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REVIEW ARTICLE

A brief review of three manipulations of the Stroop task focusing on the automaticity of semantic access

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Since Stroop (1935), semantic access has been seen as automatic but today this is questioned, following minor modifications of the Stroop task. Besner, Stolz and Boutilier (1997) showed that coloring a single letter differently from the others and asking the participant to name the color of this letter, significantly reduced the Stroop effect. Huguet, Galvaing, Monteil and Dumas (1999) showed that another person's presence during the test significantly reduced the Stroop effect. Raz, Shapiro, Fan and Posner (2002) showed a reduction in Stroop effect when hypnotized participants were told what would appear on the screen was not a word. These reductions suggest that semantic access of a word needs attentional resources, and is not automatic.

This review summarizes recent results concerning reduction of the Stroop effect through the three manipulations mentioned above. The similarities and conflicts of these studies are illustrated. The conclusions suggest that these manipulations seem not to reduce or prevent automatic semantic activation, but rather reduce non-semantic task-relevant response competition. Using measures other than behavioral measures like Event-Related Potentials and a new definition of automaticity are proposed to understand better the different results cited.

Keywords: automaticity; semantic activation; Stroop interference; word reading; attention

Introduction

Semantic access of a word is the main objective of reading. This access is done very quickly (around 400 ms, Kutas & Hillyard, 1980). This fast access to semantics questions about its automaticity of this function. Automatic behavior is often defined (Bargh, 1994; Neely & Kahan, 2001; Posner & Snyder, 1975) as a phenomenon that occurs without intent and cannot be prevented (see Moors & De Houwer, 2006 for a review of different conceptualizations of automaticity).

The automaticity of semantic access in Stroop task (Stroop, 1935) is currently debated (see Augustinova, Flaudias, & Ferrand, 2010).

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The Stroop task is a well known task to study automatic behavior. This is the "gold standard of automated performance" (Raz, Shapiro, Fan, & Posner, 2002). In this classical task, the participant must indicate the color in which a word is written. A longer reaction time (RT) is observed when the word is incongruent (e.g. the word "red" written in *green*) compared with a control condition (e.g. a series of Xs) or when he word is congruent (e.g. the word "red" written in *red*). This effect is due to the fact that, in the incongruent condition, two concepts are simultaneously activated in the memory: the meaning of the word (e.g. red) and the color of the ink used (e.g. *green*), which in this case is the correct answer. These activations create a conflict whose resolution takes a while, explaining why we observe a longer RT. This task therefore seems consistent with the hypothesis of an automatic activation of semantics. Indeed, in this example, the participants are requested not to read the word but to concentrate on the color of the word. Despite this, the results show that the participant cannot refrain from reading the word. The presence of the Stroop effect is an indicator of semantic access and specifically the automatic nature of this access.

Automatic access to semantics has recently been called into doubt by the use of three manipulations of the Stroop task: coloring differently a single letter in the word, the presence of other people during the experiment and making a specific suggestion to participants.

The aim of this article was to review studies exploring the question of automaticity of semantic access along these three variations.

Method

This review was based on an electronic search, conducted in January 2013 using the following databases: Medline, Psychinfo, Web of Science and Google Scholar. There was no restriction on date, language or publication status. The key words were "semantic", "Stroop" and citation of the original source article of each manipulation (Besner, Stolz, & Boutilier, 1997; Huguet, Galvaing, Monteil, & Dumas, 1999; Raz et al., 2002; see below for a description of these articles). Exclusion criteria concerned Stroop task: only studies using words, and no pictures or sound, and no patients were included.

The summary of this literature search is described in the next three sections and three corresponding tables, categorised by the manipulation used.

The single letter coloring manipulation (see table 1)

Studies in favor of a temporary blocking of semantic activation

In their study, Besner et al. (1997) investigated the automatic nature of semantic access. Their hypothesis was based on McClelland's interactive model of reading (1987). In this model, the recognition and understanding of a word consist of several steps. Firstly, the process begins with the visual recognition of the letters. Then, once recognized together, these letters allow the composition of the word, and thus access to the orthographic lexicon. Finally, the semantic memory connected with the word in question is retrieved. This model is called "interactive" because high level could inform low level of the activation. The activation of level is not serial but rather a simultaneous parallel process. For Besner et al. (1997), it is possible to stop the propagation of the activation at the orthographic level with the use of a letter search task which is a paradigm successfully used in a priming task (Smith, Theodor, & Franklin, 1983). To apply this paradigm to the Stroop task, they used a similar presentation by Kahneman and Henik (1981).

They used the classical Stroop task where participants had to name the color in which the word was written. They also included a new condition, according to which participants had to name the color of a single letter that was colored differently from the rest of the word. The letter was positioned randomly in the word (beginning, middle or end). The remaining letters were colored grey. In this paradigm, the authors added an arrow below and above the letter the color

Study	Exp.	NP	CLL	Coloring of remaining Letters	SE Classical All letters	SE Classical Single letter	SE Associated All letters	ES Associated Single letter	Control Condition	response modality
Augustinova & Ferrand (2007)	1	21	Initial	A single color from the response set	80 ms***	56 ms***	24 ms**	18 ms*	Neutral Words	Vocal
Augustinova & Ferrand (2007)	2	24	Initial	Gray	91 ms***	59 ms***	52 ms*	52 ms*	Neutral Words	Vocal
Augustinova et al. (2010)	1	79	Initial, Middle, End	A single color from the response set	60 ms***	18 ms***	18 ms***	22 ms***	Neutral Words	Vocal
Augustinova et al. (2010)	2	67	Initial, Middle, End	A single color from the response set	80 ms***	46 ms***	12 ms*	19 ms*	Neutral Words	Vocal
Augustinova et al. (2010)			OVP	A single color from the response set	102 ms***	31 ms***	16 ms**	20 ms*	Neutral Words	Vocal
Besnet et al.[1] (1997)	1	64	Initial, Middle, End	Gray	103 ms 67 ms	72 ms 50 ms	XX XX	XX XX	Congruents pseudohomophones	Manual
Besnet et al.[1] (1997)	2	64	Initial, Middle, End	Gray	34 ms	-1 ms	XX	XX	non-words	Manual
Besner & Stolz[2] (1999a)	1	22	Initial, Middle, End	A single color from the response set	78 ms**	21 ms**	XX	XX	Congruents	Manual
Besner & Stolz[2] (1999a)	2	34	Initial, Middle, End	A single color from the response set	62 ms**	25 ms**	XX	XX	Congruents	Manual
Besner & Stolz[2] (1999a)	3	45	Initial, Middle, End	A single color from the response set	XX	1 msns	XX	XX	non-words (idem Besner et al. 1997)	Manual
Besner & Stolz[2] (1999a)	4	35	Initial, Middle, End	A single color from the response set	XX	9 msns	XX	XX	non-words (idem Besner et al. 97)	Manual
Besner & Stolz (1999b)	1	46	Initial, Middle, End	Gray	31 ms**	1 msns	XX	XX	Congruents	Manual
Besner & Stolz (1999b)	2	18	Initial, Middle, End	Gray	39 ms***	-1 msns	XX	XX	Congruents	Manual
Besner & Stolz (1999b)	3	55	Initial, Middle, End	Gray	30 ms**	20 ms*	XX	XX	Congruents	Manual

Contd.

