Competing for a Desired Reward in the Stroop Task:
When Attentional Control is Unconscious but Effective
Versus Conscious but Ineffective

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Abstract Recent studies using Stroop's paradigm have shown that word recognition processes can be controlled when the local context of the task is manipulated. In the present study, factors related to the participants' broader context (i.e., presence vs. absence of a competitor and of a desired reward) were manipulated. The results (1) support the conclusion that control of semantic-level activation can be unconscious but effective versus conscious but ineffective, (2) suggest that unconscious control alone operates on line (i.e., when the participant is responding), and (3) clarify the impact of socio-contextual factors that have been confounded in past research. Taken together, these findings strengthen the view that word recognition processes are controllable and offer new reasons to pay constant attention to the social environment of cognition.

In the standard Stroop task, individuals are required to identify the colour of the ink in which words and control signs are printed. Typically, the time needed to identify the colour of incongruent words (e.g., the word RED printed in green) is greater than the time needed to name the colour of control signs (e.g., XXX printed in green). This robust effect is called Stroop interference (see MacLeod, 1991, for a review). A core assumption of virtually all theoretical accounts of this interference is that skilled readers process the incongruent word without conscious intent. The reading of the word is said to be automatic in the sense that readers cannot refrain from accessing the meaning of the word despite explicit instructions not to do so. As Reisberg (1997) put it, “The automatization of word recognition allows much quicker reading… but also leaves us vulnerable to the Stroop effect… knowing about this effect is not protection – the processes are not open to control” (p. 603).

There is a large body of evidence, however, suggesting that few processes, if any, are entirely independent of attentional control (e.g., Logan, 1980). Many of the relevant findings have come from the Stroop paradigm (e.g., Algom, Dekel, & Pansky, 1990; Besner, 2001; Besner & Stolz, 1995a, 1995b; Besner, Stolz, & Boutilier, 1997; Kehneman & Chajczyk, 1983; Logan, 1980; Logan & Zbrodoff, 1979; Stolz & Basner, 1995; Tzelgov, Henik, & Berger, 1992). Besner et al. (1995a), for example, used a modification of the Stroop task in which only a single letter of the incongruent words was coloured. Stroop interference was either reduced or eliminated in this condition, suggesting that spatial attention was focused, thus preventing lexical-semantic activation (at least temporarily). Besner and Stolz (1995b) also found that the precuing (with a small arrow) of a single letter position (with all letters of irrelevant words coloured) can serve to focus spatial attention more narrowly, so that subsequent word-recognition processes operate less efficiently or not at all, as indicated by a reduction or elimination of the Stroop effect (see also Besner, 2001, for a combination of such manipulations). In these studies, all participants were explicitly asked to ignore the words. The fact that the Stroop effect still occurred when intact Stroop stimuli were used and disappeared with modified stimuli leads to the conclusion that word processing was controlled without conscious intent (to control) (see Besner & Stolz, 1995b; Stolz & Besner, 1999).

Further evidence that attention can be diverted from the semantic level is found in Stolz and Besner’s (1996) study using the semantic priming paradigm. Semantic priming was reduced or eliminated by a letter-search task that affected the distribution of attention during prime word processing (see also Stolz & Besner, 1996, 1997). Taken together, these findings suggest that processing words at the lexical-semantic level, although typically unintentional, is the default set rather than automatic in the sense of being inevitable. This conclusion is problematic for the classic or decontextualized “automatic” processing account of the Stroop effect that has prevailed in the Stroop literature for the last six decades. Furthermore, it runs
counter to a very influential idea in cognitive psychology whereby control of mental processes is associated with consciousness and lack of control with unconsciousness. As suggested by Besner and Stolz (1999a), it seems that conscious intent (to control) need not imply effective control, and effective control need not imply conscious intent to control.

In line with this, it is assumed here that word processing at the lexical-semantic level is the default set, which can be disabled and/or overridden by contextural factors. The factors examined in the present study are not related to the local context of the task but to the social context in which cognition always takes place. Can this broader context also divert attention from the semantic level in the Stroop task? We start with a brief description of previous studies (e.g., MacKinnon, Geiselman, & Woodward, 1985) where a reduction of the Stroop effect was associated with relatively simple socio-contextual manipulations (e.g., competing for a desired reward vs. no competition). Then we report a new experiment. The results of this experiment support the conclusion that control of semantic level activation can be unconscious but effective as well as conscious but ineffective, suggesting that unconscious control alone operates on-line (i.e., when the participant is responding). They also clarify the impact of social factors that have been confounded in the past.

Social Context and Stroop Effect

MacKinnon et al. (1985) used the standard vocal version of the Stroop task and tested the influence of effort on the Stroop effect. Participants were tested either individually or in pairs. In the latter condition (competition), they were told that the fastest one on the task would receive one extra credit, which was a very valued reward in this context. A coin was flipped to determine which participant would do the Stroop session first. While one participated in this session, the other waited outside until it was his/her turn. As expected by the authors, competing for a reward increased self-reports of effort and the Stroop effect was indeed 25% smaller in this condition, compared with the individual or no-competition condition. In their second study, the reduced Stroop effect was associated with a significant decrease in recognition memory for the Stroop words, suggesting that increased effort in the competition-reward condition did cause attention to focus more exclusively on the letter colour cues, at the expense of word meaning. These findings offered preliminary evidence that relatively simple socio-contextual factors can prevent lexical-semantic activation in the Stroop task. MacKinnon et al.’s studies had several limitations, however.

