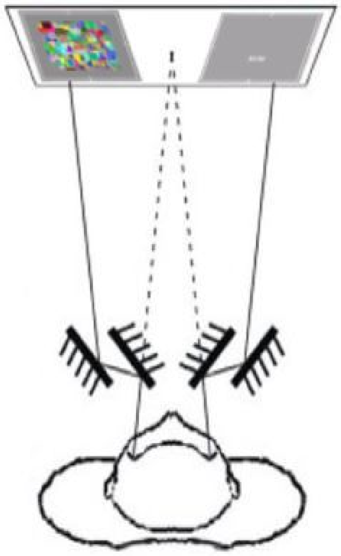

Figure 1. Setup of the experiment (Rochal, 2017, p. 22).

Procedure. First, the participants had to fill in an informed consent form. After this the participants had to fill in a questionnaire (see Appendix A) with for example questions regarding their English language abilities and whether they have a normal or corrected to normal vision. Both forms were presented in English. Before each experiment began, the participants had time to adjust the height of the chinrest and the two frames presented on the screen, so that the participants were able to perceive the two frames as one. After this, the participants received a paper with instructions, in English, regarding the task. The instructions (see Appendix B) were quite similar to the instructions used by Rochal (2017) and emphasize for example the importance of both accuracy and speed. However, the part of the instructions that induced expectancy differed from Rochal's instructions. Whereas Rochal stated that the cue word is most likely going to help the participant to detect the words, our current research stated that in half of the cases, the target word will be the same as the cue word and that knowing this will help the participant detect the targets faster. The change in the instructions was made to make the instructions more clear, since the interpretation of 'most likely' can be subjective.

In total there were 320 trials: 160 trials in the first part of the experiment, the direct replication, and 160 trials in the second part, the conceptual replication. Half of the trials in both parts of the experiment were in the congruent condition, where the cue predicted the target. The other half of the trials were in the incongruent condition, where the cue differed from the target. An example can be seen in figure 2. The congruent and incongruent trials were presented in random order.

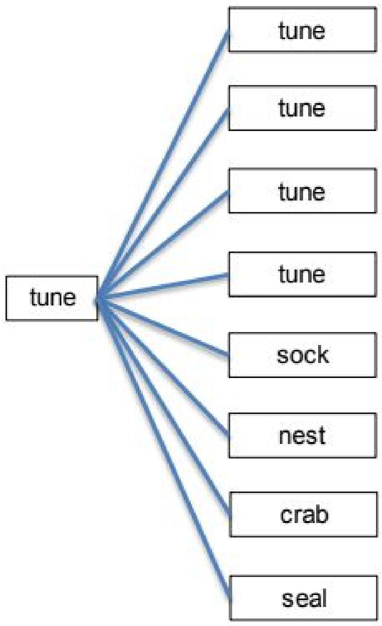

Figure 2. An example of a cue-word and it's possible, subsequent target words (Rochal, 2017, p. 61).

The first part of the experiment started with four practice trials to let the participants familiarize with the experiment. The experimental trials that followed after this consisted of a visible cue that first was presented for one second to both eyes. After this, a flashing Mondrian pattern was presented in one eye with a refresh rate of 10 Hz, and after one second the in-fading target word in the other eye. After one second the infading word was fully emerged. The time-lapse of one trial is visualised in figure 3. The participants had to detect these words through the CFS mask. Their task was to press the “up arrow” button or “down arrow” button as soon as they perceived a word at the top or at the bottom of the square, respectively. There were 2.5 seconds between trials.

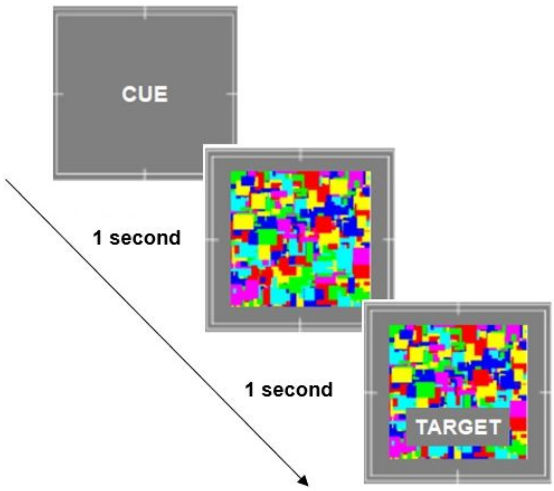

Figure 3. The time-lapse of one trial. One second after the cue word, the target word appears at a low brightness. After one second the target word is at full brightness.