Study	Exp.	NP	CLL	Coloring of remaining Letters	SE Classical All letters	SE Classical Single letter	SE Associated All letters	ES Associated Single letter	Control Condition	response modality
Besner (2001)		48	Initial, Middle, End	White	93 ms**	39 ms**	XX	XX	Congruents	Manual
Brown et al. (2002)	1	36	Middle	Black	190 ms* 115 ms*	108 ms* 90 ms*	XX XX	XX XX	Congruents Neutral	Vocal
Brown et al. (2002)	2	35	Middle	Black	78 ms* 58 ms*	60 ms* 37 ms*	XX XX	XX XX	Congruents Neutral	Manual
Brown et al. (2002)	3	42	Middle	Black	108 ms*	72 ms*	XX	XX	Neutral	Vocal
Brown et al. (2002)	4	42(idem3)	Middle	Black	41 ms*	20 ms*	XX	XX	Neutral	Manual
Brown et al. (2002)	5	32	Middle	Black	50 ms*	33 ms*	XX	XX	Neutral	Vocal
Catena et al. (2002)	1	16	Randomly	White	52 ms*	8 msns	XX	XX	Neutral pseudo-homophones	Manual
Danziger et al. (2002)	1	22	All letters Initial Middle End	Gray	52 ms*** XX XX XX	XX 25 msns(p<.09) 32ms* 63ms***	XX XX XX XX	XX XX XX XX	"XXXXX"	Manual
Danziger et al. (2002)	2	20	All letters Initial (few letters) End (few letters)	Gray	39ms*** XX XX	XX 8 msns 32 ms**	XX XX XX	XX XX XX	"XXXXX"	Manual
Danziger et al. (2002)	3	20	All letters Initial (few letters) End (few letters)	Gray	14 msns XX XX	XX 1 msns 29 ms*	XX XX XX	XX XX XX	"XXXXX" or "MMMM" or "WWWWWW" or "YYYY"	Manual
Küper et al. (2012)	1	24	Initial, Middle, End	A single color from the response set	86 ms***	42 ms***	XX	XX	Neutral Words	Vocal
Küper et al. (2012)	2	24	Initial, Middle, End	A single color from the response set	68 ms ***	50 ms***	XX	XX	Neutral Words	Vocal
Manwell et al. (2004)	1	16	Initial, Middle, End	A single color from the response set	149 ms***	49 ms***	28 ms**	7 msns	Neutral Words	Vocal

Contd.

Study	Exp.	NP	CLL	Coloring of remaining Letters	SE Classical All letters	SE Classical Single letter	SE Associated All letters	ES Associated Single letter	Control Condition	response modality
Manwell et al. (2004)	na [a]	16	Initial, Middle, End	Gray	nd	nd	nd	18 ms**	Neutral Words	Vocal
Marmurek (2003)	1a	30	Initial, Middle, End	Gray	43 ms***	18 ms*	XX	XX	non-words (idem Besner et al.1997)	Manual
Marmurek (2003)	1b	30	Initial, Middle, End	Gray	47 ms***	42 ms***	XX	XX	non-words (idem Besner et al. 1997)	Vocal
Marmurek (2003)	2	48	Initial, Middle, End	Gray	65 ms***	31 ms***	XX	XX	non-words (idem Besner et al. 1997)	Vocal
Monahan (2001)	1	64	Initial, Middle, End	Gray	77 ms*	52 ms*	XX	XX	Congruents	Manual
Monahan (2001)	2	64	Initial, Middle, End	Gray	55 ms*	42 ms*	XX	XX	Congruents	Manual
Monahan (2001)	4	57	Initial, Middle, End	Gray	78 ms*	63 ms*	XX	XX	Neutral Words	Manual
Monahan (2001)	5	63	Initial, Middle, End	Gray	83 ms* 75 ms*	59 ms* 50 ms*	XX XX	XX XX	Congruents Neutral Words	Manual Manual
Parris et al. (2007)	1	48	All letters Initial OVP Middle End	Gray	105 ms*** XX XX XX XX	XX 74 ms*** 116 ms*** 70 ms*** 46 ms***	XX XX XX XX XX	XX XX XX XX XX	Neutral Words	Vocal
Parris et al. (2007)	2	20	Initial OVP End	Gray	XX XX XX	38 ms*(p<.062) 87 ms*** 40 ms**	XX XX XX	XX XX XX	Neutral Words	Vocal

Note. NP: number of participants; CLL: Cued letter location; SE: Stroop Effect; ns: not significant; nd: not available: $^{*}p<.05$; $^{**}p<.01$; $^{***}p<.001$

[1] No results of simple effects in this study. Only the effects of interactions which showed that the classic Stroop effect decreased in the single letter coloring condition was reported

[2] See Besner and Stolz (2001)'s Retraction of results which are not reproducible

Table 1: Summary of experiments studying the effect of coloring a letter differently from others in a Stroop task

of which should be named. The authors suggested that their new condition would lead participants to work exclusively at the letters level and therefore the semantic level would not be required for the task.

If the authors' hypothesis were true, the Single Letter Coloring (SLC) manipulation would temporarily block the access to the semantic level and the Stroop effect would be diminished or even eliminated compared with the All-Letter-Coloring (ALC) condition. The results seemed to confirm this hypothesis, because the difference in RT between congruent and incongruent words was higher in the ALC condition compared with the SLC condition (Experiment 1). This difference was absent when a single letter was colored and the comparison was made between the incongruent and control condition, in which items were not a color words like in Experiment 1 but non-words (Experiment 2). These results seem to be in good agreement with the hypothesis that semantic access is not obligatory and therefore would not be automatic. The spreading activation propagation from the lexical orthographic level to the semantic level would be temporarily blocked.

Following this article, several authors have tried to understand this SLC effect. Besner and Stolz (1999a) reported similar findings in a series of four experiments that explored the spatial attention provided by coloring a single letter. In Experiments 1 and 2, the authors varied the subscripting (the arrow could indicate: a letter of the word in the ALC condition; the letter which was colored differently in the SLC condition; the color of the other letters except the one colored differently in SLC, or all the letters in the ALC condition). Experiment 2 differed from the first by a space between each letter of the word. Results from both of these experiments indicated a reduction of the Stroop effect in SLC condition. Moreover, the authors observed an elimination of this effect in Experiments 3 and 4. The principal difference between these two sets of experiments was the control condition used. In Experiments 1 and 2, the control condition consisted of congruent words, whereas in Experiments 3 and 4 the authors used pseudo-homophones items (identical to those used by Besner et al., 1997). Thus, manipulation of spatial attention (by an arrow cueing the letter the color of which had to be named) leads to a reduction or even an elimination of the Stroop effect. In 2001, Besner and Stolz wrote a retraction article explaining that these results could not be replicated. Therefore, interpretation of these results is difficult.

For Besner and Stolz (1999b), coloring one letter differently from the others encouraged the participant to work on a new dimension of the item. In other words, the word is not treated as a word. Thus in their first experiment, the authors used neutral words with ALC presentation or SLC presentation (the letter colored differently from the others was randomly located at the beginning, the middle or the end of the word). The participant had to name the color of the word. This word was presented above or below a color word written in white on a black background. Thus the incongruent condition consisted of neutral words presented centrally and written in a different ink color to the distractor word (the name of a color located above or below the target item). In the second experiment, stimuli were not neutral words but names of shapes (e.g. "circle", "square"). In Experiment 3, geometric shapes were presented, rather than words, for stimulus. For this late condition, the SLC presentation ("single letter colored" presentation is not really a correct term, but we retain this expression for better comprehension) consisted of one segment of the geometric shape colored differently. The objective of this study was to show that the manipulation of the color of a single letter implied that the apprehension of the Stroop task was different. In this hypothesis, participants have to work on another dimension, in this case, visual information. In fact, the authors observed that, when the central stimulus and color word were

in the same domain, i.e. when both were words (Experiments 1 and 2), the Stroop effect was eliminated in SLC presentation, whereas, when the stimulus and the color word belonged to two different domains (Experiment 3), SLC condition increased the Stroop effect. This study showed that, when the target stimulus was a letter colored differently from the other letters in the word, the influence of the meaning of the color word seemed no longer effective because the attentional focus was on the same dimension (treatment of visual color and not an alphabetic item), and therefore semantic access was inhibited in favor of the visual treatment of the color. This change in attention seemed to demonstrate that attention was needed to perform correctly the semantic access. This is in contradiction with the view of an automatic process which does not need attentional resources.