First of all, the Stroop stimuli were not isolated but presented all together on cards (different cards were used for the incongruent words and for the control signs). As Knips and Glickman (1962) noted, this group version of the Stroop task is not very accurate for measuring response speed. Most researchers currently interested in Stroop interference use a more analytic methodology where individual stimuli can be presented and timed (see MacLeod, 1991). Second, the Stroop difference score combined interference from incongruent colour words (e.g., RED, GREEN) and incongruent colour-related words (e.g., SKY, BLOOD). The question that arises is whether the impact of the competition-reward manipulation was on the classic component of Stroop interference, namely, on the incongruent colour words, and/or on words that were not colour words but colour-related words. Because of their use of a group version of the Stroop task, MacKinnon et al. (1985) could not isolate these two components of the Stroop effect. Third, there is an alternative explanation for the recognition findings: Participants in the competition-reward condition performed poorly on the recognition memory task because they had a shorter exposure time to the incongruent words. This explanation would be not acceptable if the Stroop stimuli had been isolated and if their duration had been fixed across trials. Fourth, because the presence of a competitor and the possibility of being rewarded were confounded, it is still unclear which factors account for the results. In a more recent study (Huguet, Galvaing, Monteil, & Dumas, 1999, Study 2), participants performed a manual version of the Stroop task in the presence (supposedly incidental) versus absence of a confederate-coactor (i.e., a peer working simultaneously but independently on an identical task). The reduced Stroop effect was associated with coaction, suggesting that the mere presence of a competitor is a sufficient condition for MacKinnon et al.’s findings to occur. Finally, and more generally, these authors concluded that participants can reduce Stroop interference when their effort is focused in that direction. It is well-known, however, that a skilled reader’s intent to not read the colour words is not enough to prevent lexical-semantic activation in the Stroop task. Exactly how, then, can MacKinnon et al.’s findings be explained?

A reasonable account is that competition and the possibility of being rewarded had not the same influence. Whereas competition may have led to unconscious but effective control, the presence of a desired reward may have led to conscious but ineffective control. Once more, there is evidence of unconsciously controlled processing brought about by contextual manipulations in Stroop’s paradigm (see Besner, 2001,
ATTENTION AND STROOP EFFECT

Besner & Stolz, 1999a, 1999b; Stolz & Besner, 1999). In MacKinnon et al.'s (1985) studies, changes in the allocation of attention during the processing of the Stroop words may have been due to ruminations about anticipated interactions with the competitor (during which a social comparison would take place) and/or about the level of performance needed to win. This could divert attention, at least temporarily, from the semantic level (i.e., it could preclude the spread of activation to this level), resulting in a smaller Stroop effect. Such a phenomenon probably also occurred in our study (Huguet et al., 1999), in which participants were forced to compare their response speed throughout the Stroop session with that of a slower, similar, or faster confederate (who made particularly loud keypresses that could not be easily ignored). Those working in coaction were indeed accurate in their ratings of relative performance speed (i.e., how quickly they performed relative to the person present), suggesting that they allocated some attention to the confederate during Stroop word processing. According to Baron (1986), attending to a person present in order to gain information about one's relative standing may also serve to focus spatial attention more narrowly, in such a way that subsequent word recognition processes operate less efficiently or not at all. Consistent with this, there is ample evidence that one immediate consequence of an overloaded attentional system is the selective narrowing of attention to a small number of central stimuli (Cohen, 1978), especially when the participant is working in the real or implied presence of others (for reviews see Baron, 1986; Geen, 1991; Huguet, Galvaing, Dumas, & Monteil, 2000). In MacKinnon et al.'s studies, then, the reduction of the Stroop effect was not necessarily associated with a conscious effort in view of obtaining a reward. This reduction could also be taken as evidence of unconsciously controlled processing resulting from competitive pressure.

The Present Study

The presence versus absence of a competitor and of a desired reward were manipulated orthogonally. Participants performed the Stroop task (where individual stimuli could be presented and timed) either alone or in the presence of a slightly slower, similar, or slightly faster competitor. Whereas a desirable reward was present for half of them, it was not for the other half. At the end of the Stroop session, all rated their level of effort on the Stroop task and performed an unexpected recognition task of the Stroop words. Based on our account of MacKinnon et al.'s (1985) findings, competition should facilitate Stroop performance but should have no effect on self-reports of task-specific effort (unconscious but effective control).

The prospect of a desirable reward should increase self-reports of effort but should have no impact on the size of the Stroop effect (conscious but ineffective control). This pattern of results would provide further evidence of unconsciously controlled processing via contextual manipulations in Stroop's paradigm. It would also help clarify MacKinnon et al.'s findings as well as our own (Huguet et al., 1999). Once more, participants in our previous study did not explicitly compete for a desired reward. They were forced to compare their performance speed with that of the person present, and this was enough to reduce the Stroop effect. However, this reduction could not be taken as direct evidence of unconsciously controlled processing via competitive pressure. Direct evidence would be a reduction of the Stroop effect under such pressure while conscious control due to the possibility of being rewarded is ineffective. Jumping ahead, this is exactly what happened.

Method

Participants

Eighty female undergraduates volunteered to participate in partial fulfillment of a course requirement. Only females were included because of the low number of males at the time of the experiment. The participants' sex had no effect in MacKinnon et al.'s (1985) studies. It had no effect in our previous research either. All participants were right-handed, reported normal or corrected-to-normal vision, and were naive about the purpose of the experiment, presented as part of a larger research project on colour perception.

