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Stroop interference and disorders of selective attention

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Abstract—Fourteen patients with a right-hemisphere CVA and 8 patients with a left-hemisphere CVA were examined for selective attention deficits using a variant of the Stroop color-word task: the picture-word interference task. Experiments 1 and 2 first compared the performance of the two patient groups and a control group in three tasks of increasing difficulty: picture-word detection, word reading, and picture naming. The results showed that (a) the two patient groups were significantly slower than the control group, but did not differ from each other, and (b) the difference in mean RT between the two patient groups and the control group did not increase with task difficulty. In Experiment 3, the subjects were required to name pictures while ignoring accompanying distractors: nonletter symbols, unrelated words or semantically related words. In this task, the right hemisphere patients showed a much larger semantic interference effect than both the left hemisphere patients and the control group. It is argued that this finding most probably reflects problems in visual selective attention with the right hemisphere patients.

Key Words: Stroop interference; selective attention deficits; cognitive functioning.

Introduction

There are many factors that may interfere with an optimal functioning of the brain, in particular with the processing of information. One can think, for instance, of neurological diseases, the consequences of accidents resulting in damage of neurological tissue, the use of psychopharmaca or alcohol, psychiatric disorders, and the exposition to poisonous substances in industrial settings. Clinical studies looking at the consequences of these conditions for cognitive processes practically always include an assessment of attentional problems. In test batteries of many clinical studies evaluating cognitive functioning in subjects with demonstrable or suspected brain disorders, tasks are typically included to assess selective, divided, and sustained attention. Perhaps the best known among the tasks that are supposed to detect selective attention deficits is the Stroop task.

The traditional procedure to assess problems in selective or focused attention with the Stroop task is as follows [8]. A subject is given a card (Card A) with rows of color words and he is requested to read these aloud. He is then given a second card (Card B) with rows of colored rectangles and he is asked to name these aloud. Finally, he is presented with color words printed in colors that do not match with the meaning of the words (Card C) and has to name the colors in which the words are printed. The time to complete each of these cards is registered. In general, it takes more time to name the colors of the words on Card C than the colors of the rectangles on Card B. Sometimes, the difference in time between Card C and Card B is referred to as Interference Time.

Van Zomeren and Brouwer [20] mention the Stroop task as a measure to investigate focused attention, i.e. the capacity to selectively attend to specific stimuli or aspects of a stimulus and ignore irrelevant information. In the Stroop task subjects are required to concentrate on the color of the printed words, while ignoring the word. According to such a description of the task, a subject has to select a particular type of information, namely color, and consider the orthographic information as irrelevant. It therefore seems the task has face validity as an instrument to assess selective attention. Moreover, the fact that Card C requires longer naming
times than Cards A and B suggests that selection is
taking place, requires time, and may sometimes even
lead to (overt or covert) "selective attention deficits"
(according to Shiffrin and Schneider's [17] terminology).
When a subject demonstrates a particularly large
interference effect, one is tempted to assume that it is
caused by a problem in focusing on the relevant
information and that it can therefore be concluded
that this patient has a disorder of selective attention.

However, one must be careful to draw such a
conclusion. The most important reason is that in some
patient groups all cognitive processes may be slowed
down. In general, it has proven quite difficult to
demonstrate attentional disturbances that cannot be
interpreted as conditioned by a decrease in processing
rate. The observed increase in response latency may then
depend on the complexity of the task: a complex task
will show a larger increase in mean response latency
than a relatively simple task. So a larger Stroop
interference effect in some patient groups could be the
result of a general slowing down, and one should
therefore correct the interference effect for the general
rate of cognitive processing.

Within experimental psychology, at least four
different proposals have been made with respect to
the locus of the Stroop interference effect. First, the
distractor word may disrupt the identification of the
color by diverting attention from it [4]. This inter-
pretation is generally rejected on the basis of the
finding that congruent distractor words (e.g. the word
red printed in red ink) do not cause any interference.
Second, the distractor word may hamper the semantic
encoding of the target stimulus. In this view, advanced
by Seymour [16], the interference is due to an
ambiguity that arises when color and word activate
closely related concepts in semantic memory. This
interpretation has been criticized on the basis of results
that show that Stroop interference strongly diminishes
or even disappears when nonverbal reactions to the
colors are required [21]. Third, the interference has
been attributed to a competition between the distractor
word and the name of the color at a response output
level (response competition, see, e.g. Keele [5]). While it
is generally acknowledged that response competition
plays a role in Stroop interference, the major part of
Stroop interference has recently been attributed to the
process of word retrieval. In this fourth account, it is
assumed that the distractor word hampers the activa-
tion or selection of the name of the target color in the
mental lexicon [3, 6, 13, 15].

