Automaticity Revisited: When Print Doesn't Activate Semantics

Elsa M. Labuschagne

A thesis

presented to the University of Waterloo

in fulfillment of the

thesis requirement for the degree of

Master of Arts

in

Psychology

Waterloo, Ontario, Canada, 2014

Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

It is widely accepted that the presentation of a printed word “automatically” triggers processing that ends with full semantic activation. This processing, among other characteristics, is held to occur without intention, and cannot be stopped. The results of the present experiment show that this account is problematic in the context of a variant of the Stroop paradigm. Subjects named the print colour of words that were either neutral or semantically related to colour. When the letters were all coloured, all spatially cued, and the spaces between letters were filled with characters from the top of the keyboard (i.e., 4, #, 5, %, 6, and *), colour naming yielded a semantically based Stroop effect and a semantically based negative priming effect. In contrast, the same items yielded neither a semantic Stroop effect nor a negative priming effect when a single target letter was uniquely coloured and spatially cued. These findings undermine the widespread view that lexical-semantic activation in word reading is *automatic* in the sense that it occurs without intention and cannot be derailed.

Acknowledgements

I would like to thank my supervisor, Dr. Derek Besner, for his guidance during the conduction of my thesis research. His enthusiasm and encouragement helped me finish this project in a much more timely manner than I had thought possible. I would also like to thank my second readers, Dr. Evan Risko and Dr. Jonathan Fugelsang, for their thoughtful and constructive feedback.

I am extremely grateful to my friends and family for their continuous love and support. I would like to extend a special thank-you to Dr. Jonathan Carriere, Sherif Soliman, and Tanya Jonker, whose support and advice, both personally and professionally, were invaluable and greatly contributed to the success of this project.

Table of Contents

List of Table

List of Figures

Automaticity Revisited: When Print Doesn't Activate Semantics

Many cognitive psychologists, cognitive neuroscientists, and social psychologists view the automatic-controlled distinction to be of fundamental importance (this distinction can be found in many cognitive textbooks; e.g., Ashcraft, 1994; Ashcraft & Klein, 2010; Galotti, Fernandes, Fugelsang, & Stolz, 2010; Goldstein, 2011; Levitin, 2011; Matlin, 2013; Rayner & Pollatsek, 1989, among others). We concern ourselves here with the automatic processing side of this distinction in which such processing is often defined as unconscious, occurring without intention, ballistic (cannot be stopped or prevented from starting), and needing no capacity or attention of any kind (e.g., Posner & Snyder, 1975; Neely & Kahan, 2001, among many others). The only role for attention is to direct the products of such processing (e.g., selection for action). This view is related to late-selection accounts in which all the contents of competing sources are analyzed without attention – up to and including semantics. Attention plays a role *after* such processing (e.g., Deutsch & Deutsch, 1963; Norman, 1969).

Moors and De Houwer (2006) argue that not all of these characteristics need to be simultaneously present for some process to be considered automatic. This conclusion lends weight to the importance of being clear about which particular characteristic of automaticity is being considered. Here we restrict ourselves to the criteria in which such an automatic process is triggered without intent, and can neither be stopped nor interfered with by other processes.

The Processing of Print

The present work concerns itself with the processing of print in the context of the Stroop task, and the question of whether lexical-semantic processing can be considered automatic in the senses used here (stimulus triggered, cannot be interfered with, and attention plays no role in being able to prevent processing). At present, visual word recognition is widely assumed to be automatic:

> …the Stroop effect demonstrates that both the name and *meaning* [italics added] of a word are processed by skilled readers even when they are trying hard not to process them.
> Rayner and Pollatsek (1989, p. 72)

> A fail-safe demonstration of automaticity, in particular the automatic nature of accessing word *meaning* [italics added], involves the Stroop task.
> Ashcraft (1994, p. 72)

> Indeed, it is fair to say that the assumption of automated word recognition in the mature reader is the "standard" or "received" view in cognitive science, in part because of the impact exerted by results from the Stroop task.
> Brown, Gore, and Carr (2002, p. 220)

> …these results improve our understanding of the automaticity of *semantic* [italics added] activation, as they add to the growing body of evidence suggesting that semantic activation in the Stroop task is indeed automatic and ballistic, in the sense that it occurs without intent and cannot be prevented…
> Augustinova and Ferrand (2012, p. 525)

Spatial Attention and Visual Word Recognition

Despite all the quotes noted above, the last several decades has seen renewed interest in whether spatial attention plays a role in lexical-semantic processing of print. One view is that if spatial attention is not focused on the right location(s) then neither semantic nor lexical processing takes place (McCann, Folk, & Johnston, 1992; Lachter, Forster, & Ruthruff, 2004; Besner, Risko, & Sklair, 2005; Lien, Ruthruff, Kouchi, & Lachter, 2010; Waechter, Besner, & Stolz, 2011). In short, spatial attention is a necessary preliminary to lexical-semantic processing of print. This work has yet to be integrated into the field's consciousness with respect to processing in the context of the Stroop paradigm. For example, Augustinova and Ferrand's (2014) consideration of the automaticity of word reading (and semantic activation in particular) in the context of the Stroop paradigm makes no mention of the spatial attention literature.