Procedure and Materials

Preliminary phase. The participants arrived individually at the laboratory and were met by a female experimenter who described the Stroop task. Then they performed five training sessions of 20 trials each including only colour-neutral words (e.g., CHAIR). They were asked to ignore the words and respond to the ink colours as quickly and as accurately as possible. On each trial, a word was presented at a fixation point in the centre of a light grey computer screen (viewing distance = 60 cm), in one of four colours (blue, green, red, or yellow). Each word was removed from the computer screen after 200 ms. Stimulus duration was long enough for the words to be read and/or the colour to be recognized. It was also short enough for each word to be off the screen before the computer key was pressed. The keys K (for BLUE), F (for GREEN), S (for RED), and M (for YELLOW) were used as correct responses (ASCII codes 109, 115, 107, and 102, respectively). They were covered by blue, green, red, and yellow adhesive labels, respectively. Participants posi-
tioned their index and middle fingers of their left and right hands on top of each of the keys. Half of them received the red and green labels on the left hand and the blue and yellow labels on the right hand, whereas for the other half the order was reversed. Participants’ mean RT (752 ms) and error percentage (1.5) at the end of session four showed that they had no difficulty learning the response keys correctly. During the fifth training session, the four coloured labels were replaced with white labels so participants knew that looking at the response keys was now useless. They were again asked to ignore the words and respond to the ink colours as quickly and as accurately as possible.

**Competition manipulation.** Participants who worked in competition performed the last training session in the presence of a same-sex (peer) confederate. Her presence was supposedly incidental because of technical problems in the adjacent room. The confederate sat at another computer opposite the participants, within their peripheral vision. As in MacKinon et al.’s (1985) studies, participants were explicitly encouraged to compete with the person present. Competition, it was said, “is an excellent way to work as hard as possible on this task.” The participants knew that the competitor had the same amount of practice as themselves on the task (the confederate publicly informed the experimenter that she had performed four training sessions before the computer crashed in the adjacent room). This information was needed because social comparison, a crucial component of competition, does not necessarily occur when the competitors differ on attributes related to the task at hand (Goethals & Darley, 1977; Wood, 1996). After answering any questions, the experimenter gave the speed-accuracy instructions again and then the starting signal.

Throughout the last training session, participants were forced to compare their response speed with that of the confederate who made particularly loud keypresses that could not be easily ignored. The confederate also responded either slightly more slowly, similarly, or slightly faster than the participants. This difference in performance speed was made possible by varying the confederate’s stimulus duration, depending on the competition condition. In each condition, each word was removed from the participants’ computer screen after 200 ms; for the confederate, word removal occurred at 350 ms in the slower competitor condition, at 200 ms in the similar competitor condition, and at only 50 ms in the faster competitor condition. Because the confederate always responded as quickly as possible to each stimulus item regardless of response accuracy, this simple technical modification produced interindividual performance-speed differences (participants-confederate) that were compatible with the competition manipulation and were approximately the same across participants in each competition condition. As in most coaction settings where individuals are working independently and simultaneously on identical tasks, the participants could readily attribute the difference in performance speed to a difference in ability. Not only did they know that they did not differ from the competitor regarding the amount of previous training, but at the end of the last training session, they were informed by the experimenter that their error rate and that of the confederate was identical. This told them that they did not differ in accuracy from the competitor. Thus, participants working in competition during the last training session were forced to compare themselves with the confederate, and those faced with a slower or faster competitor could readily attribute the difference in performance speed to a difference in ability.

Then the Stroop task was performed and the confederate behaved as in the last training session (e.g., worked either more slowly, similarly, or faster than the participants).

Participants working alone were simply encouraged to work as hard as possible both during training and during the Stroop session. The speed-accuracy instructions were also emphasized.

The experimenter left the room in both conditions (alone and competition) on all sessions (training and Stroop).

After the Stroop task, each participant alone in the room had exactly five minutes to complete a short questionnaire (see below) including items selected to check the manipulations. Then (still alone) they had to recognize the 20 words used previously in the Stroop task (see the section on Stroop and recognition tasks).

**Reward manipulation.** After the fifth and last training session, one half of the participants working in competition were told that the winner of the Stroop task would receive 15 euros (approximately US $17), which was a highly valued reward for these students. The other half did not receive this information. Likewise, one half of the participants working alone were told that, depending on their Stroop performance, they would or would not receive 15 euros. The reward was systematically presented as an encouragement to work as hard as possible on the Stroop task. This encouragement was said to be a means for the laboratory of making sure that participants in the various experiments were really motivated to participate.

**Stroop and recognition tasks.** The Stroop words (see
Appendix A) were taken from MacKinnon et al. (1985). They included 4 colour words (BLUE, GREEN, RED, and YELLOW) that were part of the response set, 4 colour words that were not part of the response set (e.g., ORANGE, GREY), and 12 colour-related words (e.g., SKY, CANARY). Each word was generated in one of the four target colours, excluding congruent colours. Colour-related words were needed for the recognition task, which could not be run on the basis of only eight colour words. Control stimuli appeared as a row of three, four, five, or six coloured Xs. Each stimulus was generated twice by the computer, resulting in 80 test trials (40 incongruent words and 40 control signs). As in the training sessions, each stimulus was removed from the computer screen after 200 ms. Stroop interference was measured by subtracting RTs for control signs (row of Xs) from RTs for incongruent words, which is the usual way of measuring it (see Dyer, 1973; Kuhl & Kazen, 1999; MacLeod, 1994). The use of congruent trials (e.g., the word RED printed in red) has also been recommended as the neutral baseline (Dalrymple-Alford & Budayr, 1966; Lindsay & Jacoby, 1994). A drawback of this procedure, however, is that the inclusion of congruent trials provides an incentive for participants to process irrelevant words. Consistent with this, increasing the proportion of congruent trials serves to increase the magnitude of the Stroop effect (e.g., Lowe & Mitterer, 1982). Likewise, in Besner's (2001) studies, the joint influence of consistent spatial cuing and single-letter colouring eliminated the Stroop effect but only when a low congruent-incongruent trial ratio (20 out of 80) was used. As noted by Besner (2001), it seems unlikely that a neutral baseline exists that would satisfy everyone. The long-standing debate about which baseline is appropriate is not restricted to the Stroop literature, and is unlikely to be resolved in the foreseeable future (e.g., Lindsay & Jacoby, 1994; MacLeod, 1991, Neely & Kahan, 2001). MacKinnon et al. (1985) used control signs (series of + signs), and this also influenced our decision to retain this baseline. In contrast, making use of a vocal Stroop task, as MacKinnon et al. did, was not appropriate in the present study (where the participants' and confederate's oral responses could interfere with each other at each trial). There is evidence that the semantic level is also activated when participants use the manual word response. In two studies that have compared vocal and manual responses in the same experiment (McClain, 1983; Reddings & Gerjets, 1977), the RT difference between incongruent words and neutral stimuli was essentially the same for vocal (111 ms) and for manual (128 ms) responses. Similarly, McKenna and Sharma (1995) reported a series of five manual response experiments in which irrelevant words that evoked negative cognitions-emotions were associated with slower colour identification times than were neutral words. As noted by Besner (2001), further analyses of Sharma and McKenna's (1998) more recent data also provide evidence for semantic-level involvement in the manual version of the Stroop task.