Whereas the question of the locus of Stroop
interference has received much attention (see MacLeod
[12], for a review), less research has been devoted to the
question of how the conflict is resolved. However, in all
proposals selective attention plays some role in this
process, either by active suppression of irrelevant
information [19] or by the selective enhancement of
relevant information in memory [1, 11].

In addressing the processes that underlie Stroop
interference effects, experimental psychologists have
developed a number of modifications of the original
Stroop task, three of which are important for our
present purposes. First, instead of the original massed
presentation technique, Stroop stimuli are presented
individually. This allows for more precise reaction
time measurements, the mixing of conditions, and the
elimination of nuisance factors like the presence of
surrounding items. Second, Stroop-like tasks have
been introduced that generalize the phenomenon to
other semantic domains and allow for a better control
of a number of variables. Examples are the naming of
pictures with superimposed words [2, 14], the naming
of faces of famous people with superimposed names
[22], and the naming of definitions followed by
distractor words [7]. Third, the number of distractor
conditions has been increased, which allows for a
decomposition of the "overall" Stroop interference
effect into effects that can be attributed to, for
instance, membership of the distractor word in the
response set, and the semantic similarity between
target and distractor word [6].

In the present study we use a picture–word inter-
ference task with individual presentation of the stimuli
to investigate (a) whether patients with verified brain
lesions show an increased amount of Stroop-like
interference in comparison with a group of control
subjects, (b) whether such an increase is obtained for all
components of the Stroop interference effect, including
the semantic component, and (c) whether the increased
interference can be attributed to problems in selective
attention or is the result of a general slowness in
processing. The same group of patients and control
subjects participated in three experiments. In the first
two experiments simple tasks were administered that
were supposed to increase in difficulty: picture and word
detection, word reading, and picture naming. These
experiments make it possible to examine (a) whether the
patient were capable of performing these type of
reaction-time tasks, (b) whether the patient groups
show larger mean response latencies than the control
group, (c) whether this difference increases with task
difficulty, and (d) whether the left and the right
hemisphere patients differ in these respects. In the
third experiment a picture–word interference task is
presented that allows for an examination of two
interference effects: interference due to the presence of
an unrelated word and interference due to the presence
of a word that is semantically related to the to-be-named
picture. This experiment makes it possible to examine
whether besides a general slowness of responding, the
two patient groups show an increase in interference
values in comparison with the control group. In all
experiments the same subjects were tested: eight patients
with a left hemisphere lesion (the LH group), 14 patients
with a right hemisphere lesion (the RH group) and 14
control subjects.
Experiment 1: Picture and word detection

In this experiment the subjects were required to react as fast as possible (by saying “yes”) to the appearance of a word, a picture, or a control stimulus in the display, irrespective of the nature of the stimulus. The stimuli presented are the words and pictures that will be used in the reading and naming tasks of Experiment 2, and in the picture–word interference task of Experiment 3. If there is a general slowness in responding in the patients groups, this should become evident in this simple detection task.

Method

Subjects. Two groups of patients admitted to the stroke rehabilitation ward of the Cooperating Rehabilitation Centres of Limburg in Hoensbroek (The Netherlands) were included in the study. All patients were right-hand dominant and the infarct or hemorrhage was located in the left hemisphere for 8 patients and in the right hemisphere for 14 patients. The patients in these groups were, on average, 57.6 years of age (S.D. = 7.4) and 57.7 years of age (S.D. = 9.1), respectively. Other details of the patients, including the localization of the infarction or hemorrhage are given in Table 1.

According to several speech pathologists’ reports 3 out of 8 patients with left hemisphere lesions had no language disorders at all, 2 were dysarthric and, 3 were moderately aphasic. The aphasic symptoms encompassed moderate sentence comprehension problems but no word comprehension disorders. Only one out of 8 patients with left hemisphere damage had minor naming problems and moderate sentence production problems. For clinical purposes 3 of these patients underwent neuropsychological testing. Of the RH group 10 out of 14 patients were tested for clinical purposes. The results of these tests are given in Table 2.

