Temporal constraints of the word blindness post-hypnotic suggestion on Stroop task performance

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Abstract

The present work investigated possible temporal constraints on the posthypnotic word blindness suggestion effect. In a completely within-subjects and counterbalanced design 19 highly suggestible individuals performed the Stroop task both with and without a post-hypnotic suggestion that they would be unable to read the word dimension of the Stroop stimulus, both when response-stimulus interval (RSI) was short (500ms) or equivalent to previous studies (3500ms). The suggestion reduced Stroop interference in the short RSI condition (54ms vs. 6ms) but not in the long RSI condition (52ms vs. 56ms), and did not affect Stroop facilitation. Our results suggest that response to the suggestion involves reactive top-down control processes that

persist only if levels of activation can be maintained.

Key words: Stroop; Suggestion: Hypnosis, Control; Attention.

The Stroop effect is one of the most robust in cognitive psychological research. However, recent studies have shown that under certain conditions the Stroop effect can be reduced or even eliminated. For example, Raz and colleagues (2002; 2003; 2005; 2006; 2007; 2011) have shown that the Stroop effect can be virtually eliminated following a post-hypnotic suggestion that describes the word dimension of the Stroop stimulus as being made up of 'meaningless symbols' and 'characters of a foreign language' (to be referred to as the *word blindness* suggestion)[1]. The effect of the word blindness suggestion on Stroop task performance was observed in highly suggestible individuals only and was remarkable in its all-encompassing effect on indices of Stroop task performance. Raz and colleagues have argued that the suggestion likely operates through a top-down effect that modulates the processing of input words, but little else is known about how endogenous executive control mechanisms produce the effect. In the present study we considered possible temporal constraints on the successful application of the word blindness suggestion on Stroop task performance by relating it to other known mechanisms of top-down cognitive control.

Increasing the time between trials on a cognitive task can either result in the capacity for cognitive control being enhanced, such as in preparatory interval effects in task switching studies (e.g. Rogers & Monsell, 1995), or diminished, such as in congruency sequence effects in selective attention tasks (e,g**.** Egner, Ely & Grinband, 2010) or repetition effects in task switching (e.g. Altmann & Trafton, 2002). One possibility given the top-down nature of posthypnotic suggestions is that the influence of the word blindness suggestion on Stroop task performance is dependent on having sufficient time between trials to prepare the mechanisms responsible for producing the effect. If this were true, an effect of the posthypnotic suggestion would be more likely or stronger at longer response-stimulus intervals (RSIs). Conversely, it might be difficult to maintain the posthypnotic suggestion over longer periods between trials and therefore its effect would be less likely at longer RSIs. To be clear, we are not arguing that the suggestion operates over the mechanisms that produce the effects mentioned above (i.e. over effortful preparatory processes that might be operating on every Stroop trial), but that it might be subject to similar temporal constraints and thus benefit from a short or long RSI. A final possibility is that the posthypnotic suggestion is not subject to limitations observed in other control mechanisms. It is possible that the influence of the posthypnotic suggestion is not dependent on RSI. Such a finding would indicate that posthypnotic suggestions are different from other control mechanisms, are more obligatory once configured and activated, and are not reimplemented on every trial, but are instead initiated and fully implemented at the signal given to activate the suggestion.

Method

Participants. 180 students from the Universities of Sussex and Bournemouth were screened for hypnotisability using the Waterloo-Stanford Group Scale of Hypnotic Susceptibility, Form C (WSGC) (Bowers, 1993). The exclusion of the age regression suggestion meant that the maximum possible score was 11. 19 proficient English speakers (13 female; average age was 21.6 years, SD = 2.4 years) were selected on the basis of their score. All participants used in this experiment scored in the highly-suggestible range (8 - 11) with a mean of 9.9 and SD of 1.3. Participants were paid £10 for their participation.