The memory task was a Yes-No recognition (unanticipated) test, also taken from MacKinnon et al. (1985), which involved 40 distractors (see Appendix B).

Finally, participants were debriefed, thanked, and dismissed. The experimental session lasted about 40 min. Both the Stroop task, including the training sessions, and the recognition memory test were run on a Power PC Macintosh using Blake Meike's Mindlab software system.

**Complementary Measures (Questionnaire)**

**Manipulation check measures.** Participants were asked whether this study included the possibility of being rewarded for having done well on the Stroop task and to what extent, if any, they valued the reward. The 7-point scales accompanying these questions were labelled "not at all" (1) at one end and "very much" (7) at the other. Participants in the competition condition were asked to rate how quickly they performed in relation to the competitor on a 7-point scale ranging from -3 (much slower) to +3 (much faster), including zero (same speed). Note that these ratings can also be used as a measure of distraction related to social comparison. To be accurate some attention had to be allocated to the other person present. In order to see whether participants perceived that they did not differ from the competitor on response accuracy, they were also asked to rate how many errors they made in relation to the competitor on a scale ranging from -3 (far fewer) to +3 (many more errors), including zero (same number of errors). The effects of social comparison on perceived response speed were also assessed on more indirect dimensions, namely, self-evaluation and feelings of well-being. Participants were simply asked to judge their performance speed and their performance accuracy on a satisfaction scale where participants select one of seven human faces ranging from -3 (terribly unhappy) to +3 (delighted), including zero (neutral).

**Self-reports of effort and distraction.** As in MacKinnon et al.'s (1985) studies, participants completed the effort scale developed by Geiselman,
Woodward, and Beatty (1982). It consisted of four items in which participants estimated their level of effort on the Stroop task on a scale ranging from 1 (not at all) to 5 (very much). This self-report measure was found to be correlated at .90 with galvanic skin reactivity and at .50 with heart rate variability, two physiological measures believed to be representative of the expenditure of cognitive effort. Participants were also asked to rate the extent to which they (1) felt they had thought of something other than the task while they were performing it (internal distraction), and (2) spent any time away from the task – turning the head or body – during the Stroop session (external distraction). The 7-point scales accompanying these measures of distraction were labelled “not at all” (1) at one end and “very much” (7) at the other. Whereas doubts have been raised as to the validity of direct verbal measures of distraction (e.g., How distracted were you during the task?), less direct measures such as those used here have been found sensitive to social presence manipulations (Baron, 1986; Sanders, Baron, & Moore, 1978).

Results

Two participants (from the no-competition condition) who made more than 15% errors on the Stroop task, and three participants (one in the slower and two in the faster competitor conditions) who were suspicious of the confederate (as revealed during the debriefing) were excluded from each of the statistical analyses reported below. The results of the statistical tests were unchanged when these participants were included.

Manipulation checks

The manipulation data were analyzed via 2 (Reward: Absent vs. Present) x 4 (Competition: None (Alone), Slower competitor, Similar competitor, Faster competitor) analyses of variance (ANOVAs). As expected, the main effect of reward was clearly significant, $F(1, 66) = 1365$, $MSE = .42$, $p < .0001$ ($\eta^2 = .95$). The possibility of being rewarded was much more salient when a reward was present ($M = 6.74$, $SD = .61$) than when it was not ($M = 1.15$, $SD = .67$). In the former condition, the reward was also highly valued (overall mean $M = 5.60$, $SD = 1.40$, $p < .0001$ relative to the midpoint of the scale, 4). Likewise, the main effect of competition was significant on perceived relative speed of responding, $F(2, 49) = 74$, $MSE = .58$, $p < .0001$ ($\eta^2 = .75$). Not only were the three corresponding means in the expected direction (see Figure 1), but each differed significantly from the other two (Scheffe, $p < .05$). Perceived relative speed of responding also correlated positively with self-evaluation of response speed ($r = .45$, $p < .001$), which was itself positively correlated with feeling of well-being ($r = .29$, $p < .02$). Also as expected, no effects of competition were found on perceived relative response accuracy ($M = .01$, $SD = .23$, overall). This variable did not correlate with self-evaluation of response accuracy ($r = .17$, ns), which did not correlate either with feeling of well-being ($r = .00$). Thus, the manipulations were clearly successful.