According to Table 2, 5 patients had left-sided spatial neglect symptoms, as measured with 3 conventional subtests of the Behavioral Inattention Test (line crossing, letter cancellation and star cancellation). All these patients underwent rehabilitative training for their hemi-inattentive disorder. The control subjects were healthy relatives of the patients in the

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Birth (year)</th>
<th>CVA (year)</th>
<th>Recidive</th>
<th>Medication</th>
<th>Localization</th>
<th>Left/Right hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>1928</td>
<td>1991</td>
<td>No</td>
<td>No</td>
<td>Brain stem and cerebellum infarction</td>
<td>Left</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>1949</td>
<td>1992</td>
<td>No</td>
<td>No</td>
<td>Extensive middle cerebral artery infarction</td>
<td>Left</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>1928</td>
<td>1992</td>
<td>No</td>
<td>No</td>
<td>Middle cerebral artery infarction extending to capsula interna</td>
<td>Left</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>1931</td>
<td>1992</td>
<td>No</td>
<td>No</td>
<td>Middle cerebral artery infarction extending to basal ganglia</td>
<td>Left</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>1931</td>
<td>1992</td>
<td>No</td>
<td>No</td>
<td>Middle cerebral artery hemorrhage extending to putamen</td>
<td>Left</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>1931</td>
<td>1992</td>
<td>No</td>
<td>No</td>
<td>Cerebral infarction with tissue damage laterally of the sella media</td>
<td>Left</td>
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<tr>
<td>7</td>
<td>M</td>
<td>1933</td>
<td>1992</td>
<td>Yes</td>
<td>Prothiaden, Prozac</td>
<td>Middle cerebral artery hemorrhage extending to basal ganglia</td>
<td>Left</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>1944</td>
<td>1992</td>
<td>No</td>
<td>Neuleptil</td>
<td>Frontal temporal infarction</td>
<td>Right</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>1937</td>
<td>1991</td>
<td>No</td>
<td>Extensive middle cerebral artery infarction</td>
<td>Right</td>
<td></td>
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<tr>
<td>10</td>
<td>F</td>
<td>1944</td>
<td>1992</td>
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<td>No</td>
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<td>Right</td>
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<tr>
<td>11</td>
<td>F</td>
<td>1915</td>
<td>1992</td>
<td>No</td>
<td>Nortrilan</td>
<td>Lacunair infarction in corona radiata</td>
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<tr>
<td>12</td>
<td>M</td>
<td>1925</td>
<td>1992</td>
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<td>No</td>
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<td>Right</td>
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<tr>
<td>13</td>
<td>F</td>
<td>1932</td>
<td>1992</td>
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<td>No</td>
<td>Temporo-parietal infarction</td>
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</tr>
<tr>
<td>14</td>
<td>M</td>
<td>1939</td>
<td>1992</td>
<td>No</td>
<td>Diphatonine, Noctamid</td>
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<td>Right</td>
</tr>
<tr>
<td>15</td>
<td>F</td>
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<td>1992</td>
<td>No</td>
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<tr>
<td>16</td>
<td>M</td>
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<td>1992</td>
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<td>No</td>
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<tr>
<td>17</td>
<td>M</td>
<td>1935</td>
<td>1992</td>
<td>Yes</td>
<td>Normison</td>
<td>Middle cerebral artery infarction extending to basal ganglia</td>
<td>Right</td>
</tr>
<tr>
<td>18</td>
<td>M</td>
<td>1930</td>
<td>1992</td>
<td>No</td>
<td>Ludiomil</td>
<td>Temporal infarction at capsula interna and globus pallidus level</td>
<td>Right</td>
</tr>
<tr>
<td>19</td>
<td>M</td>
<td>1934</td>
<td>1992</td>
<td>No</td>
<td>Tegetrol</td>
<td>Parieto-occipital infarction</td>
<td>Right</td>
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<tr>
<td>20</td>
<td>F</td>
<td>1949</td>
<td>1992</td>
<td>No</td>
<td>No</td>
<td>Cerebral infarction with right temporal tissue damage</td>
<td>Right</td>
</tr>
<tr>
<td>21</td>
<td>F</td>
<td>1927</td>
<td>1992</td>
<td>No</td>
<td>No</td>
<td>Middle and anterior cerebral arteries infarction (fronto-parietal tissue damage)</td>
<td>Right</td>
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<td>22</td>
<td>M</td>
<td>1942</td>
<td>1991</td>
<td>No</td>
<td>Trazolan, Seresta</td>
<td>Middle cerebral artery infarction with extension to sella media</td>
<td>Right</td>
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</tbody>
</table>
Available neuropsychological test scores

