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Spatial and Semantic Inhibitory Processing in Schizophrenia

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Two experiments assessed inhibitory mechanisms associated with the posterior and anterior attention networks in schizophrenia. Experiment 1 assessed the inhibition of return effect of the posterior network. Both healthy adults and schizophrenic adults showed inhibition of return, suggesting that this inhibitory mechanism of visual orienting is preserved in schizophrenia. Experiment 2 assessed semantic inhibition, which supposedly taps the anterior network, in a lexical-decision task. Healthy adults showed semantic inhibition effects in both visual fields. Schizophrenic adults showed semantic inhibition effects when targets were presented to the left visual field, involving the right hemisphere. However, semantic facilitation rather than inhibition was observed when targets were presented to the right visual field, involving the left hemisphere. These results reflect left hemisphere dysfunction associated with deficits in attentional control in schizophrenia.

Attention disorders seem to underlie certain pathological behavior that could be classified as schizophrenia (Frith, 1992). However, saying that schizophrenic individuals show attentional deficits is rather vague if we think of the multifaceted nature of attention. Components of attention include readiness to respond to external events, orientation to locations of objects, and selection of information on the basis of physical and semantic features. Recent cognitive–anatomical studies of attention have tied these components to specific areas of the brain (for reviews, see Posner & Petersen, 1990; Posner & Raichle, 1994). This cognitive-neuroscience approach to the study of attention, therefore, might provide new insights about the underlying pathophysiology of schizophrenia (DiGirolamo & Posner, 1996).

Attentional Networks

Data from neuropsychological and brain-imaging studies have revealed that a few distinct attentional networks may be identified in the brain (Posner, Inhoff, Friedrich, & Cohen, 1987; Posner & Petersen, 1990; Posner, Petersen, Fox, & Raichle, 1988; Posner & Raichle, 1994). These have been termed *the executive network, the orienting network,* and *the alerting network.* This research is concerned with the first two.

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From a functional point of view, the executive and the orienting networks involve elementary operations related to selection of relevant information. For instance, the executive network is associated with the selection of objects on the basis of high-level characteristics (e.g., meaning), whereas the orienting network is associated with filtering relevant information occurring in specific locations. From an anatomical point of view, these attentional networks involve different areas of the brain. The areas of the executive network primarily implicated are the anterior cingulate, the supplementary motor area, and portions of the basal ganglia that supply dopamine to the frontal lobe. Positron emission tomography (PET) studies have found activation of the anterior cingulate during performance of tasks that required selection of stimuli on the basis of physical features, such as color or shape (Corbetta, Miezen, Dobmeyer, Shulman, & Petersen, 1991), or during tasks that require attention-dependent semantic processing, such as detecting animal names from a list of nouns, generating a verb for a given noun, or completing a sentence with an appropriate last word (Frith, Friston, Liddle, & Frackowiak, 1991; Nathaniel-James, Fletcher, & Frith, 1997; Petersen, Fox, Posner, Mintun, & Raichle, 1988). Frontal areas are also activated when semantic associations are made, word meanings are processed, and sentences are completed (Nathaniel-James et al., 1997; Posner, Petersen, et al., 1988). In contrast, the areas of the orienting network have a more posterior localization in the brain. Orienting attention within the visual field involves disengagement, movement, and engagement operations that have been localized in the posterior parietal lobe, midbrain areas (e.g., the superior colliculus), and some areas of the thalamus (e.g., the pulvinar), respectively (LaBerge, 1990; Posner, 1988; Posner & Petersen, 1990). Because anterior brain areas have been associated with the executive network and posterior brain areas have been associated with the orienting network, we refer to those attentional networks as the anterior attentional network (AAN) and the posterior attentional network (PAN), respectively.

Excitatory and Inhibitory Processing in Selective Attention

Selection in both attention networks takes place through excitatory and inhibitory processing. Excitatory processes selectively activate relevant information above threshold, enabling it to control our actions. Inhibitory processes are used to prevent irrelevant stimuli from taking control of our thoughts and actions (Allport, Tipper, & Chmiel, 1985; Keele & Neill, 1978; Tipper, 1985). Excitatory and inhibitory processes in the AAN have been observed in semantic priming tasks (see Nakagawa, 1991). For instance, when expectations based on prime stimuli are correct (i.e., the target *dog* follows the prime *cat*), participants respond to targets more efficiently than in a neutral condition (the target follows a neutral stimulus like the word *neutral,* or a string of Xs; Meyer & Schvaneveldt, 1971; Neely, 1977). On the other hand, if expectations based on primes are not correct (i.e., the target *dog* follows the prime *sea*), participants respond to targets less efficiently than in the neutral condition (Neely, 1977). Facilitation (benefits) in priming tasks is due to both automatic and attention-based activation from primes (Fuentes, Carmona, Agis, & Catena, 1994; Fuentes & Tudela, 1992; Fuentes, Vivas, & Humphreys, in press; Neely, 1977; Posner, Sandson, Dhawan, & Shulman, 1989). Inhibition (costs), in contrast, is just an attention-based phenomenon (Fuentes et al., in press; Neely, 1977; Posner & Snyder, 1975).

Excitatory and inhibitory processing in the PAN have been observed in visual orienting tasks. For instance, when a cue signals the most likely location in which the target will come up, participants' responses are faster if the target is presented at the cued location than if the target is presented at the uncued location, compared with a neutral condition in which no cue is presented. This advantage of cued locations with respect to uncued locations in participants' responses has been termed *the validity effect,* and it occurs even when participants do not move their eyes to the location of the cue (Posner, 1980). However, orienting does not always facilitate detection of targets at cued locations. If attention is drawn to one location by the cue and then withdrawn by either using a second central cue (the double-cue procedure) or a single cue with a rather long cue-target interval, detection is often slowed for targets presented at the original location. This is thought to reflect a bias in the attentional network to not return attention to previously explored locations and has been termed *inhibition of return* (Posner & Cohen, 1984). This spatial inhibition seems to involve some areas of the midbrain (e.g., the superior colliculus), on the basis of findings that patients with lesions in that part of the brain do not show inhibition of return (Posner, Rafal, Choate, & Vaughan, 1985).