Spatial Attention and Visual Word Recognition in the Context of the Stroop Paradigm

The picture is less clear when it comes to the relation between spatial attention and lexical-semantic processing of print in the context of the Stroop paradigm. Here, there appear to be pervasive lexical-semantic effects of a distractor word when the task is to name a colour and the subject is instructed to ignore a distractor colour word that is physically separated from the colour patch (e.g., Brown et al., 2002; Lachter, Ruthruff, Lien & McCann, 2008; Waechter et al., 2011, Experiment 5). Some authors argue that such distractor processing, despite spatial attention being cued to a different location in space, is evidence for word identification without (spatial) attention (e.g., Lachter et al., 2008; Brown et al., 2002).

In contrast, Waechter et al., (2011) proposed a different account in which colour processing is typically less demanding of spatial attention than is word processing. The consequence is that spatial attention is more distributed and hence the distractor word gets processed – but *with* spatial attention. Some evidence for this proposal is provided by Robidoux, Rauwerda, and Besner (2014), who showed that the size of the spatial cueing effect (widely taken as a measure of spatial attention) is significantly smaller for colour naming than for reading words aloud. This result is consistent with the hypothesis that visual word recognition makes more demands on spatial attention than does colour naming, and hence that spatial attention may be more widely distributed when colour naming (even when the spatial cue is 100% valid) than when word reading. Consequently, colour naming may afford processing of a distractor word appearing in a different spatial location.

Distribution of Spatial Attention *Within* a Word in the Context of the Stroop Paradigm

The debate as to whether lexical-semantic processing is automatic or not has also been pursued with several spatial attention manipulations *within* a word in the context of the Stroop paradigm. For example, Besner, Stolz, and Boutilier (1997) reported a significant reduction in the size of the Stroop effect when only a single letter in a word was coloured compared to when the whole word was coloured (Experiment 1). In a second experiment, Besner et al. (1997) used non-words as a neutral baseline instead of congruent colour words, and found that single-letter colouring eliminated the Stroop effect entirely. Further, Besner and Stolz (1999) reported that spatially pre-cueing a single letter in uniformly coloured words produces a significantly smaller Stroop effect than pre-cueing all the letters (Experiments 1 and 2). This finding suggests that word recognition depends on the distribution of spatial attention across the letters in a word. Besner and Stolz (1999; Experiments 3 and 4 in particular) also reported that the Stroop effect could be eliminated by colouring the pre-cued letter differently from the un-cued letters and requiring the subject to identify the colour of that letter. These findings appear inconsistent with the widespread view that word recognition is automatic in the sense that lexical and semantic information is inevitably completely activated by the visual presentation of a word.

To be sure, these conclusions have been challenged in several quarters. One important issue is whether a reduction in the size of the Stroop effect demands the interpretation that *semantic* processing has been derailed, at least some of the time, or whether other processes have been compromised instead. In particular, Augustinova and Ferrand (2014) raise a number of methodological and theoretical objections. They conclude that semantic processing is automatic whereas response competition associated with lexical processing is not:

> …even a complete elimination of Stroop interference does not necessarily guarantee that word reading has been prevented because such a reduction might once again simply reflect the elimination of response conflict rather than the elimination of semantic conflict.
>
> Augustinova and Ferrand (2014, *in press*)

> …the methodological and empirical arguments discussed above clearly indicate that no empirical evidence from the Stroop task currently contradicts the widespread automatic view of word reading. It can therefore be conceptualized as a process that can be neither prevented nor controlled.
>
> Augustinova and Ferrand (2014, *in press*)

On the other hand, Manwell, Roberts, and Besner (2004) reported an experiment in which cueing and colouring a single target letter in neutral (e.g., "keg") and colour-associated (e.g., "sky") words whose colours were to be named aloud eliminated a semantically based Stroop effect. This result has been challenged by Augustinova, Flaudias, and Ferrand (2010) who failed to eliminate or even reduce a semantically based Stroop effect with single-letter cueing and colouring. However, if spatial attention is important for word processing (as argued by Besner et al., 2005; Lachter et al., 2004; Lien et al., 2010; Roubidoux et al., 2014; Waechter et al., 2011), a potentially critical difference between these experiments is that the stimuli in Augustinova et al. (2010) did not include empty spaces between letters whereas Manwell et al.'s (2004) experiment did. Indeed, none of the research reviewed by Augustinova and colleagues (2014) has employed a condition in which there were empty spaces between letters in the word. Such spacing may be critical for allowing spatial attention to be sufficiently narrowly tuned so as to prevent adjacent letters from being processed and, given the typically small stimulus set, counteract the activation of enough letters to identify the word.[1]

The Present Investigation

Semantic Stroop. Here we return to the issue of whether semantic processing in the context of the Stroop paradigm can be prevented. Mindful of the spatial attention literature and Gestalt grouping principles (e.g., similarity; Reynolds, Kwan, & Smilek, 2010) we combined