<table>
<thead>
<tr>
<th>Patient</th>
<th>Lesion (site)</th>
<th>Stroop interference (sec)</th>
<th>Left-side cancellations in B.I.T. Line</th>
<th>Letter</th>
<th>Star</th>
<th>Rivermead Behavioral Memory Test (screening score)</th>
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</thead>
<tbody>
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<td>N.A.</td>
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<td>3</td>
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<td>3</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>LH</td>
<td>44</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>9</td>
<td>RH</td>
<td>77</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>RH</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>6</td>
</tr>
<tr>
<td>14</td>
<td>RH</td>
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<td>0</td>
<td>3</td>
<td>25</td>
<td>N.A.</td>
</tr>
<tr>
<td>15</td>
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<td>42</td>
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<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>16</td>
<td>RH</td>
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<td>0</td>
<td>15</td>
<td>27</td>
<td>7</td>
</tr>
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<td>RH</td>
<td>146</td>
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<td>3</td>
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<td>N.A.</td>
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<td>N.A.</td>
<td>3</td>
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<tr>
<td>19</td>
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<td>6</td>
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<td>0</td>
<td>6</td>
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<td>11</td>
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<tr>
<td>22</td>
<td>RH</td>
<td>N.A.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
</tr>
</tbody>
</table>

Note. Patient numbers correspond to those in Table 1. N.A.: no information available.

Results

The raw data were treated in the following way. First, RTs obtained when the voice key was triggered inappropriately ("voice-key errors") and RTs longer than 3000 msec were excluded. Next, to reduce the variance in the data, RTs that deviated more than 2 standard deviations (S.D.s) from their cell mean per subject per condition were excluded. In the picture-detection task, the voice key errors, the 3000 msec criterion and the 2 S.D. criterion accounted for 4.3, 0.3, and 3.1% of the data, respectively. In the word-detection task these values were 2.9, 0.7, and 4.2%, respectively. The data-trimming procedure resulted in roughly the same rejection rates in the three subject groups. The remaining RTs were used in the calculation of the means per subject per condition. The mean RTs and the mean percentages of errors of the three groups of subjects are shown in Table 3.

Analyses of variance (ANOVA) were performed on the detection times for words and pictures separately. The word-detection times differed significantly between groups of subjects, $[F (2, 33) = 10.7, P < 0.001]$. A Newmann–Keuls post hoc analysis showed that the control group differed significantly from each of the two patient groups ($P < 0.05$). In comparison with the control group, the LH group and the RH group showed an increase in word-detection time of 195 and 177 msec, respectively. The difference between the two patient groups was significant ($P < 0.05$).
The raw data were treated in the same way as in Experiment 1. The voice-key errors, the 3000 msec criterion, and the 2-S.D. criterion accounted for 2.2, 1.3, and 4.1% of the data, respectively, in the picture-naming task, and for 1.5, 0.8, and 4.1%, respectively, in the word-naming task. The data-trimming procedure resulted in roughly the same rejection rates in the three subject groups. The mean RTs and the percentages of errors of the three groups of subjects in the two tasks are shown in Table 4.

ANOVA was performed on the word-reading times and the picture-naming times separately. The word-reading latencies differed significantly between groups of subjects, \(F(2, 33) = 7.3, P < 0.005\). The Newmann-Keuls post hoc analysis showed that the control group differed significantly from each of the two patient groups \((P < 0.05)\). In comparison with the control group, the LH group and the RH group showed increases in word-reading times of 155 and 134 msec, respectively. The difference between the two patient groups failed to reach significance. The picture-naming times showed a similar pattern. The three groups differed significantly \(F(2, 33) = 8.5, P < 0.005\), and the Newmann-Keuls analysis indicated a significant difference between the control group and each of the two patient groups \((P < 0.05)\). In comparison with the control group, the LH group and the RH group showed increases in picture-naming latencies of 172 and 167 msec, respectively. The LH group made somewhat more naming errors than the other two groups, but this difference did not reach significance \((P > 0.05)\).