Stroop performance

Only RT data from correct responses were analyzed. Before any statistical analyses were conducted, these RT data were subjected to a recursive trimming procedure in which the criterion cutoff for outlier removal
ATTENTION AND STROOP EFFECT

TABLE 1
Stroop and Recognition Memory Performances as a Function of Competition and Reward (Standard Errors in Parentheses)

<table>
<thead>
<tr>
<th></th>
<th>No Reward</th>
<th>Reward</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Alone</td>
<td>Slower</td>
<td>Similar</td>
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<td></td>
<td>n</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All the Words</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colour Words</td>
<td>1.07</td>
<td>1.00</td>
<td>841 (.50)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(95.70) (2.90)</td>
</tr>
<tr>
<td>Colour-Related Words</td>
<td>1.02</td>
<td>1.25</td>
<td>.856 (.00)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(64.01) (1.25)</td>
</tr>
<tr>
<td>Response-Set Colour</td>
<td>892</td>
<td>1.25</td>
<td>764 (.64)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(46.58) (0.89)</td>
</tr>
<tr>
<td>False Alarms</td>
<td>849</td>
<td>2.25</td>
<td>765 (.65)</td>
</tr>
<tr>
<td></td>
<td>(43.16) (1.00)</td>
<td></td>
<td>(56.43) (0.42)</td>
</tr>
<tr>
<td>A</td>
<td>.91 (.01)</td>
<td>.90 (.02)</td>
<td>.91 (.02)</td>
</tr>
<tr>
<td>B ′</td>
<td>.52 (.10)</td>
<td>.45 (.15)</td>
<td>.52 (.22)</td>
</tr>
<tr>
<td>Recognition Hits</td>
<td>.75 (.05)</td>
<td>.80 (.03)</td>
<td>.79 (.04)</td>
</tr>
<tr>
<td>False Alarms</td>
<td>.07 (.02)</td>
<td>.11 (.04)</td>
<td>.11 (.03)</td>
</tr>
</tbody>
</table>

was established independently for each participant, in each condition, by reference to the sample size in that condition (Van Selst & Jolicoeur, 1994). The trimming procedure resulted in 0.50% of the correct RT data being discarded for the entire sample (ranging from 0.29% in the reward/slower competitor condition to 0.77% in the no reward/no competition condition). The trimmed mean RTs and percentage error for each type of stimulus item in each competition group are displayed in Table 1. A 2 (Stroop stimuli: incongruent words vs. Control signs) x 4 (Competition: None (Alone), Slower competitor, Similar competitor, Faster competitor) ANOVA, with Stroop stimuli as the within-subject variable, was carried out on the RT data. In this first analysis, the incongruent colour words included each type of stimulus item (response-set colour words, nonresponse-set colour words, and colour-related words, referred to as “all the words” in Table 1), as in MacKinnon et al. (1985).

The main effect for Stroop stimuli was significant, F(1, 67) = 68.74, MSE = 1,479.60, p < .0001 (η2 = .51). Faster RTs were found for the control signs (M = 7.49, SD = 1.27) than for the incongruent words (M = 8.00, SD = 1.38), indicating the emergence of a Stroop effect (51 ms). More interestingly, this effect was qualified by a significant Stroop stimuli x Competition interaction, F(3, 67) = 4.14, p < .01 (η2 = .16). In order to better understand the overall interaction (see Figure 2), it was broken down into three orthogonal contrasts with the global Stroop difference score (i.e., all words minus control) as the dependent variable. The first contrasted the alone condition (86 ms) with the average of the three social conditions (41 ms). The second contrasted the faster coactor condition (59 ms) with the average of the other two coaction conditions (32 ms). Finally, the third contrasted the similar (54 ms) and slower (50 ms) coactor conditions. Only the first contrast was significant (p < .005), providing further evidence that competition is a sufficient condition for a reduction of the Stroop effect to occur. No other effects were found on the global Stroop difference score.

Once more, the difference score was calculated as in MacKinnon et al. (1985) (i.e., interferences from each type of word were combined). As noted earlier in this paper, however, the Stroop effect is more commonly defined as the difference in RTs between response-set colour words and the baseline. Did the present findings hold when this more conventional difference was used as the dependent variable? It did. Among the three orthogonal contrasts used earlier for the global interference, the first one was still significant on the classic Stroop difference score (162 ms for the alone condition vs. 86 ms for the three competition conditions averaged, p < .05, see Figure 3). This strengthens our confidence that competition is a suffi-
cient condition for reducing the Stroop effect. The first contrast was only marginally significant (142 ms vs. 86 ms, $p < .10$) or significant (46 ms vs. 12 ms, $p < .01$) when the nonresponse-set colour words and the colour-related words, respectively, were used (see Figures 4 and 5). On this last component (colour-related words), the second contrast between the faster coactor condition and the other two coaction conditions was also significant (32 ms vs. 3 ms, $p < .04$). The effects involving reward were significant neither on the global Stroop difference score (Stroop stimuli x Reward, $F < 1$; Stroop stimuli x Reward x Competition, $F < 1$) nor on the difference score derived from each type of stimulus item ($F$s < 1).

**Error rate**

The 2 (Item type) x 2 (Reward) x 4 (Competition) mixed ANOVA on error rate did not yield any significant effects.
Recognition memory data