In 2001, Besner continued to explore this idea with a new series of studies showing that, when the control condition was a congruent condition, when only a single letter was colored and there was an arrow above and below this letter, and finally, when the proportionality of congruent and incongruent words was reduced to 20% and 80% respectively, the Stroop effect was eliminated in the SLC condition compared with the ALC condition, regardless of these different parameters.

In 2002, Brown, Joneleit, Robinson and Brown performed a series of experiments to study the attentional focus on SLC condition. Experiments 1 and 2 used a manual and voice response respectively, with congruent words and neutral words used as control conditions. Experiments 3 and 4 also used a manual and a voice response respectively but without the use of congruent words. In this series of experiments, Brown et al. (2002) observed a Stroop effect under all conditions, with both manual and voice response and under congruent and incongruent conditions. However, the authors observed a decrease of the Stroop effect with the SLC condition.

In Experiment 5, Brown et al. (2002) used additional variations. In addition to the arrow included in the SLC presentation, a new cue was included, composed of two vertical lines. The item appeared between them. The cue could appear above, below, left, or right of the center of the screen. The word could appear where the cue suggested or at one of the other three locations that were not cued. The results also showed a decrease in the Stroop effect in the SLC condition. The authors concluded therefore that a SLC presentation reduced the degree or the speed of the processing of the word.

Studying more specifically the semantic access: the "semantically-based Stroop effect"

All these studies showed that, under specific attention conditions (e.g. coloring and cued a letter differently from the others), Stroop interference was reduced or eliminated. This seemed to indicate that semantic access could be blocked temporarily and therefore, could not be automatic. However, for Neely and Kahan (2001), Besner et al. (1997) (and subsequent studies cited above) had not really measured the semantic component of the Stroop effect. To measure the semantic aspect, it would have been preferable to use a new interfering condition developed by Neely and Kahan (2001). Indeed, the classical Stroop interference could be produced by a competition of responses that did not depend on the semantic level (e.g. the *flanker task*, Eriksen & Eriksen, 1974). Neely and Kahan (2001) showed that a word semantically related to a color (e.g. LEMON associated with *yellow,* SKY associated with *blue* ...) (see Dalrymple-Alford, 1972 and Klein, 1964 for this association) creates more interference in the Stroop task than a non-associated word (e.g. TABLE). This interference is a better indicator of a semantic conflict (two opposing colors) than a "classical Stroop interference". Indeed, if an interference with color-associated words was observed, it was only due to a competition at

the semantic level and not to a competition of response. Moreover, Besner et al. (1997, 1999a, 1999b, 2001) used a manual measure for recording the RT, which is less appropriate than measuring the verbal response as it is less sensitive to semantic encoding (see MacLeod, 1991; and Sharma & McKenna, 1998). Finally, some of the neutral words used were phonologically close to the color names (e.g. "ret"/"red"). Marmurek, Proctor and Javor (2006) have recently shown that naming the color with which a word is written is facilitated when the initial phoneme is identical for the color name and the written word, so the decrease of the Stroop effect in the Besner et al. (1997) experiment could only be due to an increase in the RT for the condition control which was composed of words the initial phoneme of which was close to color words. There was an interference effect between the color to be named and the color activated with the related phoneme. This control condition was not a correct "control condition" in this case.

Manwell, Roberts and Besner (2004) used the same paradigm as Besner et al. (1997), taking into account the various points mentioned above. They used a verbal response rather than a manual one, the neutral condition consisting of non-words without phonological overlap with the color words, and they added a *color-associated word condition* (as recommended by Neely & Kahan, 2001). The results showed a significantly reduced interference with the SLC condition compared with the ALC condition for the classical incongruent condition. Thus the *classical Stroop interference*, which is, in this case, the difference between the RT for color words presented in the incongruent condition subtracted from the RT for the control condition (in this case, neutral words), is reduced in the SLC condition. In addition, the *semantically-based Stroop* interference, which is the difference between the RT for the color-associated words presented in the incongruent condition and the RT for control items, is completely eliminated in the SLC condition.

In conclusion, all these studies show a reduction or even elimination of the *classical Stroop effect* when a single letter is colored differently from the other letters in a word. More importantly, this also appears true for the *semantically-based Stroop effect*. This elimination seems to show that semantic access, though unconscious, can be controlled and therefore is not automatic.

Studies in favor of a different explanation than blocking temporary semantic access

There are many criticisms and contradictory observations about the studies previously presented. First, Danziger, Estevez and Mari-Beffa (2002) worked on the position of the letter to be named. They observed that the Stroop interference was reduced when the first letter was colored but that interference was increased when it was the last letter that was colored in SLC condition. Thus, the results obtained by Besner et al. (1997) would mainly be due to the position of the letter. The fact that no decrease was observed in all the SLC presentations (in this case, when the letter was the last) is in contradiction with the hypothesis that this manipulation can help the stimulus to be treated by another dimension.

Parris, Sharma and Weekes (2007) observed a decrease in the Stroop effect when the initial fixation position was at the end of the word compared with the Optimal Viewing Position (OVP). The OVP is in the center left of the word. It is the position in a word that allows the full and complete reading of the word when the first fixation is on this position (O'Regan, Levy-Schoen, Pynte, & Brugaillere, 1984). These authors observed that in the studies by Besner et al. (1997), the letter was randomly located at the beginning, middle or end of words, but never in the OVP. Thus, focusing the attention of participants on these positions did not result in the optimal reading position of the word. If it is physically impossible to read the word, it is difficult to have semantic access. The authors found that when the OVP was used, participants took

more time to name the color in which a color word was written than with a neutral word. In other words, when the letter the color of which is to be named is located in the OVP, the Stroop effect is not reduced, it can even increase in SLC condition. But Augustinova, et al. (2010) (Experiment 2) observed no difference in the Stroop effect between the use of the OVP and when the letter to be named was randomly located (see Note 4 of the article by Augustinova, et al. (2010) for possible explanations of the differences between these experiments).

These studies tend to show that, rather than semantic access, it is primarily an effect of the perception of the word that reduces the Stroop effect.

Catena, Fuentes and Tudela (2002) also conducted a study using SLC in the Stroop task in a manipulation similar to that of Besner et al. (1997). Under the same conditions they observed an elimination of the classical Stroop effect. They also studied "negative priming". *Negative priming* is a robust measure consisting of a pair of trials wherein the word ignored in Stimulus 1 is identical to the ink color of the immediately following Stimulus 2. In such cases, the RT to Stimulus 2 is typically longer than if Stimulus 1 contained a word that did not become the ink color in Stimulus 2 (see Mayr & Buchner, 2007 for a review). Thus, in this study, the authors found positive priming (when SLC in Stimulus 1, the RT to a related Stimulus 2 is reduced) when there was a lack of Stroop effect (i.e. on SLC condition), and a negative priming when there was a Stroop effect (i.e. on ALC condition). The authors believed that positive priming with the SLC condition was the product of two components: an automatic component (semantic access) which was delayed by a configuration of the non-familiar prime, and a controlled component which was initiated once attention was focused on the currently displayed target. According to the authors, even if interference could not be observed, the semantic access would not be blocked.

Marmurek (2003), using a vocal response, did not observe the decline in classical Stroop interference reported by Besner et al. (1997), who used a manual response mode. Thus, when using a response modality that appears to benefit semantic access, the *classical Stroop interference* reappears and does not seem to be modified by the SLC condition.