In summary, the results of this experiment show that, in comparison with the control group, the two patient groups are significantly slower in both word reading and picture naming. The size of the increase in RT was comparable to the values obtained in the detection task in Experiment 1. LH patients were 155 msec slower in reading words, and 172 msec slower in naming pictures than the control subjects (the corresponding differences in the detection task were 195 and 190 msec, respectively). RH patients were 134 msec slower in reading words, and 167 msec slower in naming pictures than the control subjects (the corresponding differences in the detection task were 177 and 183 msec, respectively). So,
the increase in mean RT observed in the patient groups in comparison with the control group remains rather constant across a number of tasks that vary in complexity. The question whether this pattern changes when the target stimulus is accompanied by a distractor will be examined in Experiment 3.

Experiment 3: Stroop-like picture naming

In this experiment a standard picture-word interference task is used [2, 9], in which a to-be-named picture is accompanied by a to-be-ignored distractor word. Four distractor conditions are used: (a) the distractor word is semantically related to the target picture (e.g. the picture of a car accompanied by the word TRAIN), (b) the distractor word is unrelated to the target picture (e.g. the picture of a car accompanied by the word MOUSE), (c) the distractor is a series of nonletter characters (the control condition), and (d) the picture is presented in isolation. In this way, the overall Stroop-like interference effect (defined as the difference in mean RT between the semantically related and control conditions) can be decomposed into an effect that is due to the semantic similarity between target and distractor (the semantic interference effect) and an effect that is due to the presence of an unrelated word.

Method

Subjects. The same subjects participated in this experiment as in Experiment 1.

Stimuli. The 15 line drawings used in Experiments 1 and 2 were used as target pictures in this experiment: train, bicycle, car, piano, trumpet, guitar, hammer, saw, pincers, mouse, dog, duck, lamp, clock, and feather. The first 12 of these pictures belong to four different semantic categories: vehicles (train, bicycle, car), musical instruments (piano, guitar, hammer), tools (hammer, saw, pincers), and animals (mouse, dog, duck). The three remaining pictures do not belong to a single semantic category, and were only included because they were used in Experiments 1 and 2. However, the results obtained with these pictures were not included in the analyses. Four distractor conditions were used. In the semantically related condition, the 12 pictures that belong to the four semantic categories were accompanied by the name of the other two pictures in the same semantic category. For example, the picture of a bicycle was once accompanied by the word TRAIN and once with the word CAR. So, in this condition 24 different picture-word combinations were used. In the unrelated word condition, the 12 target pictures were accompanied by three words (picture names) from the other semantic categories (e.g. the picture of a bicycle was accompanied by the word PINCERS). Thus, the total number of unrelated picture-word stimuli amounted to 36. In the control condition all 12 pictures were presented twice in combination with the string >=<><<><, resulting in 24 stimuli. Finally, in the target-alone condition, the 12 pictures were presented twice in isolation, resulting in 24 stimuli. The to-be-named target picture was presented right above the central fixation point (contour-contour distance 3 mm). The distractor was presented at the same distance right below the central fixation point. In all further respects the stimuli were identical to those in Experiments 1 and 2.

Apparatus. The apparatus was the same as in Experiment 1.

Procedure. Subjects were tested individually in a dimly illuminated room. At the start of the session, the subjects were instructed to look at the central fixation point and to name as fast as possible the picture while ignoring the accompanying word. Subjects were shown the target pictures and were asked to name them. If necessary, the correct names were provided. Next, a practice series was run, containing all pictures in combination with randomly selected distractors. If necessary, this practice series was repeated. Each trial involved the following sequence. A fixation point was presented at the center of the display for 3000 msec, directly followed by target picture and distractor. In all further respects, the procedure was identical to that in Experiment 2. The experiment took about 25 min.

Results

The raw data were treated in the same way as in Experiment 1. The voice-key errors, the 3000 msec criterion, and the 2 S.D. criterion accounted for 2.7, 1.3, and 4.8% of the data, respectively. The data-trimming criterion, and the 2 S.D. criterion accounted for 2.7, 1.3, and 4.8% of the data, respectively. The data-trimming procedure resulted in roughly the same rejection rates in the three subject groups. The mean RTs and the percentages of errors of the three groups of subjects in the four distractor conditions are shown in Table 5.