Inhibitory Processing in Schizophrenia

Inhibitory processing has been shown to be affected in schizophrenia (for a review, see Hemsley, 1996). Major evidence of inhibitory processing deficits in schizophrenia comes from negative priming (Tipper, 1985), blocking effects (Kamin, 1969), and latent inhibition (Lubow & Gewirtz, 1995; Lubow, Weiner, & Feldon, 1982). For instance, negative priming occurs when participants respond to targets that were distractors on previous trials. Responses are slower and less accurate on these trials than on control trials (in which targets were not distractors previously; Tipper, 1985). Evidence of negative priming has been interpreted as inhibition acting on the representations of ignored stimuli during selective attention (Fuentes & Tudela, 1992; Houghton & Tipper, 1994; Neill & Westberry, 1987; Yee, 1991), although other interpretations have been also proposed (for reviews, see Fox, 1995; May, Kane, & Hasher, 1995). Active inhibition is engaged to reduce processing of distracting information so that selection of relevant stimuli can be easily reached. Several studies have shown that schizophrenic individuals and individuals scoring highly on questionnaires that measure schizotypy have deficits in inhibiting distractor information in negative priming tasks (Beech, Baylis, Smithson, & Claridge, 1989; Beech & Claridge, 1987; Beech, McManus, Baylis, Tipper, & Agar, 1991; Beech, Powell, McWilliam, & Claridge, 1989, 1990; Claridge, Clark, & Beech, 1992; LaPlante, Everett, & Thomas, 1992; Salo, Robertson, & Nordahl, 1996). This deficit in dealing with distractor information in selection tasks is also reflected in larger magnitude of interference from word meaning in patients with schizophrenia compared with controls, as it is revealed in studies that have used the Stroop Color–Word Interference Task (Cohen & Servan-Schreiber, 1992).

The Present Study

In this research, we sought to explore the attentional deficits associated with schizophrenia within the framework of anatomically related attention networks. This framework has proven useful to study deficits in attentional components underlying different pathologies (for a review, see Posner & DiGirolamo, 1998) and might help increase understanding of the symptoms underlying schizophrenia. We used an inhibition-of-return procedure that is thought to tap the PAN (Posner et al., 1985) and a semantic-inhibition task that is supposed to tap the AAN (Fuentes et al., in press).

In Experiment 1, inhibition of return was examined in a group of schizophrenic patients and a matched control group. As noted earlier, inhibition of return has an important role in biasing visual attention to explore new locations. This component serves as a filtering mechanism of information that operates early in stimulus processing, mediated by the superior colliculus. So far, few studies have examined inhibition of return in schizophrenia. For instance, Huey and Wexler (1994) reported impairments in inhibition of return in medicated patients, compared with control participants. However, because the authors did not use a second central cue to withdraw attention from the periphery, the observed impairment in inhibition of return could have been due to a deficit in the processes that control intrinsic reorientation of attention rather than due to a deficit in filtering information that appears at inhibited locations (see Faust & Balota, 1997, for a similar interpretation of a failure to observe inhibition

of return in individuals with Alzheimer's disease). Thus, additional research concerning the operation of inhibitory mechanisms associated with the PAN in schizophrenia is required.

In Experiment 2, we sought to show an inhibitory effect in the semantic domain, similar to inhibition of return in the spatial domain (Fuentes et al., in press). In this task, attention is first drawn to the category of a prime word. Then, a second word from a different category is presented to withdraw attention from the category of the prime. Now, the target can be related or unrelated to the prime, and semantic priming is measured in a lexical-decision task. Fuentes et al. have shown that this procedure is useful in measuring semantic inhibition in healthy adults. That is, related targets produce longer responses than unrelated targets when the intervening stimulus is a word but not when it is a string of Xs. Thus, we suggest that this task probably taps cognitive operations controlled and mediated predominantly by the AAN. This task can be used to investigate the manner in which this attentional network operates in the semantic network of schizophrenic patients.

Experiment 1

The purpose of Experiment 1 was to assess whether schizophrenic patients inhibit previously attended locations as effectively as healthy adults. In this experiment, we used a modified version of the inhibition-of-return procedure (Posner & Cohen, 1984). Participants were presented with three white boxes, one in the middle and two in the periphery. To measure inhibition of return, one of the peripheral boxes served as a spatial cue by changing to red. Participants were told to detect the appearance of a target word in one of the peripheral boxes, and the target could be presented either at the previously cued location or at the uncued location. The central box also changed to red before the target was presented, favoring extrinsic orientation of attention away from the previous peripheral cue. Fuentes et al. (in press) showed that this procedure is useful to measure inhibition of return in undergraduate students.

Method

Participants. Sixteen healthy adults and 16 patients diagnosed with schizophrenia participated in this experiment. Healthy adults were recruited from the Hospital General Torrecárdenas de Almería, Almería, Spain, staff. Control participants were excluded if they had histories of serious head injury, psychiatric illness, or drug or alcohol abuse. Schizophrenic adults were inpatients of the Unidad de Salud Mental del Hospital General Torrecárdenas de Almería, Almería, Spain. All participants had normal or corrected-to-normal vision and explicitly consented to participating in this study.

Age for healthy adults and the schizophrenic patients ranged from 21 to 55 years and from 19 to 40 years, respectively. Participants were matched in years of education and demographic characteristics.

Participants were diagnosed by a staff psychiatrist following the International Classification of Diseases, 10th revision (ICD–10) criteria for schizophrenia. Table 1 shows the main characteristics of patients relevant to the purposes of the present research.

Materials and apparatus. The words *gato* (cat), *dedo* (finger), *vino* (wine), and *rio* (river), printed in lowercase, served as target words for all the experimental conditions. Every letter subtended an average 0.48° by 0.38° in 40-column text mode at the viewing distance of 60 cm. Three boxes arranged horizontally were also used as stimuli for cuing purposes. The boxes subtended viewing angles of 5.4° by 1.3° when seen from the viewing distance of 60 cm. The inner sides of the two peripheral boxes were each located 4.9° from fixation. All stimuli were presented on a color monitor of an IBM/PC compatible computer (Victor Computer, Almería,