Monahan (2001) suggested another hypothesis to explain the results of a decrease in the Stroop task with the SLC condition. The Stroop effect (classical or semantically-based) is the difference between the RT for incongruent words and those for control condition. It inevitably decreases if the RT increases in the control condition. Experiments showing a decrease or even an elimination of Stroop effect with SLC presentation observed an increase in RT for control conditions (Augustinova & Ferrand, 2007; Besner et al., 1997; Manwell et al., 2004; Parris et al., 2007; but this effect was not specifically analysed). Indeed, in the ALC condition, neutral words (or other control conditions) have only one possible response and it does not conflict with the semantics of the word (e.g. TABLE written in *red*). On the other hand, in the incongruent condition (color-associated words or color words), the name of the color conflicts with the semantics of the displayed word (e.g. RED written in *green*). This explains the longer RT for this condition compared to the control condition, as the participants have to perform a selection process, which takes time. The same reasoning could apply to the SLC condition. RTs are longer when participants must perform a selection process between two conflicting colors. In the SLC condition, the conflict is not only in the case of incongruent words (color-associated words or color words), but also in the neutral condition. Indeed, in the latter case, two colors are in conflict (e.g. for the word TABLE where "t" is written in *blue* and "able" in *green, green* and *blue* are the color conflict). Thus the difference observed between ALC condition and SLC condition for control condition could be the indicator of

this selection process. In his study, Monahan (2001) observed that coloring one element differently from the other tended to increase the RT for congruent or neutral stimuli but not for the incongruent. Thus, the observed decrease of the Stroop interference could probably be due to an increase RT in the control condition rather than a decrease in the incongruent condition. More recently, Küper and Heil (2012) used the same procedure as Manwell et al. (2004). Like Monahan (2001), in their first experiment they observed that the decrease of the Stroop effect in the SLC condition was due to an enhancement of the RT for neutral words and not a decrease of RT for classical incongruent words. In their second experiment, which was very similar, they used cueing. The arrow was absent in the first experiment. They observed the same result as in Experiment 1: the decrease of the Stroop effect was due to an increased of RT for neutral words but not for incongruent conditions.

Unfortunately, it is difficult to make conclusions on semantic access with the various studies cited above, because they did not use the color-associated word condition. Augustinova and Ferrand (2007) used the manipulation of Manwell et al. (2004) with this new condition but focused the participants' attention on only the first letter of the word. They had a classical condition and a color-associated word condition. The participant had to orally indicate the color of the letter cued by an arrow. This letter was always the first letter of the word. The results clearly showed a decrease in the classical Stroop effect as observed in the previous studies, but no reduction of the *semantically-based Stroop effect*. The same was seen when the condition consisted of a single letter colored differently from the other letters (Experiment 1A) or when one letter was colored and the rest of the word was gray (Experiment 1B). These results tended to show that a semantic conflict existed between the naming of the color and the word itself.

More recently, Augustinova, et al. (2010), using the same design as Manwell et al. (2004) in their Experiment 1, failed to find a reduction of the *semantically-based Stroop effect* with the SLC condition, even though a decrease in the *classical Stroop effect* was observed. This result was obtained with the inclusion of 79 participants compared with 16 by Manwell et al. (2004). The disappearance of the effect observed by Manwell et al. could be interpreted in terms of a Type II error. Augustinova et al. (2010) showed similar results when the word was presented centered on the differently colored letter (Experiment 2).

First Conclusions

The various authors cited above agree on the fact that coloring a single letter differently from the others may lead to a reduction of the *classical Stroop effect*. Several explanatory hypotheses are supported: blocking access to the semantics of the word (Besner et al., 1997), the initial fixation in a word (Danziger et al., 2002; Parris et al., 2007), the modality of response (Marmurek, 2003).

However, recent studies suggest that access to the semantics of the word would be preserved (if we looked at the color-associated word condition). Thus the fluctuation observed during the SLC condition is probably due to the decrease of another factor interfering with the Stroop task. It is more probable that the SLC design simply reduces the non-semantic response competition.

In parallel with these studies, other authors have been interested in the reduction of the Stroop effect by social context.

Influence of social context (see table 2)

To study the impact of social context on cognitive performance, Huguet et al. (1999) used a Stroop task with the absence or presence of somebody in the room with the participant while performing the task. They showed that in the presence of a co-actor, or simply a presence (inactive), the Stroop effect decreased in comparison with a situation where the participant was alone in the room. This reduction of the Stroop effect

Study	Exp.	NP	Presence type	SE classical	SE Associated	Others particularities	Control Condition	Modality of answer
Augustinova & Ferrand (2012b)	1	41	Alone simple presence	141 ms*** 57 ms***	78 ms*** 59 ms***	Simple presence	"XXXXX"	Vocal
Augustinova & Ferrand (2012b)	1	92	Alone simple presence	92 ms*** 68 ms***	18 ms*** 18 ms***	Simple presence	"neutral words"	Vocal
Dumas et al. (2005)	1	10 10 11 11	Alone Slower co-actor Similar co-actor Faster co-actor	49 ms*** 57 ms*** 45 ms*** 10 ms***	XX XX XX XX	Co- action situation	"XXXXX"	Manual
Dumas et al. (2005)	2	10 10 11 11	Alone Slower similar faster	94 ms*** 77 ms*** 73 ms*** 17 ms***	XX XX XX XX	No presence, just a comparison of results	"XXXXX"	Manual
Huguet et al. (1999)	1	18 22 22 24	Alone Non attentive Non visible Attentive	170 ms*** 119 ms*** 101 ms*** 71 ms***	XX XX XX XX	Same sex as participant, simple presence	"XXXXX"	Manual
Huguet et al. (1999)	2	80	Alone Slower co-actor Similar co-actor Faster co-actor	90 ms*** 77 ms*** 50 ms*** 29 ms***	XX XX XX XX	Co- action situation	"XXXXX"	Manual
Huguet et al. (2004)	1 (no reward)	10 10 10 9	Alone Slower co-actor Similar co-actor Faster co-actor	90 ms*** 32 ms*** 43 ms*** 54 ms***	XX XX XX XX	Co- action situation without reward	"XXXXX"	Manual

Contd.

Study	Exp.	NP	Presence type	SE classical	SE Associated	Others particularities	Control Condition	Modality of answer
Huguet et al. (2004)	1 (with reward)	8 9 10 9	Alone Slower co-actor Similar co-actor Faster co-actor	81 ms*** 28 ms*** 25 ms*** 64 ms***	XX XX XX XX	Co- action situation with reward of 15 € if good results	"XXXXX"	Manual
Klauer et al. (2008)	1	62	Alone (in first) Simple presence (in first) Alone (in second) Simple presence (in second)	168 ms*** 69 ms*** 53 ms*** 62 ms***	XX XX XX XX	With impression's task	"XXXXX"	Manual
Klauer et al. (2008)			Alone (in first) Simple presence (in first) Alone (in second) Simple presence (in second)	94 ms*** 105 ms*** 63 ms*** 47ms***	XX XX XX XX	Without impression's task	"XXXXX"	Manual
Klauer et al. (2008)	2	80	Alone (in first) Simple presence (in first) Alone (in second) Simple presence (in second)	141ms*** 99 ms*** 54 ms*** 64 ms***	XX XX XX XX	No psychology students	"XXXXX"	Manual
Klauer et al. (2008)			Alone (in first) Simple presence (in first) Alone (in second) Simple presence (in second)	59 ms*** 50 ms*** 43 ms*** 53ms***	XX XX XX XX		Neutral words	Manual

Note. NP: number of participants; SE : Stroop Effect ; ns: not significant; nd: not available : *p<.05; **p<.01 ; ***p<.001

Table 2: Summary of experiments studying the effect of the presence of others on a Stroop task

suggested that semantic access in the classical Stroop effect could be reduced in presence of others.