First, an ANOVA was performed on the data of the picture-alone condition, to determine whether in this experiment too, the picture-naming latencies of the two patient groups differed from the control group. This analysis showed a significant effect of groups of subjects, \( F(2, 33) = 6.2, P < 0.01 \). The Newmann–Keuls post hoc analysis showed that the control group differed significantly from each of the two patient groups (\( P < 0.05 \)). In comparison with the control group, the LH group and the RH group showed increases in picture-naming times of 170 and 143 msec, respectively. In Experiment 2, these values were 172 and 167 msec, respectively.

| Table 5. Mean picture-naming latencies in milliseconds (RTs) and percentages of errors (%E) in the various distractor conditions of Experiment 3 |
|-------------|--------|--------|--------|--------|
| Group       | Picture alone (RT) | (%)E | Control (RT) | (%)E | Unrelated (RT) | (%)E | Semantically related (RT) | (%)E |
| Control     | 677     | 2.4    | 700     | 1.5    | 744     | 1.8    | 770     | 6.8    |
| Left hemisphere | 847 | 3.1    | 906     | 3.7    | 949     | 8.5    | 965     | 10.3   |
| Right hemisphere | 820 | 0.6    | 849     | 0.3    | 936     | 1.7    | 1035    | 5.0    |
Next, separate ANOVAs were performed on three types of interference effects. First, the overall Stroop-like interference effect, defined as the difference in RT between the semantically related condition and the control condition (in which the series \( ><><> < \) was used as distractor). This interference effect differed significantly between groups of subjects, \( F (2, 33) = 6.6, P < 0.005 \). The Newmann–Keuls post hoc test revealed that the RH group showed a significantly larger amount of interference than both the control group and the LH group \( (P < 0.05) \). The latter two groups did not differ significantly. In two additional ANOVAs we examined whether this difference in interference between the RH patient group and the other two groups was due to an increase in semantic interference, an increase in interference due to the presence of an unrelated word, or both. An ANOVA performed on the semantic interference effects (defined as the difference between the interference induced by semantically related distractor words and unrelated distractor words), showed a significant difference between groups \( F (2, 33) = 7.5, P < 0.005 \). The Newmann–Keuls test indicated that the RH patients showed a larger semantic interference effect (99 msec) than both the control group (26 msec) and the LH patient group (16 msec; \( P < 0.05 \)). The latter two groups of subjects did not differ significantly. To examine the reliability of the difference between the two patient groups we compared the eight LH patients with the eight RH patients that showed the smallest semantic interference effect in their group (consisting of 14 patients). This analysis showed that even in this conservative test, the semantic interference effect differed significantly between the two groups \( F (1, 14) = 5.0, P < 0.05 \). The semantic interference effects obtained with the eight LH and eight RH patients were 16 and 42 msec, respectively.

To determine whether the semantic interference effects in the three groups reached statistical significance, separate \( t \)-tests for correlated means were performed. These tests showed that the 26 msec semantic interference effect in the control group \( t (13) = 2.96; P < 0.05 \) and the 99 msec semantic interference effect in the RH group \( t (13) = 4.08; P < 0.05 \) reached significance. The 16 msec semantic interference effect in the LH group failed to reach significance \( t (7) = 1.68; P > 0.10 \). Finally, an ANOVA performed on the interference induced by unrelated words in comparison with the control characters showed no significant difference between groups of subjects \( (P > 0.10) \).

Similar ANOVAs were performed on the error percentages. The analysis on the data of the picture-alone condition showed that the three groups did not differ significantly \( (P > 0.10) \). Additional ANOVAs were performed on the increase in error percentages due to the presence of (a) a semantically related word in comparison with a string of control characters (the overall Stroop-like interference effect), (b) a semantically related word in comparison with an unrelated word, and (c) the presence of an unrelated word in comparison with a string of control characters. None of these analyses showed a significant difference between groups of subjects, indicating that the relatively large interference effect observed in the latency data of the RH patients cannot be attributed to a speed–accuracy trade-off.

The results of this experiment are clear. First, the results obtained in the picture-alone condition replicated the findings in Experiment 2. That is, both patient groups were significantly slower in the naming of pictures than the control group. Second, the LH patients did not show significantly larger interference effects than the control subjects. So, their performance can be interpreted as resulting from a general slowness in responding. The RH patients, however, did show a marked increase in interference, both in comparison with the control group and in comparison with the LH patients. In addition, the analyses show that this result is mainly due to an increase in semantic interference with the RH patients.

It could be argued that the difference between the RH and LH patients does not reflect a greater susceptibility of the RH patients for word distractors, but to a lower susceptibility of the LH patients for these words, due to impaired language functions. For two reasons this interpretation is highly unlikely. First, there is no evidence whatsoever for impaired language functions in the LH group in Experiment 2, in which the subjects were asked to read words and to name pictures. Second, the LH patients did not differ significantly from the control subjects in both the overall Stroop-like interference effect (59 and 70 msec, respectively) and the semantic interference effect (16 and 26 msec, respectively).