[1] That said, there was little evidence in Besner and Stolz (1999) that an empty space between letters had much effect on the size of the Stroop effect. Note, however, that this contrast is a between-subject comparison (Experiment 1 vs. 2).

three elements in a *semantic* version of the Stroop task. In one block of trials, participants named aloud the colour in which neutral (e.g., “keg”) and colour-associated (e.g., “sky”) words were presented when (a) all letters appeared in one colour, (b) all letters were spatially cued, and (c) non-letter characters filled the spaces between adjacent letters. This block constituted the *all-letters cued/coloured* condition. In another block of trials consisting of the same neutral and colour-associated words with non-letter characters between letters, participants had to name the colour of a single, spatially cued, target letter that was coloured differently from the remaining letters (which all appeared in the same color). This block constituted the *single-letter cued/coloured* condition. Examples of these conditions can be seen in Figure 1. The hypothesis explored here is that combining all these elements (i.e., having non-letter characters appear between letters of the word, ***and*** spatially pre-cueing the location of a single target letter that is coloured differently from the non-target letters) serves to focus readers’ spatial attention narrowly enough to prevent lexical-semantic processing of the word. If the present experiment produces a semantic Stroop effect in the *all-letters cued/coloured* condition, but not in the *single-letter cued/coloured* condition, then this outcome supports the idea that lexical-semantic processing has been stopped.

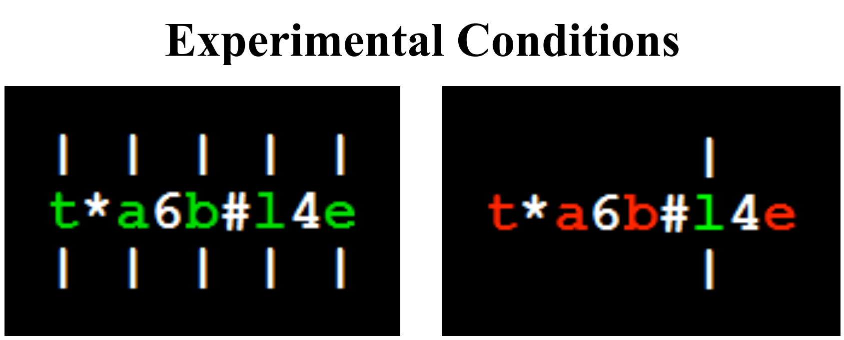

Figure 1. Sample stimuli from the *all-letters spatially cued and coloured* condition (left) and from the *single-letter spatially cued and coloured* condition (right).

Negative Priming. While the absence of a semantic Stroop effect is consistent with the absence of lexical-semantic processing, caution is indicated because a null here may not reflect an exhaustive measure of processing. In particular, it has been shown that the traditional Stroop effect can be absent in the same experiment where another measure indicates that some word processing occurred (e.g., Besner, 2001; Marí-Beffa, Estévez, & Danziger, 2000). For this reason a negative priming analysis was also conducted.

Negative priming refers to how the relation between the *previous* trial stimulus and the *current* trial stimulus affects the processing of the current trial stimulus (e.g., Besner, 2001; Marí-Beffa et al., 2000). Specifically, a negative priming effect is observed if responses are slower on trials that are preceded by colour-associated words that *match* the font colour of the current stimuli. Negative priming therefore serves as another indicator of whether the irrelevant word was processed at the lexical-semantic level. A more detailed description follows in the Results section.

To anticipate the results of the present experiment, there was both a semantically based Stroop effect and a semantically based negative priming effect in the all-letters cued and homogenously coloured condition. In contrast, neither of these effects was significant in the single-letter cued/coloured condition. We take these results to be problematic for the idea that lexical-semantic processing is automatic in the sense that it occurs without intent and cannot be stopped.

Method

Participants. Forty-two undergraduate and graduate students from the University of Waterloo participated in the experiment. Each participant was tested individually and received either course credit or monetary remuneration for participating. All participants had normal or corrected-to-normal vision, as well as normal colour vision.

Stimuli. The stimuli consisted of the neutral words *keg*, *jail*, *table*, and *palace*, and the colour-associated words *sky*, *frog*, *lemon*, and *tomato*, taken from Manwell et al. (2004). These items were matched for length and frequency with the colour words in the response set: red, blue, green, and yellow. Items were presented individually, in lowercase, with the spaces between letters filled with a mixture of the characters #, %, and * from the top of the keyboard, and the numbers 4, 5, and 6. Stimuli were presented in Courier New font, size 18. The characters separating the letters were presented in white (RGB: 255, 255, 255) and the letters were coloured using the four colours from the response set: red (RGB: 255, 0, 0), green (RGB: 0, 255, 0), blue (RGB: 0, 40, 255), and yellow (RGB: 255, 255, 0).

In the all-letters cued/coloured condition, all letters were presented in the same colour, with colour-associated trials always presented in an incongruent colour (e.g., *sky* presented in green, as opposed to blue). In the single-letter cued/coloured condition, a target letter (any letter except the first or last letter of the word) was coloured in one colour and the remaining letters were all coloured in another colour from the response set. In this condition, both colours were incongruent with colour-associated words. Spatial cueing was also a factor; this is described below.