To verify that this decrease was not simply a question of motivation, Huguet, Dumas, and Monteil (2004) used the same paradigm and, to one group, proposed an extrinsic motivation (a financial compensation) to each person obtaining a good result. No significant difference was found between the group that received the financial compensation and the group that did not. These authors observed a decrease of the Stroop effect in both groups when a co-actor was present.

In 2005, Dumas, Huguet, Monteil and Ayme used the same protocol but with a group with no other person present but simply a comparison of their results on computer with a fictitious co-actor. This study showed a decrease in the Stroop effect only when the co-actor was faster, whether they were physically present in the room or not. This study showed that unfavorable social comparison, more than the presence of others, could be the cause of a reduction of the Stroop effect and temporarily block semantic access of the word.

Conty, Gimmig, Belletier, George and Huguet (2010) showed that the results were influenced more by the feeling of being watched than by the presence of others. In this study, the participant had to perform a Stroop task but a picture with eyes that were either open or closed was positioned above the item. If the eyes were open, they either looked directly at the participant or they looked away. Conty et al. (2010) observed a greater decrease in the Stroop effect when the eyes looked directly at the participant.

To summarize, all these studies tended to show a decrease in the *classical Stroop effect* in the presence of other persons (as co-actor, a simple presence). In addition, recent studies have shown that, more than the presence of another person, it is the meaning we give to this presence which is important. Similar effects were observed without the physical presence of another person but with a simple visual picture or information on the performance of others.

Klauer, Herfordt and Voss (2008) showed a decrease in the Stroop effect when the "presence of others" condition was preceded by the "alone condition". However, this reduction disappeared when the "alone condition" occurred after the "presence of others" condition. In addition, the observed decrease was even stronger when the participant knew that he would have to complete a questionnaire on his impressions at the end of the task, compared with when he did not know. Klauer et al. (2008) found similar results when they did the same study on non-psychology students. More interestingly, the decrease was not seen when the control condition was composed of neutral words instead of simple crosses (XXXX).

Very recently, Augustinova and Ferrand (2012b) conducted two experiments measuring the impact of social presence on the *semantically-based Stroop effect*. The first experiment consisted of a cross-like control condition (XXXX) while the second used neutral words. Both experiments used vocal answers. A decrease in the *classical Stroop effect* was observed with the "simple presence" condition. However, the same was not seen for the *semantically-based Stroop effect*. They concluded that semantic access was an automatic process and that the observed decrease of the classical Stroop effect was better explained by the decrease of the response competition (De Houwer, 2003; Neely & Kahan, 2001).

Conclusion

In conclusion, we can see that in all the previous studies, the *classical Stroop effect* seems to be reduced when there are other people present or when the situation leads to an unfavorable social comparison. These data seem to indicate that semantic access could be temporarily stopped, therefore it cannot be automatic. Several criticisms can be made of these studies. Firstly, Huguet et al. (1999) used color-associated words, but no separate

analysis of these items was reported. Moreover, as we have previously seen, it is this condition which is essential for concluding a decrease of semantic access. This is especially true in the case of Klauer et al. (2008), who showed that when neutral words were used as the control condition, there was no decrease, suggesting that semantics was not the cause of this decline. Likewise, when color-associated words were used, no decrease of semantic access was observed (Augustinova & Ferrand, 2012b).

Suggestion and the Stroop effect (see table 3)

In parallel with the studies cited above, other authors have studied a phenomenon that reduces the Stroop effect: suggestion. Suggestion is the act of leading the participant, with the help of a simple sentence, towards an action that they would not otherwise have tended to perform. This phenomenon is a derivative of hypnosis techniques.

In 2002, Raz et al. decided to study the Stroop effect on participants who were susceptible to hypnosis. In fact, hypnosis does not function on everyone. Only "highly suggestible" people can be hypnotized correctly. Under hypnosis, the participants of Raz et al. were given a sentence which suggested that what they were about to see would not be a word but only an item without significance. *The classical Stroop effect* was eliminated for these participants when compared with those that were not under hypnosis. These results were found when comparing incongruent items with neutral words or congruent items. The reduction of the Stroop effect was not observed with participants who were not susceptible to hypnosis. These results suggested that, when a person was susceptible to hypnosis, he would be able to ignore the meaning of a word (as suggested by the suggestion) and to focus only on the color of the word. This effect would seem to indicate a temporary blocking of semantic access.

Following this study, MacLeod and Sheehan (2003) reported the case of a patient with somnambulism (reputed to be highly susceptible to hypnosis) in whom the *classical Stroop interference* was reduced after having received hypnotic induction and suggestion.

In this context, it was possible that participants susceptible to hypnosis actually blurred their vision in order to perceive only the color of the letter (despite an instruction not to do this). This case was not a cognitive process which was modified by suggestion. Thus, Raz, et al. (2003) undertook the same experiment as before but with one additional condition: cycloplegia (the loss of power in the ciliary muscle of the eye, which results in an absence of visual accommodation) was pharmacologically induced in participants. The study showed that, despite the inability to blur their vision, participants in the post-hypnotic suggestion condition had a reduced *classical Stroop effect*. This result suggested that these participants correctly visualized the words and it was, therefore, the semantic access which was being temporary blocked. The results also showed that participants who were not susceptible to hypnosis, but who were asked to look into the corner of the computer screen and not at the item, had a reduced *classical Stroop effect* in the same way as those who were highly susceptible.

To further explore this phenomenon, Raz, Fan and Posner (2005) subjected their participants to a similar experiment measuring event-related potentials (ERPs) and functional Magnetic Resonance Imaging (fMRI). The objective was to study the activation of the ACC (anterior cingulate cortex) during a hypnotic suggestion. Indeed, the ACC is known to be activated when a conflict is detected (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004 ; Bush, Luu, & Posner, 2000 ; Kerns, Cohen, MacDonald III, Cho, Stenger, & Carter, 2004). The results confirmed the authors' hypothesis, that during hypnotic suggestion, the ACC of participants susceptible to hypnosis is less activated than when the same individuals perform the task without receiving a suggestion. fMRI showed this reduction but also a reduced activation of visual areas. Moreover, the ERPs showed a decrease

Study	Expt.	NP	Sensibility to hypnosis	SE classical with suggestion	SE classical without suggestion	SE associated with suggestion	SE associated without suggestion	Control Condition	Modality of Answer	Under Hypnosis
Augustinova & Ferrand (2012a)	1	28	Sensitive	31 ms**	70 ms**	17 ms**	18 ms**	Neutral words	Vocal	No
Augustinova & Ferrand (2012a)	2	15	Sensitive	114 ms**	146 ms**	22 ms**	18 ms**	Neutral words	Vocal	No
McLeod & Sheehan (2003)	1	1	Sensitive	37 ms -2 ms 111 ms 13 ms	93 ms[1] 102 ms[1]			"XXXX" Congruents	Vocal	No Yes No Yes
Raz et al. (2002)	1	32	Sensitive Not sensitive Sensitive Not sensitive	-2 msns 87 ms*** 5 msns 121 ms***	112 ms*** 79 ms*** 157 ms*** 104 ms***			Neutral words Congruents	Manual	Yes
Raz et al. (2003)	1	12	Sensitive Not sensitive Sensitive Not sensitive	19 msns -12 msns 22 msns 34 mstd(p=.096)	102 ms** 129 ms** 135 ms** 107 ms**	SE blur vision 71 ms* 93 ms* 107 ms* 139 ms*		Neutral words Congruents	Manual	Yes
Raz et al. [2] (2005)	fMRI ERP	8	Sensitive	41 ms* 9 msns	139 ms** 90 ms**			Congruents	Manual	Yes

Contd.