After the first part of the experiment, participants had to take a short break, to minimize fatigue in the second part. After this break, the experimenter started the second part, where the cue words were presented in capitals. Again, the participants went through four practice trials to let them familiarize with the task and get into the flow of the experiment. At the end of the experiment, the participants had to fill in the remaining questions on the questionnaire. We asked them if they had moved their head or closed one eye somewhere during the experiment. This could cause them to see the target word faster because it interrupts the fusion of the eyes. The number of movements of the participants head or closing of one eye did not affect the results and were therefore not used as covariates. For their participation the participants either received a monetary reward (€7,-) or study credits (for psychology students at Utrecht University).

Results

The direct and conceptual replication were analyzed separately, using a one-tailed paired samples t-test analysis. There were no significant differences found between the congruent condition and the incongruent condition in the direct replication, $t(24) = 1.117$, $p = 0.137$, Cohen's $dz = 0.22$. There were also no significant differences found between the congruent condition and the incongruent condition in the conceptual replication, $t(24) = 0.486$, $p = 0.316$, Cohen's $dz = 0.097$. Although no significant differences were found, in both replications the TTE was slightly lower in the congruent condition than in the incongruent condition, as can be seen in table 1.

Table 1.

The means and standard deviations found with the t-tests.

	Direct replication		Conceptual replication	
	M	*SD*	*M*	*SD*
Congruent condition	-0.0195	0.0867	-0.0088	0.09155
Incongruent condition	0.0193	0.08681	0.0089	0.09091

Note. Mean and standard deviation were calculated using z-scores.

A repeated measures ANOVA was used to compare the two experiments. There was a significant main effect of experiment, $F(1,24) = 21.437$, $p < 0.001$, partial $\eta^2 = 0.471$. TTE was significantly lower in the conceptual replication, which was the second part of the experiment, than in the direct replication, which was in the first part of the experiment, for both the congruent condition and incongruent condition. There was no significant main effect of congruency, $F(1,24) = 1.358$, $p = 0.255$, partial $\eta^2 = 0.054$. There was also no significant interaction effect, $F(1,24) = 0.702$, $p = 0.410$, partial $\eta^2 = 0.028$.

A second repeated measures ANOVA was done to compare 'sock' to the other stimuli. This revealed a main effect of both experiment, $F(1,24) = 16.471$, $p < 0.001$, partial $\eta^2 = 0.406$, and 'sockness', $F(1,24) = 24.262$, $p < 0.001$, partial $\eta^2 = 0.503$, but no interaction, $F(1,24) = 0.870$, $p = 0.360$, partial $\eta^2 = 0.035$. In other words, in the congruent trials, 'sock' was perceived faster than the other words, but it was not perceived extra fast in the conceptual replication. An additional one-tailed paired samples t-test performed on the direct replication showed that in the first part of the experiment the word 'sock' was perceived significantly faster than other words as well, both in the congruent and the incongruent condition, $t(24) = 2.575$, $p = 0.009$, Cohens $dz = 0.52$. To see if there were lower level differences between the stimuli, the number of pixels and the width of the stimuli were measured. This analysis revealed that 'sock' had a larger number of pixels than three of the other stimuli, and was on average 10% wider than the other words.

Discussion

Expected or relevant stimuli are detected and perceived more readily than unexpected or less relevant stimuli (Kristjánsson & Campana, 2010). To investigate whether this means that expected stimuli enter consciousness faster than unexpected stimuli, we replicated a study by Rochal (2017). This study showed that when a presented stimulus matches an expectation, it reaches awareness faster. However, the expected cue and target words were identical on a sensory level, making it difficult to exclude the possibility that perceptual priming caused the effect. To investigate whether unconscious processing of a higher order took place, we conducted a conceptual replication as well, where the cue words were presented in capitals.

The analyses showed that in both the direct and conceptual replication, the mean time to emerge (TTE) was lower in the congruent condition than in the incongruent condition, which suggests there is a small congruency effect. However, these effects were not significant and effect sizes were small. We also did not find a significant interaction effect. Based on these results, we cannot conclude that expected words enter awareness faster than unexpected words. The only significant effect found was a main effect of experiment, i.e. in the conceptual replication TTE was lower than in the direct replication. This finding probably reflects a general task performance effect, similar to the one found between blocks in the original study.