Design. The experiment consisted of a 2 cued/coloured (all letters vs. single letter) x 2 relatedness (neutral vs. colour-associated) within-subjects design. The experiment was blocked (all-letters cued/coloured vs. single-letter cued/coloured), the order of which was counter-balanced across participants. There were a total of 192 experimental trials, with 48 trials per condition.

Apparatus. Stimuli were displayed on a 22-in. LG Flatron W2242TQ colour monitor (29.5 cm high x 47.5 cm wide). Stimulus presentation and data recording were controlled by E-Prime 2.0 experimental software, which was run on an Ultra Vault PC with an Intel® Core™2 Quad CPU @ 2.40 GHz processor. The display had a refresh rate of 60 Hz and a resolution of 1680 x 1050 pixels, while the screen resolution in E-Prime was set to 640 x 480 pixels. Participant responses were collected via an Altec Lansing microphone headset attached to a voice key assembly. Response times were measured to the nearest millisecond.

Procedure. Participants were seated approximately 70 cm away from a computer monitor, and were instructed to name aloud the colour of the target letter(s). They were instructed to respond as quickly and as accurately as possible. Each block began with a set of 16 practice trials that were followed by 96 experimental trials. All words were presented such that the center letter, number, or character was at fixation.

At the beginning of each trial, a white fixation marker appeared in the center of the screen on a black background for 500 ms. Next, a spatial cue, consisting of a white, vertical line (i.e., "|"), appeared above and below the position(s) where the target letter(s) would appear. The end of each cue that was closest to the cued letter was 9 mm from the center of the screen. In the all-letters cued/coloured condition, each letter in the word was cued by vertical lines. In the single-letter cued/coloured condition, only the target (odd-colour-out) letter was cued by vertical lines. The participants' task was to name the colour of the cued letter(s).

The spatial cue(s) appeared on the screen for 125 ms, followed immediately by the stimulus word. The entire display remained on the screen until the participant made a response. Once a response had been made, the screen remained blank until the researcher had coded the response as correct, incorrect, or spoiled (e.g., cough or microphone failure). This was followed immediately by the appearance of a fixation marker, which remained on the screen for 500 ms and marked the beginning of the next trial.

Results

The data of two participants were discarded due to high error rates (more than 2.5 standard deviations above the grand mean error rate), resulting in a final sample size of 40, with 20 participants in each counterbalance. Percentage errors were calculated after the removal of spoiled trials (6.3%). Reaction time (RT) analyses were conducted on correct responses only (i.e., incorrect and spoiled trials were removed). Correct RTs were subjected to an outlier removal procedure (Van Selst & Jolicœur, 1994) in which RTs more than 2.5 standard deviations above or below the mean RT per subject, per condition, were excluded from all analyses. This resulted in 2.4% of correct responses being discarded. Table 1 shows the mean RT, 95% confidence interval (CI), and mean percentage error for each condition. Confidence intervals were computed following the procedures outlined in Masson and Loftus (2003) for within-subject designs.

Table 1

Mean Reaction Times (RTs in ms), 95% Confidence Intervals (± CIs), and Percentage Error (% E) as a Function of Relatedness and Cueing/Colouring

	All Letters Cued/Coloured			One Letter Cued/Coloured		
Relatedness	RT	± *CI*	% E	RT	± *CI*	% E
Colour-Associated	630	*6*	0.8	690	*6*	0.7
Neutral	608	*6*	0.9	689	*6*	0.9
Difference	**22**		**- 0.1**	**1**		**- 0.2**

Semantic Stroop Effect. Mean RTs were analyzed in a 2 x 2 x 2 mixed factorial analysis of variance (ANOVA) with cued/coloured (all letters vs. single letter) and relatedness (neutral vs. colour-associated) as within-subject factors, and counterbalance (all-letters cued/coloured condition completed first vs. single-letter cued/coloured condition completed first) as the between-subject factor. The three-way interaction was not significant ($F(1, 38) < 1$). However, the critical interaction between cued/coloured and relatedness was significant ($F(1, 38) = 12.55$, $MS_e = 343.96$, $p < .01$), indicating that the size of the semantic Stroop effect differed for the all-letters and single-letter cued/coloured conditions. Planned comparisons confirmed that the 22 ms semantic Stroop effect was significant in the all-letters cued/colored condition ($t(39) = 4.93$, $SE = 4.37$, $p < .001$), whereas it was absent (1 ms) in the single-letter cued/coloured condition ($t(39) = 0.21$, $SE = 3.45$, $p > .8$).

Errors. Neither the three-way interaction nor the critical two-way interaction (cued/coloured x relatedness) was significant in a 2 x 2 x 2 mixed ANOVA of the errors ($F(1, 38) = 2.44$, $p = .126$ and $F(1, 38) < 1$, respectively).