Table 1
Main Characteristics of Schizophrenic Patients

Patient	Sex	Age	Education (years)	Symptoms	Duration (years)	Medication
S.E.	F	25	8	AH, TB, DR, PD	7	NL, NL-R, A-COL
D.T.	F	19	7	TB, AX, A, DC	8	NL, A-COL, A-EPI, H
A.C.	M	31	15	TI, AH, CH, VH, TB, DR, AS, AA	11	NL, H
J.T.	M	32	8	AH, TB, DR, DC, AX, PC	16	NL, NL-R, A-COL
I.R.	M	40	17	TB, ANH, AX, PC	23	NL, A-COL, BZ, A-DP
P.P.	M	35	11	TI, AH, DC, DR, PD, AL, AX	21	NL, A-COL, H
D.M.	M	24	7	AH, DR, PD, AL, AX, SA, PC	7	NL, NL-R, A-COL
S.G.	M	30	8	TI, A-DP, DR, AH, CH, AL, AS, ANH, AA, PC	4	NL, NL-R, A-COL
M.C.	M	33	15	AH, DR, DSP, TB, AL, AS	12	NL-R, BZ
J.F.	M	36	8	TI, AH, CH, TB, A, AS	11	NL, BZ, H
J.M.	M	22	8	DSP, A	7	NL-R, BZ
J.V.	M	28	9	PD, PC	7	NL, H
J.G.	M	39	10	AA, ANH, PC, AX	17	NL, BZ, H
F.R.	M	27	8	PD, DR, DSP, PC	4	NL
F.N.	M	24	4	AH, PD	7	NL, BZ, H
J.A.	M	23	10	PD, DR, AX	4	NL, A-COL, H

Note. AH, TB, DR, PD, DC, TI, CH, VH, and DSP are positive symptoms. A, AS, AA, ANH, and AL are negative symptoms. F = female; M = male; AH = auditory hallucinations; TB = thought broadcast; DR = delusions of reference; PD = paranoid delusions; AX = anxiety; A = athymia; DC = delusions of control; TI = thought insertion; CH = corporal hallucinations; VH = visual hallucinations; AS = asociality; AA = avolition-apathy; PC = problems of conduct; ANH = anhedonia; AL = alogia; SA = substance abuse; DSP = delusions of special power; NL = neuroleptic; NL-R = neuroleptic retard; A-COL = anticholinergic; A-EPI = antiepileptic; H = hypnotic; BZ = benzodiazepine; A-DP = antidepressive.

Spain), and participants' responses were recorded through a response box interfaced with the parallel port of the computer.

Procedure. Participants sat approximately 60 cm from the computer, and the experimenter explained the task to them verbally with a drawn representation of the sequence of stimulus events (see Figure 1).

Each trial began with a fixation point (a plus sign) presented in the middle of the screen. It remained until the experimenter initiated the trial. Three white boxes then replaced the plus sign and were presented for 1,000 ms. Next, one of the peripheral boxes changed to red for 300 ms. This served as a cue to attract attention to the periphery. The boxes were then all presented in white again for 200 ms, and then the central box changed to red for 300 ms (this was done to ensure extrinsic reorientation of attention away from the previous red peripheral box). The target was subsequently presented an equal number of times either at the cued or the uncued location, within the left or right peripheral box and either 950 ms or 1,250 ms after the onset of the peripheral cue (stimulus onset asynchrony [SOA]). The target remained on the screen until the participant responded. SOA values were chosen on the basis of previous studies that showed they were appropriate to observe inhibition of return in normal controls as well as in adults with Alzheimer's disease (Fuentes et al., in press; Langley, Fuentes, Overmier, Bastin de Jong, & Prod'Homme, 1998). Participants were told to push the button on the response box with their preferred finger as soon as they detected the target. Inhibition of return was measured by subtracting reaction times (RTs) in the uncued location from RTs in the cued location.

Participants were presented with three blocks of 128 trials. The first block was considered practice and was not included in the analysis of data.

Results

We first calculated the mean and standard deviation for each participant and then removed those responses that exceeded ± 2 *SD*s from the participant's mean from the data analyses. This procedure resulted in less than 1% of all correct responses being removed.

Accuracy data. Some schizophrenic patients produced detection responses before the target was presented. These responses occurred in less than 1% of trials on average, and when analyzed by a variance analysis, they did not produce any significant effect. This kind of anticipation response as well as those exceeding the standard deviation criterion were not included in the RT data analysis.

RT data. Mean RTs are shown in Table 2. Data were submitted to a 2 × 2 × 2 × 2 mixed analysis of variance (ANOVA), with group (healthy adults, schizophrenic patients) as the between-subjects variable and location (cued, uncued), visual field (left, right), and SOA (950 ms, 1250 ms) as the within-subjects variables. The main effects of group (the schizophrenic group was slower than the healthy adult group), $F(1, 30) = 23.6$, $p < .0001$, location (responses at cued locations were slower than responses at uncued locations; i.e., the inhibition of return effect), $F(1, 30) = 79.1$, $p < .0001$, and SOA (the 950-ms SOA produced slower responses than the 1250-ms SOA), $F(1, 30) = 84.3$, $p < .0001$, were significant. The Location × SOA interaction was also significant, $F(1, 30) = 7.96$, $p < .01$. The