The fact that our findings were not completely in line with those of Rochal (2017) could be due to several methodological factors. First of all, the sample size used in our experiment was smaller than the prior estimated, required sample size. It may well be that with more participants we would have found the same results as in the original study. Secondly, in Continuous Flash Suppression (CFS) studies, as mentioned in the introduction, there is a lot of variability, increasing the risk of false positives. A number of approaches to this problem have been proposed, ranging from Bayesian analysis (Moors et al., 2016) to log-transforming (Rabagliati et al., 2018) and other forms of transformation of scores (Gayet & Stein, 2017). Because this was meant to be a direct replication, only z-transforming was done, which is considered by Gayet and Stein (2017) to be a less successful method, though in our case the average z-scores, calculated during our analysis, were 0.54 at most. A successful way to reduce variability, that was used in the original study as well as in the replications, was fading targets in. Other ways to reduce variability could have been including more practice trials and eliminating participants showing large differences between their dominant and non-dominant eye. Thirdly, our instructions were somewhat different from those of Rochal and we may have included less practice trials, which may have led to different expectations in participants and a higher variability in data.

Given these considerations, the findings of both replications in our current study have to be carefully interpreted and can not be seen as evidence that Rochal's results are a chance finding. In other words, it is possible to conclude that there probably is a congruency effect, though probably just a small one, since in both studies effect sizes were small. Theoretically, such a small effect can still be interesting. So, to our first question, is it possible that expected stimuli are perceived more readily, at least in part, because they enter consciousness faster, our answer is a guarded yes, which brings us to our second question. Could a congruency effect be the result of unconscious processing of a higher order?

Though the effect size for the conceptual replication was smaller than the effect size for the direct replication, the fact that no interactions were found, suggests that the congruency effect found by Rochal was not, or at least not entirely, due to perceptual priming. Even when the cues were in capitals, there was still a small, though not significant congruency effect. This could be due to the fact that the time between the cue and target word was too long for this phenomenon to occur. According to Dehaene & Changeux (2010), subliminal priming is unlikely after 500 ms. In the current study, the target word appears 1000 ms after the cue word, at its lowest brightness. It takes another 1000 ms for the target word to reach its full brightness. This could mean that there needs to be less time between our cue and target word for a congruency effect to occur, if perceptual priming is what caused this effect. Thus, uncertainty around the origin of the effect remains, therefore we will discuss suggestions for future research below.

In both the direct and conceptual replications, only visual cues were used. Perception covers of course all the senses. Quite a fundamental perspective that lives within neuroscience, is the idea that multisensory integration takes place. Sensory systems are interconnected, there is an exchange of sensory information and the sensory modalities can influence each other on their processing (Alais, Newell, & Mamassian, 2010). Therefore, one can also investigate the effects of presenting a cue in a different sensory modality than the visual. For future research we suggest a similar CFS experiment to investigate expectancies in which the cues are spoken words. This way the cue can not facilitate perception through perceptual priming, nor interfere with it. Furthermore, as Rochal (2017) points out as well, there is no standardized set up for CFS developed yet. Therefore, CFS studies vary in for example the refresh rate of the mask and the fade-in time of the targets, as well as in their use of data transformations. This makes comparison between CFS studies difficult and stresses again the importance of (direct) replication. Lastly, the fact that 'sock' was perceived significantly faster than the other stimulus words, probably due to a slightly larger number of pixels and a larger width, was not considered a big problem, because in the used design each target was congruent as often as it was incongruent. However, this unintended finding shows how big the influence can be of low level characteristics in studies using CFS.

In this study, as in the original study by Rochal (2017), expectancy can be seen as a conscious top down influence, as it was at least partly the result of the instruction given to the participants. However, in predictive coding theory a perceptual priming effect would also be considered the result of a top down process, albeit an unconscious one. Furthermore, both top down processes would be seen as automatic. After all, once the relevant simulation was pre-activated, in both cases the processing would be the same, i.e. it would occur before the target stimulus was presented, though not on the same level, and also no different from normal processing, just faster. In contrast, the processes needed to conclude that something was wrong in the incongruent trials of Mudrik et al. (2011) and Sklar et al. (2012), would be much more complex, involving both differentiation and integration.

Indeed, one of the interesting implications of predictive coding theory is that top down and/or higher order processing, such as inference making, can be considered to be unconscious and automatic, since it is assumed that content does not enter awareness until the prediction error is minimized. The idea that controlled and automatic processes are on a continuum (Barrett, 2017) is also in line with het idea of consciousness as an emergent phenomenon. Lastly, it is our everyday experience, since we can all report our conclusions but have little insight into the thinking process of which they are the result. It may even be so that finding the words to express our thoughts helps us combine concepts in a meaningful way (Jackendoff, 1996), it can be argued that this is best seen as an interactive process.