Vincentile Analysis. A Vincentizing procedure was used to determine whether the effects seen in the mean RT data, reported above, are seen throughout the RT distributions. First, each participant's RT data were sorted into 10 bins, ranging from their fastest to their slowest responses. The RTs in each percentile range were then averaged across participants to produce mean RTs for the 10 bins in each experimental condition. Figures 2 and 3 show the Vincentile plots of RTs and associated 95% CIs for neutral and colour-associated (i.e., incongruent) trials for the all-letters cued/coloured and single-letter cued/coloured conditions, respectively.[2]

[2] The 95% CIs for the Vincentile means were calculated using the *MS errors* associated with the 2 x 10 interaction terms (relatedness x bin) from two ANOVAs (computed separately for the *all-letters cued/coloured* condition and the *single-letter cued/coloured* condition).

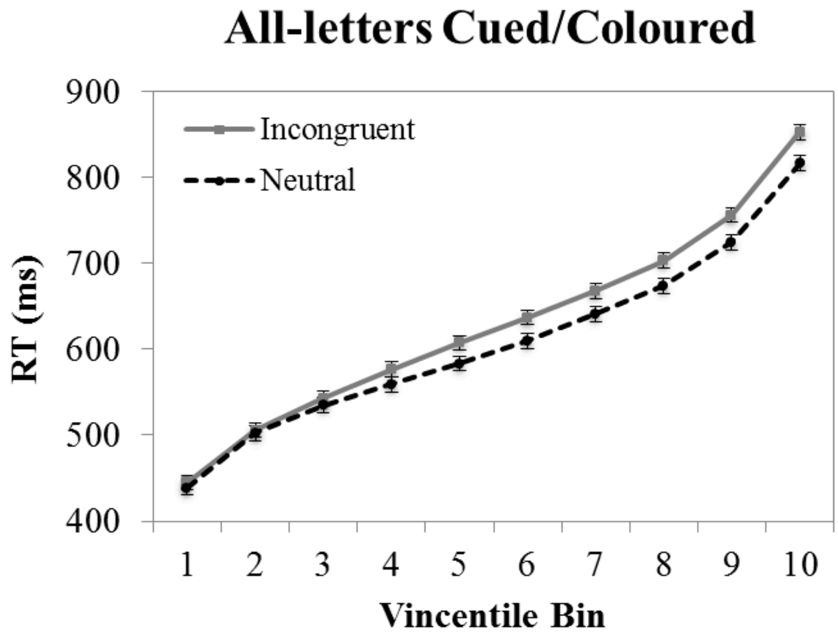

Figure 2. Vincentile RT means for incongruent (i.e., colour-associated) versus neutral stimuli in the all-letters cued/coloured condition with 95% confidence intervals.

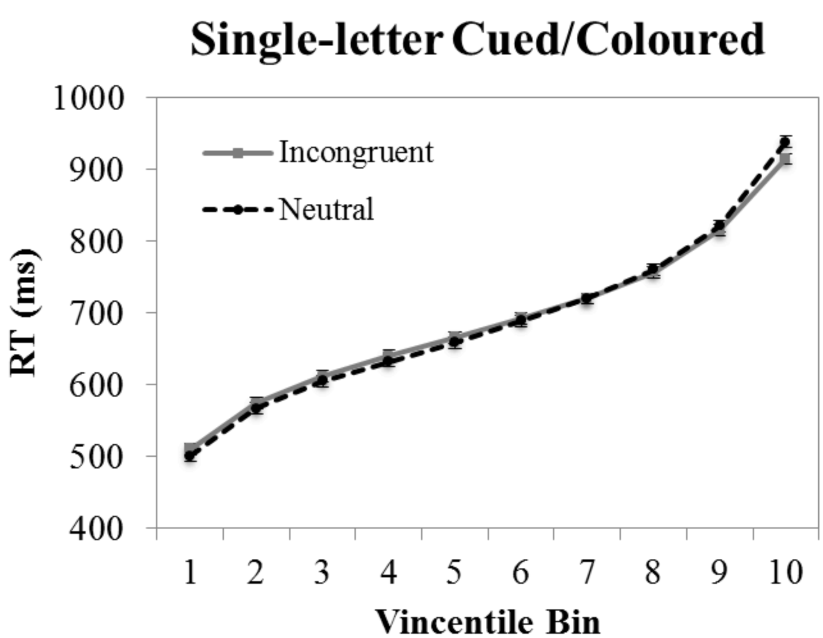

Figure 3. Vincentile RT means for incongruent (i.e., colour-associated) versus neutral stimuli in the single-letter cued/coloured condition with 95% confidence intervals.