Study	Expt.	NP	Sensibility to hypnosis	SE classical with suggestion	SE classical without suggestion	SE associated with suggestion	SE associated without suggestion	Control Condition	Modality of Answer	Under Hypnosis
Raz et al. (2006)	1	25	Sensitive Sensitive	53 ms*** 77 ms*** 43 ms*** 76 ms***	94 ms*** 132 ms*** 78 ms*** 116 ms***			Neutral words Congruents Neutral words Congruents	Manual	Yes No
Raz et al. (2007)	1	49	Sensitive	6 ms 16 ms***	78 ms*** 118 ms***			Neutral words Congruents	Manual	No
Raz & Campbell[3] (2011)	1	49	Sensitive Not sensitive	7 ms^{ns} 46 ms***	84 ms*** 89 ms***			Neutral words	Manual	No
Raz & Campbell[3] (2011)		49	Sensitive Not sensitive	18 ms** 65 ms***	125 ms*** 109 ms***			Congruents	Manual	No

Note 1. NP: number of participants; SE: Stroop Effect; ns: not significant; nd: not available: $^{*}p<.05$; $^{**}p<.01$; $^{***}p<.001$

Note 2. The study of Goldfarb et al.(2011) reported only p-value and not the size in ms of the Stroop effect. It's why this study doesn't appear in this table.

[1] Averages that we have calculated from the three practice blocks. The fact that this study is on a single participant explains the lack of p values

[2] For this study, only data of participants sensitive to the suggestion in the incongruent condition are reported

[3] The data concerning the "negative priming" are not reported here.

Table 3: Summary of experiments studying the effect of suggestion on a Stroop task

in posterior activation when participants were under hypnotic suggestion, which is an additional indicator of the reduced activation of visual areas. This study showed that hypnotic suggestion was able to influence behavior by influencing brain structures. The fact that the ACC was activated less under hypnotic suggestion seemed to indicate that the conflict had not been detected or treated. Therefore, the color to be named did not create a conflict with the semantics of the word.

All the studies cited above were made on participants with a hypnotic induction. Raz, Kirsch, Pollard and Nitkin-Kanner (2006a) showed that the hypnotic induction, even if it helped further reduce the Stroop effect, was not essential for the reduction of the Stroop effect, as similar results were obtained when a simple suggestion was given to participants who were highly susceptible to hypnosis but without hypnotic induction. Also, in 2007 Raz, Moreno-Iñiguez, Martin and Zhu used a similar experiment (without hypnosis) on 49 participants who were highly susceptible to hypnosis. The authors again noticed a decrease in the Stroop effect. In other words, a simple suggestion without hypnotic induction could decrease the *classical Stroop effect* for participants highly susceptible to hypnosis.

The same results were observed more recently by Raz and Campbell (2011). In their study, they observed a reduction on the *classical Stroop effect* for participants highly susceptible to hypnosis when they received a hypnotic suggestion, compared with when they did not. However, observation of negative priming by these authors conduced them to conclude that suggestion appeared to have an influence on both the participants susceptible to hypnosis and those who were not. This influence appeared greater in the participants susceptible to hypnosis, because the effect of suggestion is also visible on the *classical Stroop effect.*

Furthermore, Rubichi, Ricci, Padovani and Scaglietti (2005) hypothesized that participants with a high level of susceptibility to hypnosis also have, in normal conditions, a higher level of attention. This would explain why the hypnotic suggestions have more influence on them. In their study, they compared the results to a Stroop task under normal conditions (without suggestion). They found that those with a high level of susceptibility to hypnosis had less Stroop interference than those with a low susceptibility to hypnosis. This latest study suggested that these participants were more attentive to the task, and therefore more efficient in normal conditions, without hypnotic suggestion.

Regarding the particularity of the participants who were highly susceptibility to hypnosis, Casiglia et al. (2010) observed that not only did the Stroop effect decrease during hypnotic suggestion, but so did the hemodynamic response. The hemodynamic response is a cardiology response of the circulatory system to stimuli seen as stressor. This latter measure allowed the authors to determine that the participants not susceptible to hypnosis perceived the Stroop task as a stressor, while this was no longer the case for the individuals who were highly susceptible to hypnosis during the hypnotic induction. In a stress state, the dominant response is more salient. In this case, reading the word.

Recently, Goldfarb, Aisenberg and Henik (2011) used social priming in a Stroop task to observe the effect of a suggestion on the Stroop effect in a series of three experiments. They observed a diminution of the *classical Stroop effect* when participants have a questionnaire which activates the "dyslectic" concept, to complete before the task (experiment 1). Dyslectics are known to have reading problems. This activation, which can be seen as a suggestion, triggers this concept and its subsequent effect on behavior (Bargh, 1989, 1992). This effect is very specific, because the authors did not observe a diminution on a subsequent Stroop task when the questionnaire was about dyscalculia (Experiment 2) or painter (Experiment 3). This effect is preserved with a congruent condition or neutral word as control condition.

In summary, recent studies have shown that the Stroop effect can be modulated according to the instructions given and the susceptibility or not to this suggestion. The reduction of the Stroop effect in these studies seems to indicate the possibility of temporarily blocking semantic access, but no purely semantic measures have been studied. As we saw previously, it is primarily the color-associated word Stroop condition which is indicative of a semantic conflict, yet this condition was absent in these studies.

Augustinova and Ferrand (2012a) measured the impact of suggestion on the *semantically-based Stroop effect.* In their two experiments, the same suggestion given by Raz et al. (2002) was used on participants susceptible to hypnosis before they undertook a Stroop task (but without a hypnotic induction). The results showed a decrease in the *classical Stroop effect* when these participants received the suggestion compared with when they did not. But no decrease was observed in the *semantically-based Stroop interference.*

In conclusion, a decrease in the semantic access in a Stroop task was not observed when semantic access was correctly measured. This result seemed to suggest that the decrease in the Stroop effect was more an attentional effect than an effect on semantic access in hypnosis or in the suggestion condition. Indeed, Casiglia et al. (2010) and Rubichi et al. (2005) showed that it was the attentional capacity of the individual that was important and not the hypnotic condition. Consequently, participants who were not susceptible to hypnosis seemed more stressed by the task and had fewer attentional resources.

Finally, it is undeniable that hypnosis, especially suggestion, may have an impact on our perceptions and feelings but it does not necessarily affect semantic access.

General Conclusions

As we have seen, in recent years three new manipulations of the Stroop task have shown a reduction of the Stroop effect: coloring a letter differently from the others (Besner et al., 1997; and others), the presence of other people (Huguet et al., 1999; and others), and suggestion (Raz et al., 2002; and others). These three paradigms have jointly been able to decrease a robust effect that, since 1935, has led to the belief that reading and semantic access of a word might be automatic. The results of their experiments clearly show that a reduction and even an elimination of the Stroop effect is possible under certain conditions. Nevertheless, is it probably premature to talk about semantic blocking.

An essential prerequisite for the study of semantics in a Stroop task is the *color-associated word* condition that, as we have seen (Neely & Kahan, 2001), is a purer measure of semantics. When this condition was added, no decrease of the *semantically-based Stroop effect* was observed (Augustinova et al., 2010, Augustinova & Ferrand, 2007, 2012a, 2012b). The results favored an automatic semantic access. In addition, we have seen throughout this review that authors often confuse a lack of statistical effect with the disappearance of a behavioral effect.

In agreement with this latter point, Heil, Rolke and Pecchinenda (2004) explained that, in an analysis of behavioral measures, a lack of an effect in the RT remains problematic. Thus, one might think that this measure is not sensitive enough to detect the presence of a specific effect. The measurement of the RT does, in fact, include several processes. In the case of the Stroop task, we can have: a perceptual process that allows the viewing of the item, the various processes of reading which have been previously mentioned (the level of the letters, the lexical and the semantic level), and a process that gives the responses (including the analysis of possible responses, the preparation of a movement, and finally the movement itself). It is therefore difficult to know what exactly was measured by the RT and what processes were affected by any manipulation. Consequently, we cannot really know if we are measuring semantic access, a phenomenon that is

linked to vision, or the preparation of the answer. Heil et al. (2004) proposed the use of evoked potentials as a measurement of semantics, and more precisely the N400, which seems to indicate semantic access.