Materials, Design and Procedure. All aspects of the materials, design and procedure matched those of Raz et al. (2002) exactly apart from the RSI manipulation and screening procedure noted above. The experimental design was a mixed factorial model with congruency (incongruent, neutral, congruent), response-stimulus interval (500ms, 3500ms), and posthypnotic suggestion (absent, present) as within-subjects factors. Administration order of both the RSI and

posthypnotic suggestion conditions was counterbalanced (see Figure 1. for the four administration orders). The RSI blocks consisted of 144 trials each consisting of 48 congruent, 48 neutral and 48 incongruent trials, which were intermixed in random order. Participants were given 36 practical trials consisting of 12 of each word type and an RSI of 2000ms. The first trial of each block began with a fixation cross at the centre of the screen that remained on screen for the duration of the response-stimulus-interval (500ms or 3500ms). The stimulus remained onscreen until response. After each response visual feedback was presented stating whether the previous response was "CORRECT" or "INCORRECT". Feedback was presented in black ink for 100ms and was replaced by a fixation cross. In the posthypnotic suggestion absent condition participants were asked to respond as quickly and accurately as possible to the colour of the stimulus whilst ignoring the meaning of the presented word. In the posthypnotic suggestion present condition the participants were given a standard induction (taken from the Waterloo-Stanford scale) followed by the suggestion taken directly from Raz et al. (2002):

Very soon you will be playing the computer game. When I clap my hands, meaningless symbols will appear in the middle of the screen. They will feel like characters of a foreign language that you do not know, and you will not attempt to attribute any meaning to them. This gibberish will be printed in one of 4 inks colours: red, blue, green or yellow. Although you will only be able to attend to the symbols' ink color, you will look straight at the scrambled signs and crisply see all of them. Your job is to quickly and accurately depress the key that corresponds to the ink colour shown. You will find that you can play this game easily and effortlessly.

At the end of each block, participants were asked to rate how meaningful the words presented on screen were to assess if they still had access to word meaning. A 1 indicated "The writing had no meaning for you whatsoever", a 2 indicated "You had a sense of some vague meaning but couldn't put your finger on what it was", a 3 indicated "You knew the rough meaning but can't say precisely what it was", a 4 indicated "For some reason you knew the meaning even though the word was not English" and a 5 indicated "You knew the exact meaning and it seemed like an English word". The rating represented a global rating of meaningfulness across each block; no words were visible when making these judgments.

Results

Only the results from the correct trials are presented[2]. There were no speed-accuracy effects in our data and the error data replicated the effect seen in the RT data showing an effect of the suggestion in the short RSI condition only (see Figure 2 for percentage errors in each condition). RTs that were 3 SDs either above or below the mean were excluded from the analysis, which resulted in 1.8% of the trials being removed from the analysis.

The data were entered into a 3 (Word Type: Incongruent / Neutral / Congruent) x 2 (Post-Hypnotic Suggestion: Present / Absent) x 2 (Response Stimulus Interval: 500ms / 3500ms) repeated measures ANOVA. Crucially, the three-way interaction was significant, $F(2, 36) = 4.662$, $p < .05$, $?^2 = .206$, indicating that the effect of the posthypnotic suggestion on the Stroop effect varied according to RSI, which is the effect this study was designed to explore (see Figure 3). To investigate the three-way interaction, it was decomposed to investigate whether the effect of suggestion on Stroop interference was modulated by RSI; and the same for Stroop facilitation. For Stroop interference the three-way was significant, $F(1,18) = 6.513$, $p = .020$, $?^2 = .266$. For Stroop facilitation, the three-way interaction was non-significant, $F(1,18) = 0.835$, $p = .373$.

The interaction for Stroop interference was analyzed further by calculating the partial suggestion by word type two-way interactions for each RSI. For the short RSI, the effect of suggestion on interference was significant, $F(1,18) = 10.067$, $p < .01$, $?^2 = .359$. Specifically, without suggestion the interference effect was 54ms ($t(18) = 3.889$, $p < .01$, $r = 0.67$) and with suggestion it was reduced to 6ms ($t(18) = 0.788$, $p > .4$)[3]. For the long RSI, the effect of suggestion on interference was not significant, $F(1,18) = 0.080$, $p > .7$. Specifically, without suggestion, the interference effect was 52ms ($t(18) = 4.048$, $p < .01$, $r = 0.69$) and with suggestion it remained at 56ms ($t(18) = 7.44$, $p < .001$, $r = 0.87$).[4]

Running the omnibus analysis with RSI order (long RSI or short RSI block first) as a factor revealed that the suggestion effect observed in the short RSI condition was stronger after completing the long RSI condition ($p < .05$). This result is important because it rules out an explanation of the RSI effect as being the result of the differential time-on-task between the two RSI conditions. That is, it takes more than three times as long to complete the long RSI block than the short RSI block, so from the beginning of each block, the posthypnotic suggestion would have to be maintained for less time in the short RSI block. Time-on-task effects cannot explain the results because the effect on the Short RSI condition is actually greater after the long RSI condition. There were no other effects of order of administration.