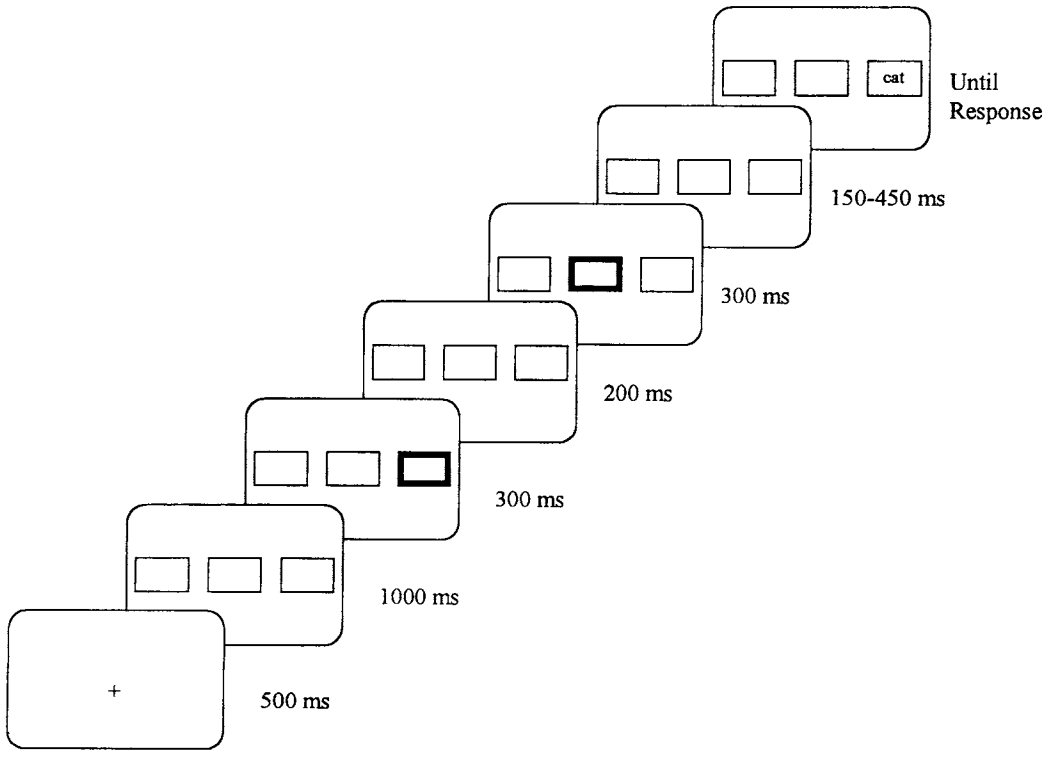

Figure 1. Sequence of events and exposure durations of stimuli in Experiment 1 using the inhibition-of-return procedure. The target has been translated into English.

Table 2
Mean Reaction Times and Standard Deviations as a Function of SOA, Location, and Visual Field for Healthy and Schizophrenic Adults in Experiment 1

Visual field and group	950-ms SOA				1,250-ms SOA			
	Cued		Uncued		Cued		Uncued	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
LVF								
Healthy adults	363	59	319	78	318	69	304	76
Schizophrenic adults	517	115	483	111	494	113	455	113
RVF								
Healthy adults	361	73	327	68	325	80	306	70
Schizophrenic adults	520	111	479	112	484	100	457	121

Note. SOA = stimulus onset asynchrony; LVF = left visual field; RVF = right visual field.

inhibition-of-return effect was bigger at the short SOA than the long SOA (38 ms vs. 26 ms), although that reduction in the inhibition-of-return effect was more pronounced in the healthy adult group (22 ms) than in the schizophrenic group (4 ms), as was indicated by the marginally significant Group × Location × SOA interaction, $F(1, 30) = 3.8$, $p < .07$. The Group × Location × Visual Field × SOA interaction was also significant, $F(1, 30) = 4.6$, $p < .05$. This four-way interaction emerged because the healthy adult group showed a statistically significant reduction in the inhibition-of-return effect across SOA, as indicated by a significant Location × SOA interaction, $F(1, 30) = 18.16$, $p < .01$, in this group; the reduction was similar for both visual fields, $F < 1$. However, the schizophrenic group showed a modest reduction in inhibition of return across SOA in the right visual field, left hemisphere (RVF/LH), and no reduction at all in the left visual field, right hemisphere (LVF/RH), although the partial Location × Visual Field × SOA interaction showing these effects was only marginally significant, $F(1, 30) = 3.29$, $p < .10$ (see Figure 2).

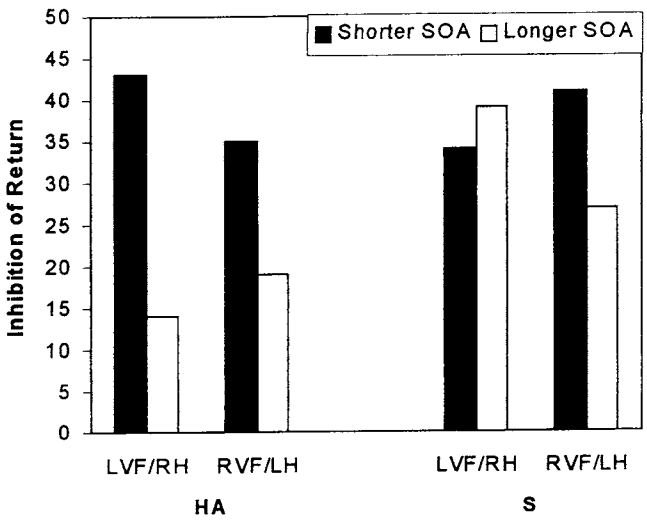

Figure 2. Inhibition of return as a function of stimulus onset asynchrony (SOA) and visual field for each group of participants in Experiment 1. LVF/RH = left visual field, right hemisphere; RVF/LH = right visual field, left hemisphere; HA = healthy adults; S = schizophrenic adults.

Discussion

The inhibition-of-return effect for healthy adults replicated that observed in previous studies with undergraduate students in a detection task (see Fuentes et al., in press, Experiment 1). The present results demonstrated that schizophrenic adults were able to filter out information that was presented at inhibited locations, as revealed by the inhibition-of-return effect found in this group. However, as mentioned in the introduction, Huey and Wexler (1994) reported deficits in inhibition of return in medicated schizophrenic patients. Although this result contradicts the present one, differences in the procedures followed in both studies might account for the discrepancy. Huey and Wexler did not use a double-cue procedure in their study. The double-cue procedure might help participants reorient attention back to the center (e.g., Abrams & Dobkin, 1994, Faust & Balota, 1997; Fuentes, Vivas, & Humphreys, 1999; Fuentes et al., in press; Posner & Cohen, 1984). Thus, the deficit reported by Huey and Wexler might reflect a delay in returning attention spontaneously to the central position. In the present experiment, we used a double-cue procedure, favoring extrinsic reorientation of attention to the middle. As a consequence, normal inhibition of return was observed. This points to inhibitory mechanisms associated with the PAN being preserved in schizophrenia, suggesting normal functioning of midbrain structures that mediate inhibition of return. However, cortical structures that control processes leading to inhibition of return might be impaired in schizophrenic patients. This also might account for the deficits in eye movements that have been observed in schizophrenia (Holzman, 1985).

Nonetheless, the significant four-way interaction found in this experiment deserves further comment (Figure 2 illustrates this interaction). For the healthy adult group, there was a strong reduction in inhibition of return with a longer SOA in both visual fields. Inhibition of return in the longer SOA was less than half the magnitude compared with that in the shorter SOA. However, that reduction was moderate in the schizophrenic group and involved only the RVF/LH. The lack of catch trials in this experiment might render the target appearance more predictable over time during the trial. Thus, the increase in target appearance predictability in the longer SOA might have caused the two groups to choose

different strategies in terms of anticipatory responding. For healthy adults, this strategy reduced the differences between the cued and uncued locations in detecting targets, and, therefore, a smaller inhibition-of-return effect was observed in the longer compared with the shorter SOA. The schizophrenic group, however, failed to show such a reduction. In contrast, they produced anticipatory responses. Thus, despite schizophrenic adults showing an inhibition of return of comparable size to that of the healthy adults, strategies in responding to delayed targets might be different in both groups of participants.