Figure 2 illustrates that the semantic Stroop effect in the all-letters cued/coloured condition was right-shifted in that it was absent in the first four bins, but evident in the last six bins. In contrast, Figure 3 illustrates that the semantic Stroop effect was absent from the first nine bins in the single-letter cued/coloured condition. However, the incongruent condition was faster than the neutral condition in the very last bin. This latter result likely reflects a Type I error.[3]

Negative Priming Effect. The lack of a semantic Stroop effect in the single-letter cued/coloured condition suggests that word processing did not occur. However, as noted earlier, it is important to be cautious when drawing conclusions based on the absence of an effect. Negative priming refers to how the stimulus on the *previous* trial affects the processing of the stimulus on the *current* trial (e.g., Besner, 2001; Marí-Beffa et al., 2000), and is thus another indicator of whether the irrelevant word was processed. A negative priming analysis of the present data is reported below, which, along with the semantic Stroop results, provide converging evidence for the claim that semantic level word processing was present in the all-letters cued/coloured condition but absent in the single-letter cued/coloured condition.

All correct trials that were preceded by a colour-associated trial to which the response was correct were coded as either *related* or *control*. The stimulus on a *related* trial had a font colour that was semantically related to the colour-associated word on the previous trial (e.g., a current stimulus presented in blue font preceded by the stimulus word "sky"). In contrast, the stimulus on a *control* trial had a font colour that was unrelated to the colour-associated word on the previous trial (e.g., a current stimulus presented in green font preceded by the stimulus word

---

[3] If one excludes the last bin the same pattern as reported in the ANOVA is observed in that the semantic Stroop effect in the all-letters cued/color condition was 20 ms ($p < .001$), whereas the 3 ms difference between incongruent and neutral trials in the single-letter cued/coloured condition was not significant ($p > .3$).

"sky"). Both neutral and colour-associated trials were classified as *related* or *control* (if they were preceded by a colour-associated trial) to maximize the number of observations.

Table 2 shows the mean RTs and CIs for the negative priming analysis. The RTs that were classified as *related* or *control* were analyzed in a 2 x 2 within-subject ANOVA, with cued/coloured (all letters vs. single letter) and trial type (related vs. control) as factors. Critically, there was a significant interaction between cued/coloured and trial type ($F(1, 39) = 7.34$, $MS_e = 758.34$, $p < .05$), indicating that the size of the negative priming effect differed significantly for the all-letters and single-letter cued/coloured conditions. Indeed, as with the semantic Stroop effect, planned comparisons revealed a significant 30 ms negative priming effect in the all-letters cued/coloured condition ($t(39) = 4.60$, $SE = 6.63$, $p < .001$). To the best of our knowledge, this is the first demonstration of semantically based negative priming in the context of a Stroop task. Critically, the 7 ms difference between related and control trials in the single-letter cued/coloured condition was not significant ($t(39) = 1.12$, $SE = 6.15$, $p > .25$).[4]

Table 2

Mean Reaction Times (RTs in ms) and 95% Confidence Intervals (± CIs) as a Function of Negative Priming Condition (Related vs. Control) and Cueing/Colouring

Negative Priming	All Letters Cued/Coloured		One Letter Cued/Coloured	
Condition	RT	± *CI*	RT	± *CI*
Related	642	*9*	701	*9*
Control	612	*9*	694	*9*
Difference	**30**		**7**	

[4] Vincentile analyses were not carried out for the negative priming data because there were too few observations in the *related* condition for reliable estimates.

Discussion

In summary, a semantically based Stroop effect (22 ms) was observed in the present experiment when (a) all the letters in the target word were homogeneously coloured, (b) non-letter characters from the top of the keyboard filled the spaces between letters, (c) all letters were spatially cued, and (d) this condition was blocked. In contrast, the semantically based Stroop effect was statistically eliminated (1 ms) when only a single target letter in the word was cued and uniquely coloured. Relatedly, a semantically based negative priming effect was observed when all letters were cued and coloured (30 ms), whereas it was absent when only a single letter was cued and coloured (7 ms). These findings undermine the widely accepted view that semantic processing is *automatic* in the sense that it occurs without intention and cannot be prevented from occurring (e.g., Anderson, 2010; Ashcraft, 1994; Augustinova et al., 2010; Augustinova & Ferrand, 2014; Posner & Snyder, 1975; Rayner & Pollatsek, 1989; Reisberg, 1997, among many others).[5]

Conclusions

The present results dovetail with results from other approaches that were noted in the introduction (e.g., tasks in which a word is to be identified [as in reading aloud or lexical decision] where spatial attention is directed to an entire word rather than a single letter in a word, and when there is a distractor word in another location and the target location varies across trials, or when there is no distractor item but the target item varies location across trials; e.g., Besner et al., 2005; McCann et al., 1992; Lachter et al., 2004; Waechter et al., 2011; Lien et al., 2010). That is, our perspective on that literature as it currently stands is that all of those results are

[5] Of course, the present data do not tell us whether semantic activation did not occur because it was blocked (i.e., lexical level activation occurred but not semantic activation), or because prior lexical level activation did not occur and hence subsequent semantic activation could not occur.

problematic for the view that visual word recognition occurs without the need for some form of attention as a necessary preliminary to lexical-semantic processing.