Finally, we analysed the data to see if previous trial congruency modulated the effect of the suggestion. Previous research has shown that interference is smaller when trial N-1 is incongruent (known as a congruency sequence effect (CSE)). CSEs were calculated using the criteria employed by Egner et al. (2010), excluding the first trial from every block and any trials on which the word or response on trial N-1 was repeated on trial N, which left 27.8% of data for the analysis. We compared the magnitude of Stroop interference from trials that followed a neutral trial to Stroop interference from trials that followed an incongruent trial, and subtracted the latter from the former (i.e. (NI-NN)-(II-IN); see Figure 4). A comparison of the CSEs for each of our four conditions revealed only a main effect of RSI where $F(1, 18) = 5.499$, $p < .05$, $n2 = .234$ which was due to positive CSEs in the short RSI conditions but negative CSEs in the long RSI conditions, which is consistent with the findings of Egner et al. However, paired-sample t-tests comparing NI-NN to II-IN in all conditions revealed no significant CSEs (p's > .05). The lack of CSEs in our study is not surprising given the results from a recent study showing that CSEs are not observed in reaction time data in Stroop studies utilizing four words and four colours (Puccioni & Vallese, in press). No other effects were significant (p's > .4), indicating that the suggestion effect was not dependent on previous trial congruency. As a way of confirming the non-dependence of the suggestion effect on previous trial congruency we plotted the RTs to incongruent trials as a function of previous trial congruency (see Figure 5). As can be seen, RTs to incongruent trials were substantially reduced by the suggestion in the short RSI condition, regardless of previous trial congruency.

Discussion

The aim of this experiment was to investigate whether RSI modulated the effect of the word blindness posthypnotic suggestion on Stroop task performance. The three-way interaction showed that the Stroop interference effect was substantially reduced by suggestion but only in the short RSI condition, suggesting that like top-down control mechanisms responsible for

congruency sequence effects (CSEs) and task repetition effects, the mechanisms responsible for the suggestion effect reduced in influence when RSI was increased.

The similarity in temporal constraints does not imply a similarity in mechanisms. For example, CSEs are the result of a reaction to conflict on trial N-1 whereby control mechanisms are activated by an incongruent trial and are thus already active for the subsequent trial, leading to a reduction in reaction time on trial N. In contrast, our results indicate that participants are attempting to apply the suggestion on every trial, regardless of previous trial congruency, indicating that the suggestion effect is not operating over the same mechanism as CSEs. However, our results do not allow us to determine whether it is the influence of the suggestion that reduces over time or the mechanism over which the suggestion operates that is short-lived. Nevertheless, unlike CSEs, the trigger appears to be the presence of any word (i.e. the object of the suggestion) indicating a mechanism specific to the suggestion., As with CSEs, after the suggestion is activated, its activation level begins to dissipate quickly. When the time between trial N and trial N+1 is long, reactivation of the suggestion on the next trial appears to be more effortful because its activation level would have reduced. When the time between trials is short, reactivation is easier. The suggestion effect is thus reactive because it reacts to the presence of the word and depends on it in the same way CSEs are dependent on incongruent stimuli. In sum, we believe the suggestion effect takes its effect on trial N (i.e. is applied on every trial), but is more likely to be successfully applied on any given trial when the context or individual capacity ensures sufficient activation of the suggestion from one trial to the next. A direct prediction from the present study is that individuals high in suggestibility and also in the capacity to sustain attention over time would be more likely to show an effect of the suggestion on Stroop task performance at longer RSIs.

As the use of suggestions extends into other areas of cognitive neuroscience (see Oakley & Halligan, 2009) it will be become more important to understand how posthypnotic suggestions take their effects and understand any associated limitations. The findings from the present study show that a suggestion is not necessarily influential once activated in response to a cue, and that it can lie effectively dormant until conditions are right. The successful application of a suggestion seems to be dependent on conditions permitting sustained activation of the suggestion between encounters of the triggering stimulus, indicating that they require effortful reactivation. These findings extend our knowledge of the mechanisms by which the word blindness suggestion, and perhaps suggestions in general, take their effects.

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Table 1. Stroop interference (ms), Stroop facilitation (ms), intrusion errors (average number) and word meaningfulness ratings (average).