**General discussion**

To assess potential deficits in cognitive functioning, in particular disorders of attention, a clinical neuropsychologist may use a wide variety of tests. The Stroop color–word test is frequently used to assess selective attention. This task, however, was not designed to test selective attention. Stroop [18] described the remarkable phenomenon that it is more difficult to name a color when it is presented in the form of an incongruent color word than when it is presented in the form of a patch. This Stroop interference effect is a normal phenomenon in the sense that it is shown by almost all healthy subjects. Therefore, on the basis of the presence of an interference effect alone, one cannot conclude that a patient has problems with selective attention. It has to be demonstrated that the interference is different from that in healthy subjects. Moreover, even if larger interference effects are observed, this might not be due to specific attentional deficits, but may simply reflect a
proportional increase in response latency in the control and incongruent conditions of the Stroop task.

The results of Experiments 1 and 2 showed that the mean response latency in the two patient groups increased with the complexity of the task: 612 msec in the detection task, 696 msec in the word-reading task, and 822 msec in the picture-naming task. However, the difference in mean RT between the patient groups and the control group was rather stable across the tasks: a difference of 186 msec in the detection task, 144 msec in the word-reading task, and 170 msec in the picture-naming task. Furthermore, the LH and RH patient groups produced rather similar results in these simple tasks. Given this pattern of results, the conclusion seems warranted that the slowness in picture naming exhibited by the patient groups in Experiment 2 is not due to specific processes that are involved in picture naming, like the visual recognition of the pictures or the process of name retrieval.

The results obtained in the picture–word interference task of Experiment 3 clearly differed for the two groups of patients. Despite longer picture-naming latencies in comparison with the control subjects, the LH patients did not show a larger interference effect. This was true for both the overall interference effect (the difference between semantically related words and the string of control characters) and for its two components: interference induced by unrelated words and the semantic interference effect. In contrast, in comparison to the control group, the RH patients did show an increase in interference. The overall interference effect was 186 msec (vs 70 msec in the control group), and this difference appeared to be mainly due to an increase in semantic interference (99 msec in the RH group vs 26 msec in the control group). Given the stable pattern of results across the various conditions in the three experiments and in view of the fact that in all other conditions the RH group was always slightly faster than the LH group (although this difference was not statistically significant), we believe that this finding reveals a specific interference effect in the RH group. The finding that this increase in interference is especially clear in the semantic component of the Stroop-like effect indicates that (a) it is not due to a general selective attention problem in the sense that these patients cannot distinguish between relevant and irrelevant information, and (b) it is not due to an increase in interference at a response output level. So, it is conceivable that the increased interference effect in the RH group (a) is due to problems in repressing irrelevant words, especially when they are primed by a semantic relation to the target picture [3, 6], or (b) is due to problems in the selective enhancement of the relevant information [11].

As the Stroop color–word test is used to assess attentional functions in patients presenting a wide variety of brain disorders, we did not have assumptions concerning the nature nor the site of the brain lesion that would be important in producing large interference effects. We decided to investigate a group of patients with clearly verifiable lesions and opted for patients with a single unilateral CVA. As we were interested in attentional problems we excluded patients with severe language problems or disorders of visual object recognition. Although the patients were slower than the control subjects, their error rates were quite low, indicating that they could perform these tasks quite well. Moreover, in the simple tasks of Experiments 1 and 2, no differences in terms of errors were found between the two groups. Nevertheless, one could argue that subtle language and perceptual problems contribute to the increase in response times. However, these effects then do not explain the surprisingly large semantic interference effect in the RH group. We do not see an obvious explanation for the fact that the right and not the left hemisphere patients appear to be sensitive to this interference effect.

In summary, the results of this study show that disproportional picture–word interference effects can be demonstrated in patients with right hemisphere lesions independent of a general decrease in speed of cognitive processing. These patients are not distracted by just any kind of distractor but semantic associations play a role and produce a significantly larger interference effect.

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References


*The fact that 5 out of the 14 RH patients showed signs of neglect at the time of neuropsychological examination does not offer an alternative account of the present findings. The semantic interference effect obtained with these patients was in fact smaller than the semantic interference effect observed with the RH patients without any signs of neglect (67 and 118 msec, respectively).