In contrast to that literature, the present experiment crosses a variant of the Stroop paradigm (colour naming) with a spatial cueing paradigm and investigates processing that occurs *within* an irrelevant word that always appears at fixation. Spatial attention is directed to a single letter that is uniquely coloured in one block as compared to another block when all letters in the word are spatially cued and homogeneously coloured. In both blocks, the spaces between consecutive letters are filled with non-letter characters from the top of the keyboard. The results of this experiment are also problematic for the widespread view that lexical-semantic processing from print cannot be stopped given that both a semantically based Stroop effect and a semantically based negative priming effect were eliminated in the critical condition.

As always, further research is warranted. For example, would the results of an event related potential (ERP) approach converge with the behavioural data reported here, or will a dissociation be seen in which ERPs (e.g., N400, N450) reveal processing at the standard point in time (i.e., at the same point in time as in the all-letters cued and coloured condition)? Whatever the answer to that question, a sufficient conclusion in the interim is that (a) single target letter colouring combined with (b) single target letter spatial cueing, and (c) non-letter characters in between letters of the word, combined with (d) all these elements appearing together in a single block, appears sufficient to eliminate both a semantic Stroop effect and a semantically based negative priming effect. These findings suggest that lexical-semantic processing can be stopped, contrary to the widely accepted view in the attention and performance, and psycholinguistic literatures.

References

Anderson, J. R. (2010). *Cognitive psychology and its implications.* New York: Worth Publishers.

Ashcraft, M. H. (1994). *Human memory and cognition.* Harper Collins.

Ashcraft, M. H., & Klein, R. (2010). *Cognition.* Toronto: Pearson Canada.

Augustinova, M., & Ferrand, L. (2012). Suggestion does not de-automatize word reading: Evidence from the semantically based Stroop task. *Psychonomic Bulletin & Review, 19*, 521–527. doi: 10.3758/s13423-012-0217-y

Augustinova, M., & Ferrand, L. (2014). Automaticity of word reading: Evidence from the semantic Stroop paradigm. *Current Directions in Psychological Science, in press.*

Augustinova, M., Flaudias, V., & Ferrand, L. (2010). Single-letter coloring and spatial cuing do not eliminate or reduce a semantic contribution to the Stroop effect. *Psychonomic Bulletin & Review, 17*, 827–833. doi: 10.3758/PBR.17.6.827

Besner, D. (2001). The myth of ballistic processing: Evidence from Stroop's paradigm. *Psychonomic Bulletin & Review, 8*, 324–330. doi: 10.3758/BF03196168

Besner, D., Risko, E. F., & Sklair, N. (2005). Spatial attention as a necessary preliminary to early processes in reading. *Canadian Journal of Experimental Psychology, 59,* 99–108. doi: 10.1037/h0087465

Besner, D., & Stolz, J. A. (1999). What kind of attention modulates the Stroop effect? *Psychonomic Bulletin & Review, 6*, 99–104. doi: 10.3758/BF03210815

Besner, D., Stolz, J. A., & Boutilier, C. (1997). The Stroop effect and the myth of automaticity. *Psychonomic Bulletin & Review, 4*, 221–225. doi: 10.3758/BF03209396

Brown, T. L., Gore, C. L., & Carr, T. H. (2002). Visual attention and word recognition in Stroop color naming: Is word recognition “automatic”? *Journal of Experimental Psychology: General, 131,* 220–240. doi: 10.1037//0096-3445.131.2.220

Deutsch, J. A., & Deutsch, D. (1963). Attention: Some theoretical considerations. *Psychological Review, 70*, 80–90. doi: 10.1037/h0039515

Galotti, K. M., Fernandes, M. A., Fugelsang, J., & Stolz, J. A. (2010). *Cognitive psychology. In and out of the laboratory.* Toronto: Nelson Education.

Goldstein, E. B. (2011). *Cognitive psychology. Connecting mind, research, and everyday experience.* Australia: Wadsworth Cengage Learning.

Lachter, J., Forster, K. I., & Ruthruff, E. (2004). Forty-five years after Broadbent (1958): Still no identification without attention. *Psychological Review, 111*, 880–913. doi: 10.1037/0033-295X.111.4.880

Lachter, J., Ruthruff, E., Lien, M., & McCann, R. S. (2008). Is attention needed for word identification? Evidence from the Stroop paradigm. *Psychonomic Bulletin & Review, 15*, 950–955. doi: 10.3758/PBR.15.5.950

Levitin, D. J. (2011). *Foundations of cognitive psychology. Core readings.* Boston: Allyn & Bacon.

Lien, M., Ruthruff, E., Kouchi, S., & Lachter, J. (2010). Even frequent and expected words are not identified without spatial attention. *Attention, Perception, & Psychophysics, 72*, 973–988. doi: 10.3758/APP.72.4.973

Manwell, L. A., Roberts, M. A., & Besner, D. (2004). Single letter coloring and spatial cuing eliminates a semantic contribution to the Stroop effect. *Psychonomic Bulletin & Review, 11*, 458–462. doi: 10.3758/BF03196595

Marí-Beffa, P., Estévez, A. F., & Danziger, S. (2000). Stroop interference and negative priming:

Problems with inferences from null results. *Psychonomic Bulletin & Review, 7*, 499–503. doi: 10.3758/BF03214362

Masson, M. E. J., & Loftus, G. R. (2003). Using confidence intervals for graphically based data interpretation. *Canadian Journal of Experimental Psychology, 57*, 203–220. doi: 10.1037/h0087426

Matlin,M. W. (2013). *Cognition*. Hoboken, NJ: Wiley & Sons, Inc.