Post-hypnotic Suggestion	Present		Absent	
Behavioural index	Short RSI	Long RSI	Short RSI	Long RSI
Interference	6	56	54	52
Facilitation	19	13	15	20
Meaningfulness ratings	3.48	3.38	4.48	4.33

Figure captions

Figure 1. Diagram showing the four task administration orders. A clap was the cue that activated the post-hypnotic suggestion; a double clap ended its influence. RSI = Response-Stimulus Interval.

Figure 2**. Percentage errors as a function of condition.**

Figure 3. **Mean reaction times and standard errors as a function of condition.**

Figure 4. Congruency Sequence Effects (CSEs) as a function of condition. CSEs are calculated by subtracting Stroop interference on trials that follow incongruent trials (I) from Stroop interference on trials that follow neutral trials (N) or more formally (NI-NN)-(II-IN). A positive value represents the typical CSE. However, none of the CSEs reached significance in the present study. There was a significant main effect of response-stimulus interval however consistent with the findings Egner et al. (2010).

Figure 5. Incongruent trial RTs as a function of previous trial congruency.

Figure 1.

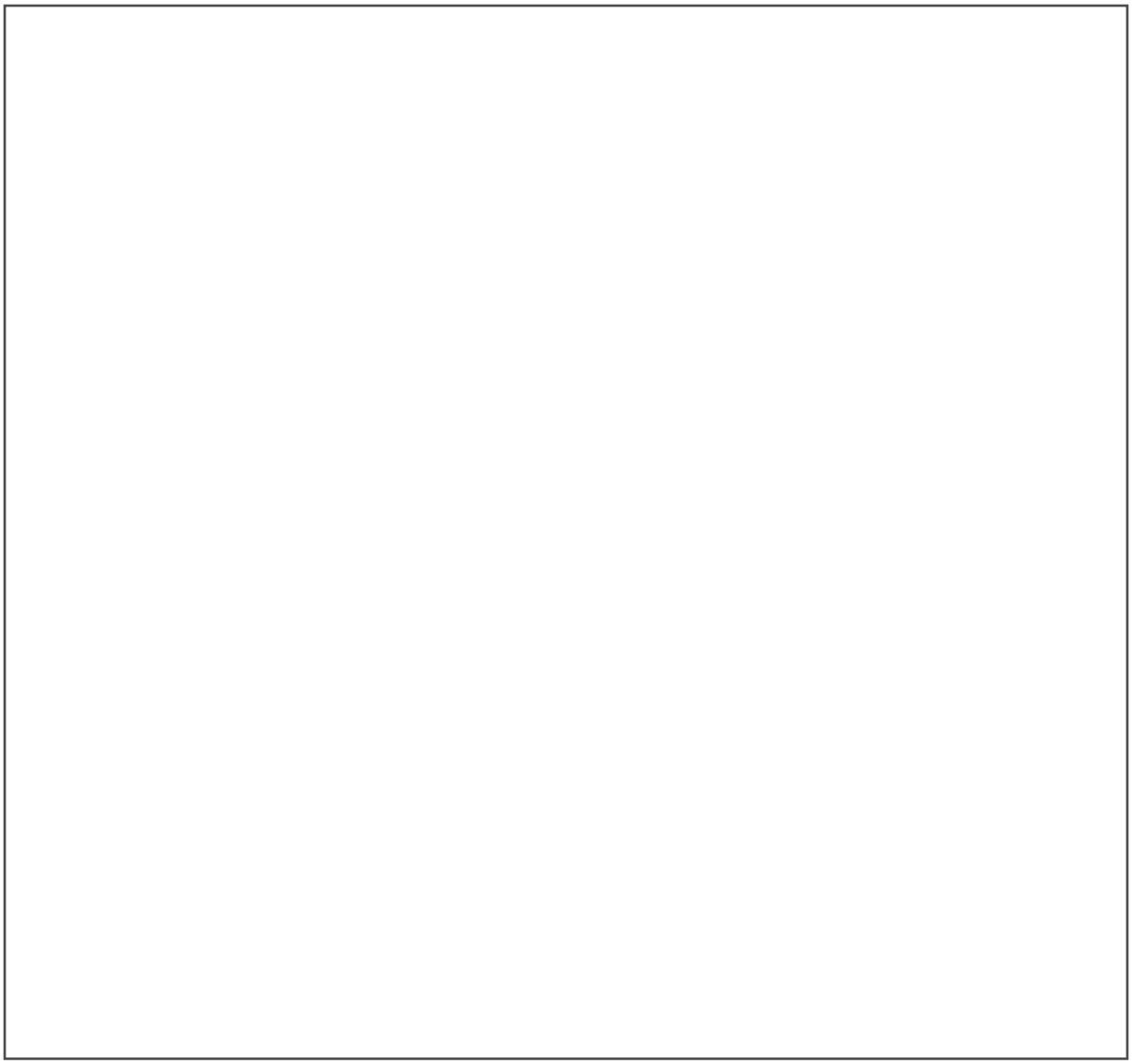


Figure 2.