These data (see Table 1) were analyzed via 2 (Reward) x 4 (Competition) ANOVAs. The only significant effect was the reward effect on the hit rate, $F(1, 67) = 5.35$, $MSE = .019$, $p < .03$ ($\eta^2 = .07$), which was lower when the reward was present ($M = .70$, $SD = .16$) than when it was not ($M = .78$, $SD = .11$). No effects were found on false alarms. In line with this, the main effect of reward was marginally significant ($p < .09$) on Snodgrass, Levy-Berger, & Haydon’s (1985) nonparametric measure ($A'$) of discriminability, which can be calculated (unlike $d'$) even when participants have hit or false-alarm scores of 1 or 0 ($3.3\%$ of our participants correctly recognized all stimulus items and $14.7\%$ made zero false alarms): $A'$ tended to be smaller when the reward was present (.88) than when it was not (.91). No effects were found on Donaldson’s (1992) $B''$, the corresponding measure of bias. The same conclusion could still be drawn when Feenan and Snodgrass’ (1990) $P$, measure of corrected hit rate was
used (.61 for the reward condition vs. .68 for the no-reward condition, \( p < .08 \)) and when Br, its associated measure of bias, was used (no effect). Complementary analyses on each type of stimulus item revealed that the reward effect on hit rate was true for both the non-response-set colour words (.57 for the reward condition vs. .73 for the no-reward condition, \( p < .05 \)) and the colour-related words (.66 for the reward condition vs. .75 for the no-reward condition, \( p < .08 \)). In contrast, competition failed to produce any significant or marginally significant effects even when the recognition score was analyzed by type of stimulus item. At a purely descriptive level, the recognition data reported in Table 1 may suggest the presence of a Reward \( \times \) Competition interaction. However, this interaction was not significant when we analyzed the global recognition score (including all words, \( p = .24 \)) or the recognition score by type of stimulus item (response-set colour words, \( p = .29 \); nonresponse-set colour words, \( p = .34 \); colour-related words, \( p = .39 \)).

Self-reports of distraction and effort

The same 2 \( \times \) 4 ANOVA was used for the self-reported distraction and effort data (see Table 2). Because the self-reports of internal and external distraction were moderately correlated (\( r = .25, p < .05 \)), they were examined separately. No effects were found on these reports. As indicated by the overall mean of internal (\( M = 2.92, SD = 1.62 \)) and external (\( M = 1.72, SD = 1.41 \)) distraction, participants generally reported a low level of distraction. Both means also differed significantly from the midpoint (4) of the scale (one-sample t-test, \( p < .0001 \)). Regarding the self-reports of effort, the main effect of reward was significant, \( F(1, \ 65) = 5.67, MSE = 24, p < .05 \) \( (\eta^2 = .08) \). Participants reported greater effort when a reward was present (\( M = 3.27, SD = .43 \)) than when it was not (\( M = 3.00, SD = .53 \)). In the reward condition, self-reports of effort also differed significantly from the midpoint (3) of the scale (one-sample t-test, \( p < .0001 \)). No other effects were found. The effort data were not correlated with the internal (\( r = -.15, ns \)) or external (\( r = .05, ns \)) distraction data.

Discussion

MacKinnon et al. (1985) suggested that Stroop interference can be brought under attentional control when the participant’s effort is directed accordingly. In line with this, they found that competing for a desired reward increased self-reports of task-specific effort, decreased the size of the Stroop effect, and altered word processing (as indicated by a reduction in recognition memory for the Stroop list words). Because competition and the presence of a reward were confounded, it remained unclear which factor(s) explained these findings. In the present study, the two factors were manipulated orthogonally and various methodological problems associated with past research were eliminated. The results were exactly as expected from our account of MacKinnon et al.’s findings. The reduced Stroop effect was associated only with competition, which had no effect on self-reports of task-specific effort. The presence of a desired reward increased these reports but did not change the size of the Stroop effect. As such, these results suggest that competition led to unconscious but effective control, whereas the presence of a desired reward led to conscious but ineffective control. As indicated by the recognition data, the reduced Stroop effect due to competition was not associated with an alteration of word processing. Although it had no impact on the Stroop effect, the presence of a reward caused this alteration to occur. These findings deserve attention in a number of important ways.

First of all, the present reduction of the global Stroop effect (i.e., all the words) is larger than that
ATTENTION AND STROOP EFFECT

observed by MacKinnon et al. (1985) with the same Stroop words and control stimuli. In their studies, this effect was 25% smaller in the competition condition than in the no-competition condition. Here, it was 52% smaller in the three competition conditions (averaged) than in the control group (i.e., participants working alone). In the slower competitor condition (associated with the smaller interference), it was 65% smaller. This is more than twice the size of the reduction reported by MacKinnon et al. This difference could be due to the use of different versions of the Stroop task (vocal vs. manual). As noted earlier in this paper, there is evidence for semantic-level activation in the manual version (see also Besner, 2001), but this activation may be more difficult to control in the vocal version, where interference effects are more robust (MacLeod, 1991). The fact that competitive pressures were especially high in the present study may also matter. If competition can divert attention from semantic activation, its intensification would indeed help reduce the Stroop effect. Competitive pressures were higher here than in MacKinnon et al.’s studies because participants could compare their response speed with that of the confederate throughout the Stroop session. Evidence that the participants engaged in social comparison was found here in the mean of perceived speed difference ratings. All of these ratings were in the expected direction (see also Figure 1), suggesting that some attention was allocated to the confederate during the Stroop session. Further evidence that participants compared themselves with the confederate was found in the self-evaluation and well-being data, which revealed the impact of perceived relative response speed at more indirect levels. All this may seem inconsistent with the lack of a competition effect on the self-reports of distraction. However, combined with the lack of a competition effect on the effort self-reports, the lack of a competition effect on the distraction self-reports can also be taken as evidence that semantic activation was unconsciously controlled in the competition conditions. Competing participants may have simply been unwilling to report a high level of distraction, as this is a socially undesirable behaviour. But this account raises an obvious question: Why were participants also unwilling to report a high level of effort, which is socially desirable in the same context? Furthermore, if effective attentional control was conscious, the presence of a desired reward would also be associated with a smaller Stroop effect. This is not what happened.

Second, as shown by the manipulation checks, participants perceived the possibility of being rewarded (when it existed) and valued the reward (as also indicated by its impact on the effort self-reports). The fact that its presence did not change the size of the Stroop effect, therefore, is not artefactual and can be taken as further evidence that competition, not the presence of a reward, reduced the Stroop effect in MacKinnon et al.’s (1985) studies. In line with this, attempts to change the size of the Stroop effect through payment of a $1 or $5 reward were unsuccessful in their pilot study (see p. 227). Faced with this finding, they combined the presence of this reward with the presence of a competitor. As revealed by the present data, these factors have specific effects and therefore should not be conflated.