McCann, R. S., Folk, C. L., & Johnston, J. C. (1992). The role of spatial attention in visual word processing. *Journal of Experimental Psychology: Human Perception and Performance, 18*(4), 1015–1029.

Moors, A., & De Houwer, J. (2006). Automaticity: A theoretical and conceptual analysis. *Psychological Bulletin, 132*, 297–326. doi: 10.1037/0033-2909.132.2.297

Neely, J. H., & Kahan, T. (2001). Is semantic activation automatic? A critical re-evaluation. In H. L. Roediger III, J. S. Nairne, I. Neath, and A. M. Surprenant (Eds.), *The nature of remembering: Essays in honor of Robert G. Crowder* (pp. 69–93). Washington, DC: American Psychological Association.

Norman, D. A. (1969). *Memory and attention. An introduction to human information processing.* New York: Wiley & Sons, Inc.

Posner, M. I., & Snyder, C. R. R. (1975). Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola Symposium* (pp. 55–85). Hillsdale, NJ: Erlbaum.

Rayner, K., & Pollatsek, A. (1989). *The psychology of reading.* Englewood Cliffs, NJ: Prentice Hall.

Reisberg, D. (1997). *Cognition: Exploring the science o f the mind.* New York: Norton.

Reynolds, M., Kwan, D., & Smilek, D. (2010). To group or not to group: An ecological consideration of the Stroop effect. *Experimental Psychology, 57,* 275–291. doi: 10.1027/1618-3169/a000033

Robidoux, S., Rauwerda, D., & Besner, D. (2014). Basic processes in reading aloud and colour naming: Towards a better understanding of the role of spatial attention. *The Quarterly Journal of Experimental Psychology, 67*, 979–990. doi: 10.1080/17470218.2013.838686

Van Selst, M., & Jolicœur, P. (1994). A solution to the effect of sample size on outlier estimation. *Quarterly Journal of Experimental Psychology, 47*, 631–650. doi: 10.1080/14640749408401131

Waechter, S., Besner, B., & Stolz, J. A. (2011). Basic processes in reading: Spatial attention as a necessary preliminary to orthographic and semantic processing. *Visual Cognition, 18*, 171–202. doi: 10.1080/13506285.2010.517228

Appendix A

Individual Participants' Mean Reaction Times (ms) for Each Experimental Condition

	Reaction Time			
	All Letters Cued/Coloured		Single Letter Cued/Coloured	
Subject	Neutral	Colour-Associated	Neutral	Colour-Associated
1	612	596	650	624
2	618	636	735	741
3	585	586	716	707
4	607	597	635	640
5	525	528	539	543
6	707	676	705	704
7	671	659	862	872
8	777	793	772	819
9	552	561	697	650
10	822	744	849	866
11	627	626	661	661
12	699	660	767	768
13	576	562	713	735
14	524	528	531	521
15	473	447	531	527
16	645	539	795	813
17	618	581	772	750
18	462	473	676	664
19	854	793	704	729
20	493	440	606	605
21	708	665	758	770
22	613	607	672	652
23	529	527	595	600
24	519	502	668	599
25	652	617	684	684
26	570	570	677	683
27	687	660	771	763
28	650	637	749	748
29	674	677	761	742
30	666	639	705	692
31	686	643	675	697
32	647	565	689	671
33	676	650	588	554
34	621	582	608	636
35	693	673	692	701
36	748	729	741	758
37	713	673	761	743
38	625	620	655	665
39	579	578	688	687
40	494	499	542	581

Appendix B

Individual Participants' Mean Percentage Errors (%) for Each Experimental Condition

	Percentage Error			
	All Letters Cued/Coloured		Single Letter Cued/Coloured	
Subject	Neutral	Colour-Associated	Neutral	Colour-Associated
1	0	2	2	2
2	0	0	2	0
3	0	2	0	0
4	2	0	0	2
5	0	0	2	2
6	0	2	0	2
7	2	0	2	0
8	0	3	0	2
9	2	5	0	2
10	2	2	0	2
11	0	5	0	0
12	0	2	0	0
13	0	0	0	0
14	2	0	0	0
15	0	0	0	0
16	0	0	0	0
17	0	0	0	0
18	0	0	0	0
19	2	2	0	2
20	0	0	2	0
21	0	0	5	0
22	0	0	0	0
23	0	0	0	0
24	0	0	0	0
25	2	0	0	0
26	2	2	2	2
27	2	2	2	6
28	7	2	2	2
29	0	0	0	0
30	4	0	0	2
31	0	0	0	2
32	0	0	0	0
33	2	0	2	0
34	0	4	0	0
35	0	0	0	0
36	0	0	0	0
37	0	0	2	4
38	3	0	2	3
39	0	0	0	0
40	0	0	0	0