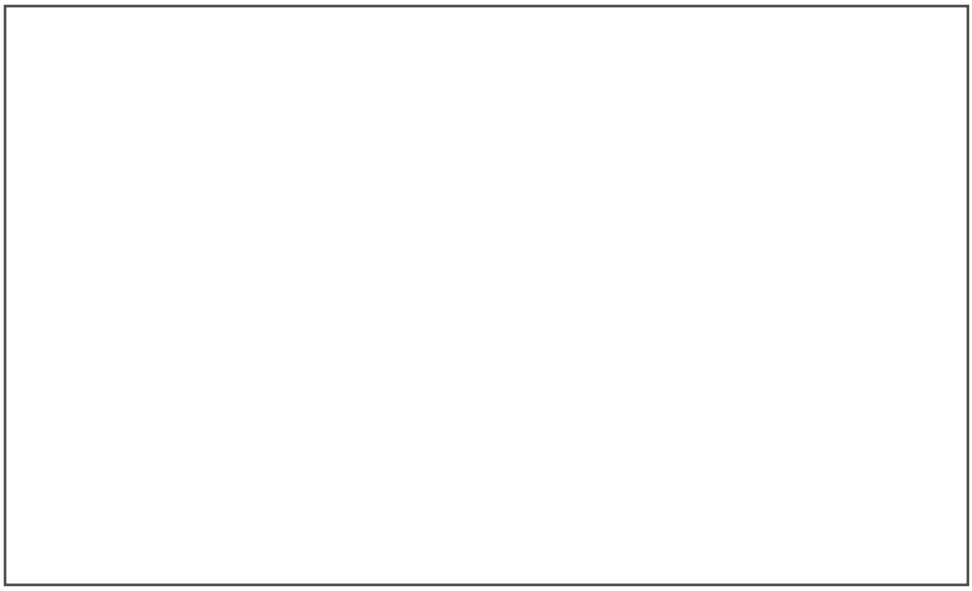


Figure 3.