Experiment 2

In the semantic-priming procedure of Experiment 2, participants were presented with a prime word within a central box. The target (a word or a nonword), appearing either to the left or the right, followed the prime. When it was a word, it could be related or unrelated to the prime. Previous work in our lab has shown that this procedure is useful in measuring semantic priming, even when few words are used as primes and targets. Most important, when an intervening item (a word from another category) is presented between the prime and the target, the facilitatory semantic priming becomes inhibitory; that is, longer reaction times are observed in the related condition compared with the unrelated condition. Fuentes et al. (in press) accounted for this result in terms of semantic inhibition. That is, the intervening word could result in attention being withdrawn from the category of the prime. Now, when a related target is presented, attention returns to the previous category that might already be inhibited, producing a sort of semantic inhibition-of-return effect, which we refer to as the *semantic-inhibition effect.* This supports Posner's (1978) suggestion that the orienting network may be thought of as a model network, so that similar components in the spatial domain may be also found in attention within the semantic domain. Because we wanted to simulate in the semantic domain, an effect that has been usually found in the spatial domain, we used only a few words for the semantic effects, as few spatial locations are commonly used to measure spatial effects.

In this experiment, we sought to examine semantic inhibition in both healthy adults and schizophrenic patients. As mentioned before, schizophrenia has been associated with deficits in cognitive inhibition. Thus, we expected schizophrenic patients to show deficits in semantic inhibition associated with the AAN in this task.

Method

Participants. The same participants that completed Experiment 1 also participated in this experiment.

Materials and apparatus. The equipment used in this experiment was the same as in the previous experiment. The words *perro* (dog) and *mano* (hand) served as primes, the words *pan* (bread) and *mar* (sea) served as intervening stimuli, and the words *gato* (cat) and *dedo* (finger) and the nonwords *cato* and *dode,* served as targets. Target nonwords were formed by either changing a single letter (e.g., cato) or swapping two letters (e.g., dode) of the target words. Both primes and intervening words were printed in uppercase; targets were printed in lowercase. The same three boxes in Experiment 1 were used in this experiment.

Procedure. Figure 3 shows the sequence of events and exposure durations for this experiment. The procedure was similar to that of Experiment 1. The difference was that now the central box, instead of one of the peripheral boxes, changed to red. The prime word appeared inside the central red box. Then, the three boxes changed to white for 200 ms. As in Experiment 1, the central box then turned to red. This was done to ensure attention was kept at the central location. Contrary to Experiment 1, the central box now contained an intervening stimulus. The intervening stimulus was always a word from different categories to those words used as prime and target stimuli and was presented to cause attention to be withdrawn from the prime category (cf. Fuentes et al., in press). Next, the target (a word or a nonword) was presented in one of the peripheral boxes and remained on the screen until a response was made. When the target was a word, it could be either related (i.e., PERRO–gato) or unrelated (i.e., PERRO–dedo) to the prime. When the target was a nonword, it could be generated from a related target word (i.e., PERRO–cato) or from an unrelated target word (i.e., PERRO–dode). Targets were presented an equal number of times in the left and right. In half of the trials, the target was a word, and in half of the trials, it was a nonword. Participants were told to make lexical decisions to targets by pushing the proper button on the response box. In this experiment, the prime–target SOA was 950 ms.

Participants were presented with three blocks of 32 trials. The first block was considered practice and was not included in the analysis of data.

Results

As in Experiment 1, we first calculated the mean and standard deviation for each participant, and then, we removed those responses that exceeded ± 2 *SD*s from the participant's mean from the data analyses. This procedure resulted in less than 1% of all correct responses being removed.

Mean RTs and percentage errors are shown in Table 3. Data were submitted to a $2 \times 2 \times 2$ mixed ANOVA, with group (healthy adults, schizophrenic patients) as the between-subjects variable and relatedness (related, unrelated) and visual field (left, right) as the within-subjects variables. We conducted two analyses, one with target words and the other with target nonwords.

Accuracy data. With words, the main effects of group (the schizophrenic group produced more errors than the healthy adult group), $F(1, 30) = 6.6$, $p < .025$, and relatedness (related targets produced more errors than unrelated targets; i.e., the semantic-inhibition effect), $F(1, 30) = 5.5$, $p < .05$, were significant. The main effect of visual field was marginally significant, $F(1, 30) = 4.0$, $p < .06$. Targets presented to the LVF produced more errors than targets presented to the RVF. However, this difference was observed in the schizophrenic group (8.6% vs. 2.7%) but not in the healthy adult group (1.6% vs. 1.6%). This result was supported by the marginally significant Group $\times$ Visual Field interaction, $F(1, 30) = 4.0$, $p < .06$. The Group $\times$ Relatedness, Visual Field $\times$ Relatedness, and Group $\times$ Visual Field $\times$ Relatedness interactions did not prove significant, all Fs ≤ 1. The analysis of target nonwords did not produce any relevant effect.