Another problem with the studies previously cited is about the definition of automaticity. For this review, we used the standard definition used in cited studies: a process is said to be automatic if it appears without intention and without attentional resources. This view is a binary view. A process is either automatic or not. But recent studies on automaticity adopted a continuum view (Moors & De Houwer, 2006). In this perspective, a process is seen as more automatic the less attention is need. This explanation is well illustrated by the model of Cohen, Dunbar and McClelland (1990) and the learning process used to explain the Stroop task. In this connectionist model, automatic process is learned with an enhancement of the link between process and answer. The more the system learns a link, the more the task is done quickly and the less attention is needed. This is not a binary view.

The difficulty of attaining a clear consensus about semantic access could be due to this lack of definition. Using a continuum perspective, semantic access could probably be considered as automatic in the sense that only particularly special circumstances could question this access. Vachon and Jolicoeur (2011), for example, used a complex "task-switching" paradigm where a participant has to change his cognitive treatment during a continuum flux of items that showed delayed semantic access.

Finally, and despite several studies showing undeniable fluctuations of the Stroop effect, drawing conclusions with regards to semantic access seems to be a bit hasty. Future studies using color-associated words and the N400 should improve our understanding of this phenomenon and explore in greater detail the attentional processes present in the three manipulations. This should help to explain the observed decrease of the *classical Stroop effect*. Moreover, a continuum perspective of automaticity could be envisaged to explain better these different results.

Conflicts of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this paper

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References

Augustinova, M., & **Ferrand, L.** (2007). Influence de la dénomination de la couleur de la première lettre dans l'effet Stroop [First-letter coloring and the Stroop effect]. *L'Année Psychologique, 107(2),* 163–179. DOI: http://dx.doi.org/10.4074/S0003503307002011

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

Augustinova, M. & **Ferrand, L**. (2012b). The influence of mere social presence on Stroop interference: New evidence from the semantically-based Stroop task. *Journal of Experimental Social Psychology, 48,* 1213–1216. DOI: http://dx.doi.org/10.1016/j.jesp.2012.04.014

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: http://dx.doi.org/10.3758/PBR.17.6.827

Bargh, J. A. (1989). Conditional automaticity: Varieties of automatic influence in social perception and cognition. In J.S.

Uleman & J. A. Barghl (Eds.), *Unintended thought* (pp. 3–51). New York, NY: Guilford Press.

Bargh, J. A. (1992). The ecology of automaticity: Towards establishing the conditions needed to produce automatic processing effect. *American Journal of Psychology, 105*, 181–199. DOI: http://dx.doi.org/10.2307/1423027

Bargh, J. A. (1994). The four horsemen of automaticity: Awareness, intention, efficiency, and control in social cognition. In R. S.Wyer Jr. & T. K. Srull (Eds.), *Handbook of social cognition* (2nd ed., pp. 1–40). Hillsdale, NJ: Erlbaum.

Besner, D. (2001). The myth of ballistic processing: evidence from Stroop's paradigm. *Psychonomic Bulletin & Review, 8(2),* 324–330. DOI: http://dx.doi.org/10.3758/BF03196168

Besner, D., & **Stolz, J. A.** (1999a). Unconsciously controlled processing: the Stroop effect reconsidered. *Psychonomic Bulletin & Review, 6(3),* 440–455. DOI: http://dx.doi.org/10.3758/BF03210834

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

Besner, D., & **Stolz, J. A.** (2001). The Stroop effect and single letter coloring : what replicates and what doesn't? *Psychonomic Bulletin & Review, 8(4)*, 858. DOI: http://dx.doi.org/10.3758/BF03196229

Besner, D., Stolz, J. A., & **Boutilier, C.** (1997). The Stroop effect and the myth of automaticity. *Psychonomic Bulletin & Review, 4(2)*, 221–225. DOI: http://dx.doi.org/10.3758/BF03209396

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & **Cohen, J. D.** (2001). Conflict monitoring and cognitive control. *Psychological Review, 108(3),* 624–652. DOI: http://dx.doi.org/10.1037/0033-295X.108.3.624

Botvinick, M. M., Cohen, J. D., & **Carter, C. S.** (2004). Conflict monitoring and anterior cingulate cortex: an update. *Trends in Cognitive Sciences, 8(12)*, 539–546. DOI: http://dx.doi.org/10.1016/j.tics.2004.10.003

Brown, T. L., Joneleit, K., Robinson, C. S., & **Brown, C. R.** (2002). Automaticity in reading and the Stroop task: Testing the limits of involuntary word processing. *American Journal of Psychology, 115,* 515–543. DOI: http://dx.doi.org/10.2307/1423526

Bush, G., Luu, P. & **Posner, M. I.** (2000). Cognitive and emotional influences in anterior cingulate cortex: *Trends Cognitive Science, 4,* 215–222. DOI: http://dx.doi.org/10.1016/S1364-6613(00)01483-2

Casiglia, E., Schiff, S., Facco, E., Gabbana, A., Tikhonoff, V., Schiavon, L., et al. (2010). Neurophysiological correlates of post-hypnotic alexia: A controlled study with Stroop test. *American Journal of Clinical Hypnosis, 52(3)*, 219–233. DOI: http://dx.doi.org/10.1080/00029157.2010.10401721

Catena, A., Fuentes, L. J., & **Tudela, P.** (2002). Priming and interference effects can be dissociated in the Stroop task: New evidence in favor of the automaticity of word recognition. *Psychonomic Bulletin & Review, 9,* 113–118. DOI: http://dx.doi.org/10.3758/BF03196265

Cohen, J. D., Dunbar, K., & **McClelland, J. L.** (1990). On the control of automatic processes: a parallel distributed processing account of the Stroop effect. *Psychological Review, 97(3),* 332–361. DOI: http://dx.doi.org/10.1037/0033-295X.97.3.332

Conty, L., Gimmig, D., Belletier, C., George, N., & **Huguet, P.** (2010). The cost of being watched : Stroop interference increases under concomitant eye contact. *Cognition, 115,* 133–139. DOI: http://dx.doi.org/10.1016/j.cognition.2009.12.005

Danziger, S., Estevez, A. F., & **Mari-Beffa, P.** (2002). Stroop Interference effects in partially colored Stroop words. *Psychonomic Bulletin and Review, 9(3),* 536–541. DOI: http://dx.doi.org/10.3758/BF03196310

Dalrymple-Alford, E. C. (1972). Associative facilitation and interference in the Stroop

color-word task. *Perception and Psychophysics, 11*, 274–276. DOI: http://dx.doi.org/10.3758/BF03210377

De Houwer, J. (2003). On the role of stimulus-response and stimulus-stimulus compatibility in the Stroop effect. *Memory & Cognition, 31*, 353–359. DOI: http://dx.doi.org/10.3758/BF03194393

Dumas, F., Huguet, P., Monteil, J. M., & **Ayme, E.** (2005). Context effects in the Stroop task: Knowledge of one's relative standing makes a difference. *Current Psychology Letters: Cognition, Brain, and Behavior, 16*, 1–12.