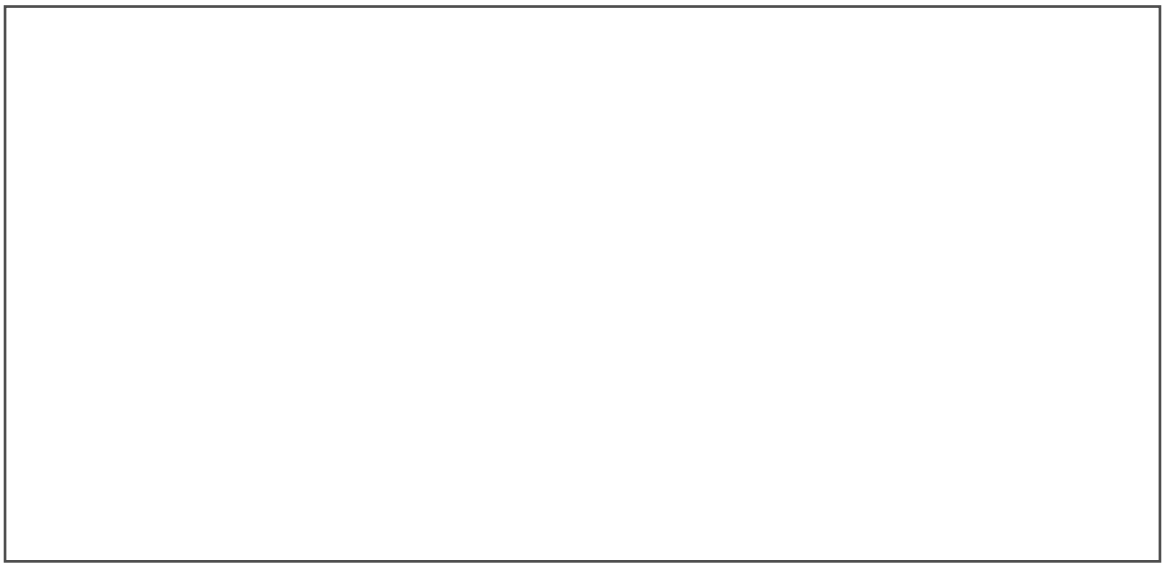
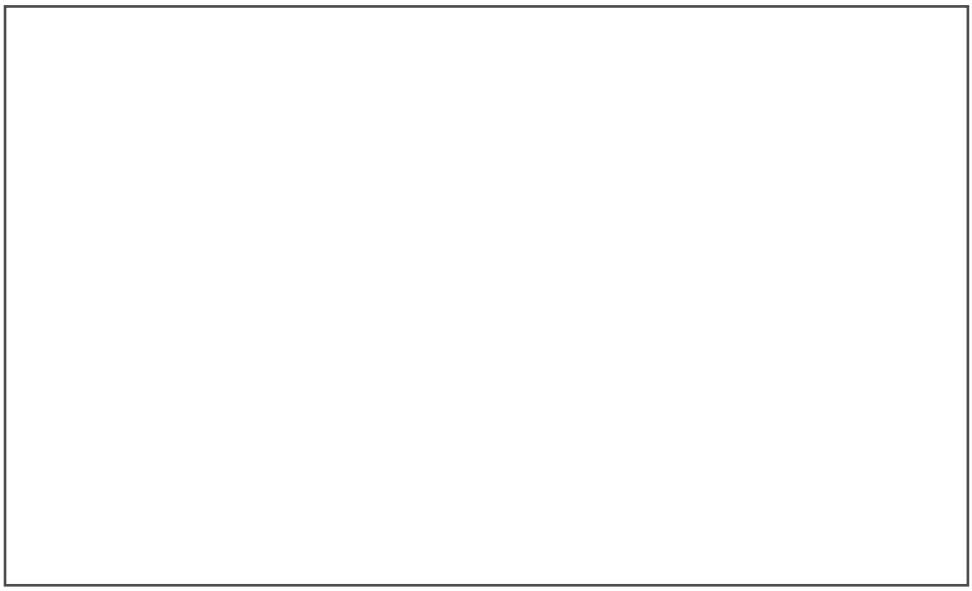


Figure 4.

Figure 5.



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[1] A post-hypnotic suggestion is a suggestion given whilst 'under hypnosis' but not acted upon until the participant is no longer in a 'hypnotized state'. When the participant is in their normal 'non-hypnotized state' a cue is given (e.g. a clap) as a sign to activate the suggestion. A hypnotic suggestion is enacted while in a 'hypnotized state'. An imaginative suggestion is the same suggestion given without any state of hypnosis being suggested. While the word blindness suggestion is procedurally typically given as a post-hypnotic suggestion, it appears just as effective as an imaginative suggestion (Raz et al, 2006).

[2] A Friedman's ANOVA showed that there were differences between levels of rated meaningfulness across the four conditions, $X^2 = 18.812$, $p < .001$ (see Table 1). Follow up tests revealed that this was due to a main effect of suggestion.

[3] The latter non-significant result is consistent either with evidence for the elimination of the Stroop effect or simply with the absence of evidence for the effect being present. To determine if there was evidence for the elimination, we used a Bayes Factor (Dienes, 2008, 2011), where we contrasted the theory that the Stroop effect had been merely reduced with the null hypothesis that it has been eliminated. We modeled the predictions of the theory of reduction with a uniform between 0 and 50ms reduction (see Dienes, 2011, Appendix), i.e. any reduction was as plausible as any other. The Bayes Factor was .44, indicating only minor evidence for the null hypothesis (.33 and below being the cut off for strong evidence for the null, Dienes, 2011). That is, there is

not strong evidence that the interference effect was eliminated; we can merely say that it was reduced.

[4] The latter non-significant two way interaction is consistent with either evidence for no reduction of the interference effect or simply with the absence of evidence for a reduction.

+9_‘auv^‰?? E] ^ ’ ‰ Á Â To determine if there was evidence for no effect of the suggestion, we used a Bayes Factor (Dienes, 2008, 2011), where we contrasted the theory that the suggestion had some effect with the null hypothesis that the suggestion had no effect. We modeled the predictions of the theory of some effect with a uniform between 0 and 50ms (see Dienes, 2011, Appendix), i.e. any effect was as plausible as any other in the full range. The Bayes Factor was .27, indicating strong evidence for the null hypothesis (.33 and below being the cut off for strong evidence for the null, Dienes, 2011). That is, there is evidence that the suggestion had no effect.