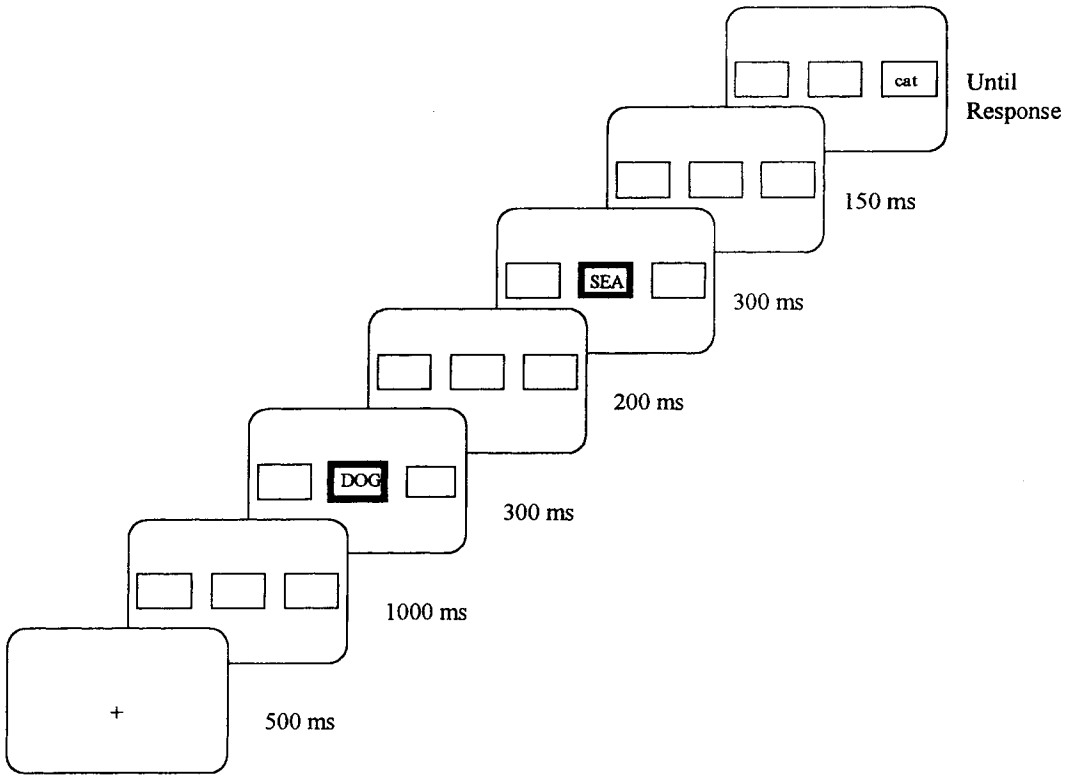

Figure 3. Sequence of events and exposure durations of stimuli in Experiment 2 using the semantic-inhibition procedure. Stimuli have been translated into English.

RT data. With words, the main effects of group (the schizophrenic group was slower than the healthy adult group), $F(1, 30) = 34.3, p < .0001$, and visual field (targets presented on the left visual field produced longer RTs than targets presented on the right visual field), $F(1, 30) = 11.5$, $p < .01$, were significant. The Visual Field × Relatedness interaction was also significant, $F(1, 30) = 9.5$, $p < .01$. Related targets produced longer RTs than unrelated targets when targets were presented to the LVF, but related targets produced shorter RTs than unrelated targets when presented to the RVF. Most important, these differences were qualified by the Group × Visual Field × Relatedness interaction, $F(1, 30) = 6.8, p < .025$. Thus, for healthy adults, related targets produced longer RTs than unrelated targets in both visual fields (27 ms of semantic inhibition for targets presented to the LVF and 16 ms of semantic inhibition for targets presented to the RVF), although the difference in the size of the effect in the two visual fields was not significant, $F < 1$. For the schizophrenic group, however, the Visual Field × Relatedness interaction was significant, $F(1, 15) = 9.6, p < .01$. Related targets produced significantly longer RTs than unrelated targets when they were presented to the LVF (67 ms of semantic inhibition), $F(1, 15) = 4.97$, $p < .05$, and shorter RTs than unrelated targets when they were presented to the RVF (65 ms of semantic facilitation), $F(1, 15) = 4.59$, $p < .05$. The main effect of relatedness and the Group ×

Table 3
Mean Reaction Times (in Milliseconds), Standard Deviations, and Percentage Errors as a Function of Relatedness and Visual Field for Healthy and Schizophrenic Adults in Experiment 2

	LVF						RVF					
	Related			Unrelated			Related			Unrelated		
Target type and group	*M*	*SD*	% error	*M*	*SD*	% error	*M*	*SD*	% error	*M*	*SD*	% error
Words												
Healthy adults	742	77	2.3	715	63	0.8	671	81	2.3	655	74	0.8
Schizophrenic adults	1,059	230	11.7	992	202	5.5	905	174	3.1	970	240	2.3
Nonwords												
Healthy adults	750	59	3.9	744	77	4.7	711	78	1.6	704	65	3.9
Schizophrenic adults	999	195	4.7	1,024	229	4.7	1,008	218	11.7	1,032	312	10.2

Note. LVF = left visual field; RVF = right visual field.

Visual Field and Group × Relatedness interactions were not significant, all Fs < 1.

With target nonwords, only the main effect of group (schizophrenic adults were slower than healthy adults), $F(1, 30) = 27$, $p < .0001$, was significant. As expected, the difference between target nonwords generated from related target words and target nonwords generated from unrelated target words was not significant.

Proportional semantic inhibition. To compare the semantic inhibition effect observed in the schizophrenic group when targets were presented to the LVF with that of the healthy adult group in this condition, we transformed the RTs to be proportional to overall RT. Previous studies have revealed that the absolute size of this kind of effect (e.g., related vs. unrelated, congruent vs. incongruent, valid vs. invalid) is related to the overall speed of participants (Faust & Balota, 1997; Spieler, Balota, & Faust, 1996). Thus, we divided each participant's condition mean by his or her overall mean and submitted the proportional data to a 2 × 2 mixed ANOVA, with group (healthy adults, schizophrenic adults) as the between-subjects variable and relatedness (related and unrelated targets presented on the LVF) as the within-subjects variable. The main effect of group failed to reach statistical significance, as did the Group × Relatedness interaction, both Fs < 1. Only the main effect of relatedness (related targets produced longer RTs than unrelated targets), $F(1, 30) = 6.5$, $p < .025$, was significant. This means that the semantic-inhibition effect observed when targets were presented to the LVF/RH did not differ between the two groups of participants.