Eriksen, B. A., & **Eriksen, C. W.** (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16(1),* 143–149. DOI: http://dx.doi.org/10.3758/BF03203267

Goldfarb, L., Aisenberg, D., & **Henik, A.** (2011). Think the thought, walk the walk – Social priming reduces the Stroop effect. *Cognition, 118*, 193–200. DOI: http://dx.doi.org/10.1016/j.cognition.2010.11.004

Heil, M., Rolke, B., & **Pecchinenda, A.** (2004). Automatic semantic activation is no myth. *Psychological Science, 15*, 852–857. DOI: http://dx.doi.org/10.1111/j.0956-7976.2004.00766.x

Huguet, P., Dumas, F., & **Monteil, J. M.** (2004). Competiting for a desired reward in the Stroop task : when attentional control is unconscious but effective versus conscious but ineffective. *Canadian Journal of Experimental Psychology, 58(3)*, 153–167. DOI: http://dx.doi.org/10.1037/h0087441

Huguet, P., Galvaing, M. P., Monteil, J. M., & **Dumas, F.** (1999). Social presence effects in the Stroop tasks: Further evidence for an attentional view of social facilitation. *Jounal of Personality and Social Psychology, 77(5),* 1011–1025. DOI: http://dx.doi.org/10.1037/0022-3514.77.5.1011

Kahneman, D., & **Henik, A.** (1981). Perceptual organisation and attention. In M. Kubovy & J.R. Pomerantz (Eds.), *Perceptual organization* (*pp.* 181–211). Hillsdale, NJ: Erlbaum.

Kerns, J. G., Cohen, J. D., MacDonald III, A. W., Cho, R. Y., Stenger, V. A. & **Carter, C. S.** (2004). Anterior cingulate conflict monitoring and adjustments in control. *Science, 303*, 1023–1026. DOI: http://dx.doi.org/10.1126/science.1089910

Klauer, K. C., Herfordt, J., & **Voss, A.** (2008). Social presence effects on the Stroop task: Boundary conditions and an alternative account. *Journal of Experimental Social Psychology, 44*, 469–476. DOI: http://dx.doi.org/10.1016/j.jesp.2007.02.009

Klein, G. S. (1964). Semantic power measured through the interference of words with colors-naming. *American Journal of Psychology, 77*, 576–588. DOI: http://dx.doi.org/10.2307/1420768

Küper, K., & **Heil, M.** (2012). Attentional focus manipulations affect naming latencies of neutral but not of incongruent Stroop trials. *Swiss Journal of Psychology, 71(2),* 93–100. DOI: http://dx.doi.org/10.1024/1421-0185/a000075

Kutas, M., & **Hillyard, S. A.** (1980). Reading senseless sentences: brain potentials reflect semantic incongruity. *Science, 207*, 203–205. DOI: http://dx.doi.org/10.1126/science.7350657

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109*, 163–203. DOI: http://dx.doi.org/10.1037/0033-2909.109.2.163

MacLeod, C. M., & **Sheehan, P. W.** (2003). Hypnotic control of attention in the Stroop task: a historical footnote. *Consciousness and Cognition, 12,* 347–353. DOI: http://dx.doi.org/10.1016/S1053-8100(03)00025-4

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(3),* 458–462. DOI: http://dx.doi.org/10.3758/BF03196595

Marmurek, H. H. C. (2003). Coloring only a single letter does not eliminate color-

word interference in a vocal-response Stroop task: Automaticity revealed. *Journal of General Psychology, 130*, 207–224. DOI: http://dx.doi.org/10.1080/00221300309601285

Marmurek, H. H. C., Proctor, C., & **Javor, A.** (2006). Stroop-like serial position effects in color naming of words and nonwords. *Experimental Psychology, 53(2),* 105–110. DOI: http://dx.doi.org/10.1027/1618-3169.53.2.105

Mayr, S., & **Buchner, A.** (2007). Negative priming as a memory phenomenon: A review of 20 years of negative priming research. *Journal of Psychology, 215(1),* 35–51.

McClelland, J. L. (1987). The case of interactionism in language processing. In M. Coltheart (Ed.), *Attention and Performance XII: The psychology of reading*. London: Erlbaum.

Monahan, J. S. (2001). Coloring single Stroop elements: Reducing automaticity or slowing color processing ? *Journal of General Psychology, 128*, 98–112. DOI: http://dx.doi.org/10.1080/00221300109598901

Moors, A., & **De Houwer, J.** (2006). Automaticity: A conceptual and theoretical analysis. *Psychological Bulletin, 132*, 297–326. DOI: http://dx.doi.org/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.

O'Regan, J. K., Levy-Schoen, A., Pynte, J., & **Brugaillere, B.** (1984). Convenient fixation location within isolated words of different length and structure. *Journal of Experimental Psychology-Human Perception and Performance, 10,* 250–257. DOI: http://dx.doi.org/10.1037/0096-1523.10.2.250

Parris, B. A., Sharma, D., & **Weekes, B.** (2007). An optimal viewing position effect in the stroop task when only one letter is the color carrier. *Experimental Psychology, 54(4)*, 273–280. DOI: http://dx.doi.org/10.1027/1618-3169.54.4.273

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. 55–83). Hillsdale, NJ: Erlbaum.

Raz, A., & **Campbell, N. K. J.** (2011). Can suggestion obviate reading ? Supplementing primary Stroop evidence with exploratory negative priming analyses. *Consciousness and Cognition, 20,* 312–320. DOI: http://dx.doi.org/10.1016/j.concog.2009.09.013

Raz, A., Fan, J., & **Posner, M. I.** (2005). Hypnotic suggestion reduces conflict in the human brain. *Proceedings of the National Academy of Sciences, 102,* 9978-9983. DOI: http://dx.doi.org/10.1073/pnas.0503064102

Raz, A., Kirsch I., Pollard J., & **Nitkin-Kanner Y.** (2006). Suggestion Reduces the Stroop Effect. *Psychological Science, 17,* 91–95. DOI: http://dx.doi.org/10.1111/j.1467-9280.2006.01669.x

Raz, A., Landzberg, K. S., Schweizer, H. R., Zephrani, Z. R., Shapiro, T., Fan, J., & **Posner, I.** (2003). Posthypnotic suggestion and the modulation of Stroop interference under cyclopegia. *Consciousness and Cognition, 12,* 332–346. DOI: http://dx.doi.org/10.1016/S1053-8100(03)00024-2

Raz, A., Moreno-Íñiguez, M., Martin, L. & **Zhu, H.** (2007). Suggestion overrides the Stroop effect in highly susceptible individuals. *Consciousness and Cognition, 16*, 331–338. DOI: http://dx.doi.org/10.1016/j.concog.2006.04.004

Raz, A., Shapiro, T., Fan, J., & **Posner, M. I.** (2002). Hypnotic suggestion and the modulation of Stroop interference. *Archives of General Psychiatry, 59,* 1155–1161. DOI: http://dx.doi.org/10.1001/archpsyc.59.12.1155

Rubichi, S., Ricci, F., Padovani, R. & **Scaglietti, L.** (2005). Hypnotic susceptibility, baseline attentional functioning, and

the Stroop task. *Consciousness and Cognition, 14,* 296–303. DOI: http://dx.doi.org/10.1016/j.concog.2004.08.003

Sharma, D., & **McKenna, F. P.** (1998). Differential components of the manual and vocal Stroop tasks. *Memory and Cognition, 26*, 1033–1040. DOI: http://dx.doi.org/10.3758/BF03201181

Smith, M. C., Theodor, L., & **Franklin, P. E.** (1983). On the relationship between contextual facilitation and depth of processing. *Journal of Experimental Psychology: Learning. Memory & Cognition, 9,* 697–712. DOI: http://dx.doi.org/10.1037/0278-7393.9.4.697

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643–662. DOI: http://dx.doi.org/10.1037/h0054651

Vachon, F., & **Jolicœur, P.** (2011). Impaired semantic processing during task-set switching: Evidence from the N400 in rapid serial visual presentation. *Psychophysiology, 48(1),* 102–111. DOI: http://dx.doi.org/10.1111/j.1469-8986.2010.01040.x

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