In conclusion, our results are in line with the conclusion of Moors et al. (2017) that CFS-studies inform us only on the default (or current) sensitivity of early visual cortex to stimuli that the individual has been (primed with and) exposed to throughout his or her life, like letters and faces, but this should not be taken as evidence that preconscious processing is unlikely or limited to low level tasks. After all, the fact that a stimulus is consciously perceived, does not mean all further processing will be conscious as well.

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Appendix A

Questionnaire

Questionnaire Perception of Expected Words under Continuous Flash Suppression
May-June 2019

1. Participant number

2. Age

3. Sex (male/female/other/no answer)

4. Do you have normal or corrected vision? (normal/glasses/contacts)
   If corrected, how many diopters are your glasses/contacts?
   Left:
   Right:
   Noteer voor nearsighted/myopic/bijziend een - teken, en voor farsighted/hyperopic/verziend een + teken.

5. Do you have a decreased ability to see color or differences in color? (yes/no)
   If so, how?

6. Do you have letter synesthesia? (yes/no)
   To some people all letters have their own color for instance. Is that true for you?
   If so, how?

7. Do you have dyslexia? (yes/no)
   If so, how?

8. What is your proficiency level in English? (basic/intermediate/advanced/ native speaker)

9. How did you learn about this experiment? (poster/flyer/sona/social media/
   invited by experimenter/other)

10. Remarks

Questionnaire after the experiment:

1. At any time of the experiment did you move your head (slightly shaking or nodding)?
   If so, how often?

2. At any time of the experiment, did you close one eye?
   If so, how often?

3. Remarks

Appendix B

Instructions

Welcome to the Perception Study

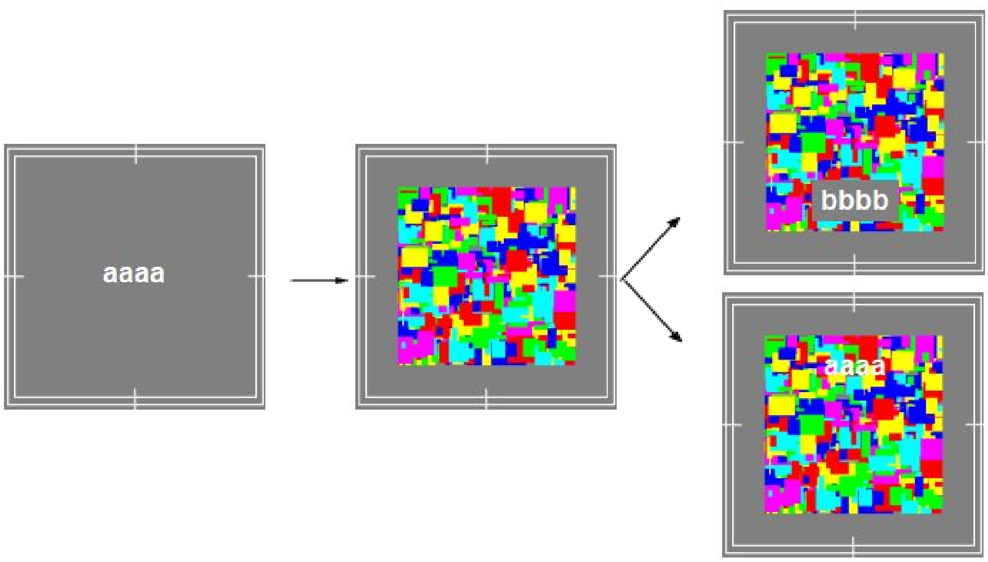
Every trial will start with a cue word. After this, you will see a **colourful flashing image**, and then a second **word** will "**pop out**", either on the top or bottom of the screen.

Your task will be to indicate **as fast as possible** where on the screen this second word appeared by pressing the **UPARROW** key "↑" for **top** and **DOWNARROW** "↓" for **bottom**.

In this experiment it is crucial that you press **accurately** the correct key as soon as you see the word on the screen - **accuracy & speed**!

However, as mentioned before, at the beginning of each trial a **cue word** will be presented. In half of the trials, the second word will be the same as the **cue word.** Research has shown that keeping this cue word in mind will help you detect the location of the second word faster and more accurately.

You will start with four **practice trials** to familiarize you with the task, with the letter strings 'aaaa', 'bbbb', 'cccc', and 'dddd'. After this, the experiment will begin right away.



Your task in the second half of the experiment is exactly the same as before. However this time the **cue word** will be presented **in capitals**. In half of the cases, the cue word will be the same as the second word, but in small letters.

You will again start with four **practice trials** to familiarize you with the task, with the letter strings ‘aaaa’, ‘bbbb’, ‘cccc’, and ‘dddd’. After this, the experiment will continue right away.