Discussion

The results of healthy adults replicated previous findings of semantic inhibition in undergraduate students (Fuentes et al., in press). This effect mimics the inhibition-of-return effect observed in spatial cuing experiments and suggests that attention is not only oriented to space, but it is also oriented within the semantic network (see Fuentes et al., in press, for further analogies between attention to the spatial and the semantic domains). However, it is yet unclear how this semantic-inhibition effect is accounted for. Fuentes et al. (in press) pointed out that this semantic-inhibition effect can be explained by Houghton and Tipper's (1994) model of inhibition in selective attention. In their model, selection is achieved through a matching process (match–mismatch detector) between inputs generated from an object field (containing activated representations of external stimuli) and inputs generated from a target field (containing internally activated target descriptions). When a target that matches its internal representation in the target field is presented, the match–mismatch detector further increases target properties in the object field through excitatory feedback, but this is at the expense of a concurrent inhibitory circuit that is also activated when a stimulus is presented. When a distractor is presented, the match–mismatch detector suppresses distractor activation in the object field. However, as soon as the exposure of the distractor ceases, the only circuit activated is the inhibitory one, producing an inhibitory rebound that renders distractor activation below baseline level, producing inhibitory effects on performance. In the present experiment (see also Fuentes et al., in press, Experiments 2 and 3), the prime word would activate its representation in the object field, and a template in the target field is then internally generated. In the absence of extra stimulation, that would be sufficient to produce facilitation (Fuentes et al., in press, Experiment 4). When the intervening word is presented, the activation of the previous prime word ceases, and a new target representation is formed in the target field that would fit with the new information in the object field (i.e., the representation of the intervening stimulus). The activation of the previous prime word will persist for a while, but will now generate a mismatch from the match–mismatch generator. This brings about an inhibitory rebound in the representation of the prime stimulus producing the semantic-inhibition effect. This model has been useful in accounting for different inhibitory effects in the literature (e.g., spatial inhibition of return; see Houghton & Tipper, 1994), and it offers an appropriate account for the semantic-inhibition effect found here.

The semantic-inhibition effect contrasts with other studies that have found either no semantic-inhibitory effect (e.g., Dannenbring & Briand, 1982) or instead facilitation (e.g., Balota & Paul, 1996) when an intervening stimulus is presented between the prime and the target. However, there are important differences between those studies and the present experiment. First, in those studies, the prime–target SOA value was rather short, presumably involving automatic semantic priming. In the present experiment, we used a long prime–target SOA (950 ms), which is thought to involve controlled attentional processing. Posner and Snyder (1975) showed that inhibitory effects only occur when long SOAs are used, a result that has been confirmed several times in the literature (e.g., Fuentes & Tudela, 1992; Neely, 1977). A second important difference is that compared with other studies, the present experiment used a very small set of stimuli that repeated over and over. Thus, it is likely that representations of every stimulus were all highly active. It is under such conditions that the use of inhibitory mechanisms is really necessary. An inspection of the negative-priming literature reveals that most of these studies usually used few stimuli that repeated over and over throughout the experiment.

Schizophrenic patients showed a deficit in the semantic-inhibition effect associated with the AAN. However, this deficit was found only when target words were presented to the RVF, affecting mainly the LH. When target words were presented to the LVF, involving mainly the RH, semantic inhibition was then observed. This lateralized effect agrees with other studies that have found asymmetries in attention-dependent tasks in schizophrenia (e.g., Carter, Robertson, Nordahl, Chaderjian, & Celaya, 1996; Posner, Early, Reiman, Pardo, & Dhawan, 1988). For instance, Posner, Early, et al. (1988) tested schizophrenic patients in a cost and benefits procedure. They found that schizophrenic patients were slower in detecting targets presented to the RVF following an invalid cue in the LVF, but participants responded normally in the opposite direction; that is, when

targets were presented in the LVF, following an invalid cue in the RVF. This reflects a deficit in the disengagement of attention from an invalid cue in the LVF due to LH dysfunction. The present results extend the LH deficits to conditions in which attention is addressed in the semantic domain.

Like healthy adults, schizophrenic patients tended to respond more rapidly and more accurately when target words were presented to the RVF/LH, than when they were presented to the LVF/RH (see Blum & Freides, 1995, for similar results). Studies with healthy adults have shown that words presented to the RVF/LH are reported more accurately than words presented to the LVF/RH (e.g., Bryden, Mondor, Loken, Ingleton, & Bergstron, 1990), even for readers of right-to-left languages such as Hebrew (e.g., Faust, Kravetz, & Babkoff, 1993). An account for this RVF/LH advantage is that for most people, visual word recognition is achieved by neural mechanisms located in the LH, which act quickly to process the word meaning for integration with previous information (Chiarello, 1991). Thus, a word presented to the LVF/RH might suffer a processing delay equal to the time required to transmit information from the right to the left hemisphere. This RVF/LH superiority in visual word recognition is further supported from neuroimaging studies showing higher levels of activity in specific areas of the LH during passive word reading (Petersen, Fox, Snyder, & Raichle, 1990).

Instead of semantic-inhibition effects when targets were presented to the RVF/LH, schizophrenic adults showed semantic facilitation. Positive priming has been observed when conditions are not appropriate for inhibitory processing to occur. For instance, in a study with normals, Yee (1991) found negative priming from to-be-ignored primes when the interval between primes and targets was rather long, favoring inhibition processes to act (Posner & Snyder, 1975). However, when the interval was shortened, positive instead of negative priming was then reported. In this latter case, the short interval hindered the complete development of inhibition. Similarly, Fuentes and Humphreys (1996) reported a case study in which a visual neglect patient showed normal negative priming when the distractor was presented ipsilateral to the side of the lesion. Negative priming was not apparent when the distractor was presented contralateral to the side of the lesion. The authors concluded that inhibition was not applied to stimuli that were not consciously represented. However, positive priming emerged in that condition, supporting the view that neglected distractors activated their representation in memory. According to these and other related studies, we should expect positive semantic priming in conditions where either by experimental manipulation (Yee, 1991) or by neural dysfunction (Fuentes & Humphreys, 1996), inhibitory processing is hampered. That was the case here. The schizophrenic patients did not show any semantic-inhibition effects when targets were presented to the RVF/LH; however, they showed semantic facilitation. This semantic-facilitation effect agrees with other studies that have found normal priming (Blum & Freides, 1995; Henik, Priel, & Umansky, 1992) or even hyperpriming effects (Kwapil, Hegley, Chapman, & Chapman, 1990; Manschreck et al., 1988; Spitzer, Braun, Hermle, & Maier, 1993) in schizophrenic patients. The conditions under which normal priming, hyperpriming, or reduced priming will be found in schizophrenic individuals are still unclear; discrepancies between the studies may be explained by variables such as type of task, symptoms shown by the patients, duration of the illness, medication, and so forth (for a similar view, see DiGirolamo & Posner, 1996; Ober, Vinogradov, & Shenaut, 1997). In any case, the present results show that this group of schizophrenic patients activated prime representations in the memory system, producing semantic facilitation when targets were presented to the RVF/LH.