Third, as noted by Besner and Stolz (1999c; see their Footnote 1), the reduction or even elimination of a Stroop effect does not speak to the ultimate fate of the words. Indeed, the reduced Stroop effect was not associated here with a change in recognition memory for the Stroop words, suggesting that word processing was unchanged. This first dissociation (i.e., decreased Stroop effect with word processing unchanged) is also consistent with Mari-Befia, Estevez, and Danziger’s (2000) claim that the reduction of the Stroop effect is not sufficient evidence for concluding that word-level processing is altered (see also Bibi, Tzelgov, & Henik, 2000). Mari-Befia et al. (2000) and Besner (2001) all used the negative priming effect for their demonstration. Negative priming in the Stroop paradigm refers to the observation that ignoring one stimulus dimension in a display (i.e., prime display) interferes with responding to the other stimulus dimension in a subsequent display (i.e., target display), if they are related (e.g., ignoring the word BLUE in the prime display and identifying the colour blue in the target display). One way of finding out whether the reduction or elimination of a Stroop effect is associated with an alteration of word processing is to see whether this reduction or elimination is associated with a negative priming effect. Mari-Befia et al. found this effect in the absence of Stroop interference. Besner found a negative priming effect despite the elimination of Stroop interference. Both findings lead one to conclude that the Stroop effect is not an exhaustive measure of word processing. A reduced Stroop effect with unchanged long-term memory for the Stroop words leads to exactly the same conclusion.

Fourth, this conclusion is strengthened by the specific influence of the reward observed here. Although it did not change the size of the Stroop effect, the presence of a reward was associated with poorer recognition memory for Stroop words and thus possibly with an alteration of word processing. This second dissociation (i.e., altered word processing with unchanged Stroop effect) suggests that the presence of a reward, not competition, affected recognition memo-
ry in MacKinnon et al.'s (1985) studies. But above all, it offers a new challenge for current theories of attentional control. As noted earlier, a well-known finding in the Stroop literature is that a skilled reader's intent to not read words is not enough to reduce the Stroop effect, suggesting that conscious control of word processing is ineffective. What happened in our study regarding the Stroop effect is consistent with this finding. At the recognition-memory level, however, the data are less consistent. It seems indeed that an intact Stroop effect is insufficient evidence for concluding that word processing is unaffected.

What does all this mean? Taken together, the two dissociations suggest that under specific conditions (e.g., when the pool of available resources is taxed), word processing can be prevented from affecting colour responding, but the words can still be processed off line (i.e., when the participant is not responding), which in turn might lead to good recognition memory. This is consistent with Besner's (2001) idea that contextual factors can sometimes serve to prevent, at least temporarily, the activation of semantic representations, with the consequence that Stroop interference is reduced. Under other conditions (e.g., when participants expand their effort to not read the words), the words can affect Stroop performance on line (i.e., when the participant is responding), but may be prevented from affecting off-line processing, which in turn might lead to impaired recognition memory.1

Word processing may not only be controlled on line, when the participant is responding, but it could also be controlled off line, when the participant is not responding. Thus, it could be that competition was associated here with unconscious but effective on-line control whereas the presence of a desired reward was associated with conscious but ineffective off-line control.

Finally, it is important to note that our contextual factors were not restricted to the local context of the task, and therefore differed from those manipulated by Besner and Stolz (see Besner, 2001, for a brief review). These authors demonstrated that colouring a single letter of the words and/or precuing a single letter position can divert attention from semantic-level activation and result in a reduction or elimination of the Stroop effect. As suggested by the present findings, factors related to the participant's broader context also make a difference and thus should not be neglected. Once more, the Stroop effect has been shown to be extremely robust when the local context is unchanged (i.e., all letters coloured, no spatial precuing, words and colours simultaneously presented in the same spatial location). In this standard condition, the reduction, and even more so the elimination, of Stroop interference seems highly unlikely. Instead, our data show that the Stroop effect can be reduced even when the local context is unchanged and therefore maximizes semantic activation. This reduction would be even more impressive with the vocal version of the Stroop task. This being said, some readers might wonder whether task version really matters in the present study. After all, MacKinnon et al. (1985) also found a reduced Stroop effect due to similar socio-contextual manipulations in a vocal Stroop task. Of course, future research is needed to understand exactly how socio-contextual factors such as those manipulated in the present study affect Stroop interference. Earlier in this paper, it was suggested that the presence of a competitor and related social comparison activities may also divert attention, at least temporarily, from semantic-level activation (i.e., preclude the spread of activation to this level), resulting in a smaller Stroop effect. In this approach, attending to another person who is present in order to gain information about one's relative standing reduces the range of cue utilization, so that subsequent word recognition processes operate less efficiently (or not at all). There is indeed evidence in the social facilitation literature (see Baron, 1986; Geen, 1991; Huguet et al., 2000) that when the presence of others threatens the organism with cognitive overload, it can serve to focus attention more narrowly. This may facilitate performance (by screening out unessential stimuli) when the task requires attending to a small number of central cues, or it may inhibit it (by neglecting certain crucial stimuli) when the task requires attending to a wide range of cues. In Bruning, Capage, Kosuth, Young, and Young (1968) Study 1, for example, being observed by the experimenter tended to improve the performance of participants faced with cues irrelevant to a learning task and impaired performance when relevant cues were added (compared with when participants were not observed). Both findings suggest that the presence of others can be associated with a reduction in cue utilization. As suggested by Easterbrook (1959), increased emotional arousal may also cause this reduction to occur. In this view, irrelevant cues are eliminated before relevant ones as capacity diminishes. Underarousal deficits would thus result from the simultaneous use of relevant and irrelevant information, and overarousal deficits, from incomplete utilization of relevant information (see also Humphreys & Revelle, 1984). In the present study, then, it could also be that the presence of a competitor increased arousal, which in turn decreased the ability

1 We thank Dinkar Sharma for this interesting view of our data.
ATTENTION AND STROOP EFFECT

Our data suggest that we pay more attention to the participant’s social environment in the study of cognitive phenomena, even when they do not imply the processing of social objects. One of the most challenging problems facing cognitive psychology and cognitive neuroscience is that of explaining how mental processes are controlled and allow the computational resources of the brain to be selected flexibly and deployed to achieve changing goals (e.g., Monsell & Driver, 2000). Examining these problems from a cognitive and social psychological perspective might help us draw new pictures of mental processes, especially those involved in the control of action.