General Discussion

Compared with healthy adults, schizophrenic patients showed similar inhibition-of-return effects (Experiment 1) and semantic-inhibition effects when targets were presented to the LVF/RH, but they failed to show semantic-inhibition effects when targets were presented to the RVF/LH (Experiment 2). In this case, the schizophrenic group showed semantic facilitation. This suggests that representations of prime words, as well as those of their associates, were activated in the schizophrenic adult's semantic network, but they failed to be inhibited in conditions in which healthy adults showed inhibition. We conclude that: Functioning of inhibitory processing associated with the PAN is relatively preserved in schizophrenia (although, see the differences in the pattern of inhibition-of-return in both groups), functioning of inhibitory processing associated with the AAN is not preserved, and schizophrenia is associated with a specific rather than a general inhibition deficit.

Schizophrenia and the PAN

Schizophrenic adults showed inhibition-of-return effects of comparable size to that of healthy adults. This suggests that filtering of information located at inhibited locations seems to be intact in schizophrenia, suggesting spared midbrain functioning. This agrees with normal saccade latencies observed in schizophrenic patients when a standard saccade procedure is used (Levin, Jones, Stark, Merrin, & Holzman, 1982). Saccades seem to require an intact superior colliculus, which is also responsible for inhibition of return. However, schizophrenic individuals seem to show an abnormal pattern of express saccades, which might also be responsible for deficits in smooth pursuit eye movements (Sereno & Holzman, 1993). Although the superior colliculus has a relevant role in generating express saccades, it seems that eye movement impairments come from other areas that control the colliculus. These areas involve the prefrontal cortex and might be responsible for some of the important deficits that underlie schizophrenia: eye movements and attention deficits.

Although schizophrenic adults showed inhibition-of-return effects, the pattern of inhibition of return across SOAs differed from that of the healthy adults. In the absence of catch trials, the longer SOA could foster an increase in target

appearance predictability, allowing the development of strategies in target detection responses. Our study shows that schizophrenic and healthy adults used different strategies in responding to targets; however, the relevance of these results for the cognitive deficits underlying schizophrenia requires further research.

To conclude, the main impairments associated with the PAN seem to be localized in more cortical areas, associated with important executive functions. Comparing the present results with previous studies (e.g., Huey & Wexler, 1994), we are tempted to suggest that the mechanisms that control processes leading to inhibition of return (cf. Faust & Balota, 1997), and likely to pursuing eye movements (Holzman, 1985) and express saccades (Sereno & Holzman, 1993), are impaired in schizophrenic patients. These mechanisms seem to be mediated by the frontal cortex.

Schizophrenia and the AAN

Anterior attentional inhibition associated with the midline areas (e.g., the cingulate cortex) appears to be affected in schizophrenia. Although certain asymmetrical deficits (e.g., shifts of attention to the right side) seem to resolve with long periods of medication (Maruff, Hay, Malone, & Currie, 1995), LH dysfunction associated with attentional executive control seems to last in time. This is further supported by the present study. As can be seen in Table 1, the schizophrenic participants had relatively long periods of illness (ranging from 4 to 23 years) and were medicated as soon as they were registered and diagnosed in the hospital. After long periods of treatment, anterior attention functioning was still impaired.

How does this executive attention deficit relate to abnormal performance in cognitive tasks and to some characteristic symptoms of schizophrenia? Some cognitive tasks that schizophrenic individuals perform poorly seem to involve executive attention. For instance, Weinberger, Berman, and Zec (1986; see also Gold, Carpenter, Randolph, Golberg, & Weinberger, 1997; Goldberg, Weinberger, Berman, Pliskin, & Podd, 1987) found that schizophrenic individuals were impaired in the Wisconsin Card Sorting Test (WCST; Heaton, 1981), a test that requires intact frontal lobe functioning. Successful WCST performance requires several complex cognitive operations, including retrieval of previous responses and their associated feedback. This working-memory component seems to be essential to success in the WCST. Working memory combines a short-term storage and active manipulation of stored information (i.e., the executive control system; Baddeley, 1986). It is this executive component of working memory that correlates with WCST performance. For instance, Gold et al. (1997) asked their schizophrenic patients to perform a letter–number span task. Contrary to the more standard digit span task, which mainly requires passive storage, the letter–number span task required the participants to order the letters and numbers, involving the executive control component of working memory. Gold et al. found that it was this latter task that was a good predictor of WCST performance in the schizophrenic group. This suggests that it is the executive control component, mediated by the frontal cortex, that is responsible for the impaired performance exhibited by schizophrenic individuals on the WCST.

Schizophrenic individuals also show an abnormal activation of remote associates during indirect semantic priming (Spitzer et al., 1993). PET studies have demonstrated that semantic processing of words activates the left dorsolateral prefrontal cortex, an area that has strong connections with the cingulate cortex (Petersen et al., 1988). Activation in the semantic network is modulated by dopamine (see Kischka et al., 1996), which is supplied to the cingulate cortex by some portions of the basal ganglia (e.g., the globus pallidus), which seem to be impaired in schizophrenia (Early, Posner, Reiman, & Raichle, 1989a, 1989b). This suggests that the abnormal activation in the schizophrenic individual's semantic network is likely due to deficits in the control of spreading activation within the semantic network, brought about by a dopamine dysfunction in some parts of the AAN (basal ganglia and cingulate cortex).

The observed failure to control selective operations in the semantic network might account for some characteristic symptoms underlying schizophrenia. For instance, some studies have shown that LH dysfunction correlates with hallucinations (e.g., Carter et al., 1996). Auditory hallucinations might arise because the semantic areas are hyperactive because of poor control from the AAN and dopamine dysregulation (for a review, see DiGirolamo & Posner, 1996). Thought disorders might be caused by impairments in inhibiting distracting information, as it is revealed in negative-priming studies (e.g., Beech, Powell, et al., 1989) and Stroop Color–Word interference (e.g., Cohen & Servan-Schreiber, 1992). Thus, by looking at the pattern of perceptual and high-level cognitive deficits shown by schizophrenic patients when they perform cognitive tasks and by comparing these patterns with those shown by healthy adults and other neurological patients, we hope to better understand the cognitive impairments of schizophrenia. The present research, together with other related studies, provides accumulative evidence showing dysfunction of the executive AAN that takes place in the LH.

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