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Further


ATTENTION AND STROOP EFFECT

Appendix A

Stroop Words According to their Font Colour

<table>
<thead>
<tr>
<th>Font Colour</th>
<th>Blue</th>
<th>Green</th>
<th>Red</th>
<th>Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response-Set Colour Words</td>
<td>Green</td>
<td>Red</td>
<td>Yellow</td>
<td>Blue</td>
</tr>
<tr>
<td>Nonresponse-Set Colour Words</td>
<td>Black</td>
<td>Orange</td>
<td>Grey</td>
<td>White</td>
</tr>
<tr>
<td>Colour-Related Words</td>
<td>Cherry</td>
<td>Sky</td>
<td>Ocean</td>
<td>Blood</td>
</tr>
<tr>
<td>Sun</td>
<td>Canary</td>
<td>Coffee</td>
<td>Mouse</td>
<td></td>
</tr>
<tr>
<td>Tar</td>
<td>Cotton</td>
<td>Fir</td>
<td>Lawn</td>
<td></td>
</tr>
</tbody>
</table>

Appendix B

Distractors Used in the Recognition-Memory Test

apricot, ashes, azure, banana, bean, brown, carrot, chick, chocolate, coal, corn, cornflower, crow, ham, lemon, lilac, lizard, mauve, meat, milk, mint, mud, navy, night, pig, pink, plant, plum, poppy, pumpkin, purple, rat, salmon, sea, smoke, snow, strawberry, sugar, tomato, tree

Sommaire

Plusieurs résultats publiés au cours de ces 25 dernières années sur l’effet Stroop suggèrent que le traitement lexical-sémantique de mots isolés n’est pas complètement automatique et peut donc faire l’objet d’un contrôle attentionnel. Pour l’essentiel, ce contrôle s’exprime par la réduction voire l’élimination de l’interférence couleur-mot lorsque certaines modifications sont apportées à la tâche de Stroop. Dans les travaux récents de Besner et de ses collègues, par exemple, l’interférence est éliminée lorsqu’une seule lettre du mot est colorée ou spatiallement indiquée (e.g., Besner, Stolz, & Boutilier, 1997; Besner & Stolz, 1999a). Alors même que tous les sujets impliqués dans ces études sont encouragés à se soustraire à la lecture du mot, seuls ceux confrontés à la tâche modifiée y parviennent, au moins momentanément. D’où l’idée d’une possibilité de contrôle efficace mais non intentionnel. Dans la présente étude, nous faisons l’hypothèse d’une altération de l’effet Stroop liée à des variations non pas de la tâche elle-même mais du contexte du sujet. Plus spécifiquement, nous envisageons la possibilité qu’en détournant une partie de sa capacité d’attention, la présence d’un compétiteur lui permette d’échapper au moins temporairement au traitement lexical-sémantique (alors même que ce traitement est maximisé par la structure de la tâche). Le sujet serait en revanche incapable de résister à l’interférence lorsqu’il s’efforce consciemment de ne pas lire le mot dans la perspective d’une récompense. En bref, la mise en jeu de l’attention dans le paradigme de l’effet Stroop ne serait véritablement efficace que lorsqu’elle n’est pas intentionnelle. Contrairement à une étude de MacKinnon et al. (1985) où compétition interpersonnelle et attente d’une récompense étaient confondues, ces deux facteurs sont manipulés dans notre étude de manière orthogonale. Les sujets sont confrontés à une version manuelle-informatisée de la tâche de Stroop en situation d’isolement versus de compétition avec un compère de même sexe qu’eux. Tandis qu’une récompense monétaire est promise à une moitié des sujets en cas de victoire sur le compère (i.e., s’ils se montrent plus rapides), cette anticipation est éliminée pour l’autre moitié. De façon à estimer le degré d’altération éventuelle du traitement lexical-sémantique, une tâche de reconnaissance des mots utilisés lors du test de Stroop est proposée à la fin de chaque session. Conformément aux attentes, la perspective d’une récompense n’a aucune influence sur la taille de l’effet Stroop, laquelle est au contraire réduite d’environ 50% en situation compétitive (aucune interaction n’est observée entre ces deux facteurs). De manière inattendue, seule la récompense détériore la performance mémorielle (i.e., taux de reconnaissance des mots). Considérées ensemble, ces deux dissociations (i.e., réduction de l’effet Stroop sous l’effet de la compétition sans altération du traitement lexical-sémantique; altération de ce traitement sous l’effet de la récompense sans réduction de l’effet Stroop) montrent que le contrôle de l’activation lexico-sémantique peut être efficace bien que non intentionnel versus inefficace bien qu’intentionnel. Elles suggèrent aussi que seul le contrôle non intentionnel opère “on line”, c’est-à-dire lors de la production de la réponse. Plus généralement, nos résultats clarifient la nature de la régulation liée à certains facteurs socio-contextuels dans la tâche de Stroop et offrent de nouvelles raisons d’accorder une attention permanente à l’environnement social de la cognition.

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