Proper Names and Noun-to-Determiner Movement in Aphasia: A Case Study

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Proper names (PN) have properties that are different from those of common names (CN) and as such underlie different syntactic rules. According to one of these rule, in many languages, PN, unlike CN, do not take the determiner. It has been suggested that this happens because PN move themselves from noun position to determiner position. The present study addressed the question of whether noun to determiner movement should be just considered a formal description or rather reflects actual processing. A single aphasia case study and a group study on Alzheimer's patients provide experimental support to the view that movement from nominal to determiner position reflects some psychological computation.

INTRODUCTION

Both semantic and syntactic differences distinguish common nouns (CN) from proper names (PN). The most important syntactic differences, in Italian as well as in other languages, concern the conditions for taking or not the determiner. Among the basic rules, those of interest here are the following:

(a) singular count nouns cannot occupy an argument position without an overt determiner;

(b) plural and mass nouns can, instead, dispense with the determiner, being subject to an indefinite interpretation (e.g., ''I eat potatoes,'' ''I drink wine'');

(c) PN also do not take the determiner.

Since PN are not plurals, nor mass, and are not, as such, subject to indefinite interpretation, Longobardi (1994) argued that they do not take the determiner because they take the determiner position themselves. This would be possible because PN are rigid designators, essentially prototypical referential expressions.

Taking the determiner (D-) position implies ''movement'' from the nominal head (N-) position. According to Longobardi (1994; 1999), N-to-D movement occurs on the basis of a prototypicality hierarchy:

(a) under no condition for CN;

(b) under all conditions for some names, i.e., the most prototypical PN, like pronouns;

(c) more or less frequently for all other names; person names (forenames and surnames), geographical names, names of the days of the week etc.

This hierarchy is very complex in Italian, where, in addition, there are dialectal variations. However, some variations are more stable and ubiquitous than others. For instance, there is a difference between surnames of males, which (with some exceptions) do not take the determiner (e.g., ''Clinton'') and surnames of females, which must take the determiner (e.g., ''la Allbright''). Another difference is that between cities and ''small and far islands'' on the one side, and states, regions, and ''large and close islands'' on the other. The former group does not take the determiner (Roma, Capri, Cuba) and requires the preposition ''a'' (to) in locative complements. The latter group, instead, takes the determiner and requires the preposition ''in.''

The present study addresses the following question: should movement from N-position to D-position be considered just a formal description of grammatical competence or does it reflect actual processing? An answer was sought by neuropsychological methods. An aphasic patient, affected by a typical case of agrammatism, was tested. Furthermore a group of patients affected by Alzheimer's disease, that are thought to be relatively depleted on processing resources, was also tested. A greater difficulty in cases where movement is required would indicate that the grammatical theory underlies performance processes, though at a certain level of abstraction.

EXPERIMENTAL INVESTIGATION

A first task (A, ''completion'') required sentence completion. Overall, 220 sentences including 60 surnames of famous people (30 males and 30 females), 60 common names (30 grammatically female and 30 grammatically male), 60 geographical names (30 belonging to cities, small and far islands and 30 belonging to states, regions or large and close islands) and 40 geographical names in locative context were visually presented to the subject.

Surnames were embedded in subject position (e.g., ''__ XXX conduce il telegiornale'', XXX reads the news on TV), direct object position (they chose __ XXX for a program) and prepositional object position (they gave a medal to __ XXX). Geographical names were also presented in sentences to be completed (__ XXX is a French island); a condition where sentences had to be completed with a preposition was also administered (the fisherman went -__ Capri). The subject was asked whether or not the void space had to be completed with the determiner (or, in the case of the preposition, with ''a'' or ''in''). The score was calculated as the number of correct responses over the number of items where the subject could demonstrate knowledge of person or of the place.

A second task (B, ''verification'') was built requiring the subject to judge whether a sentence was correct. A subset of the same sentences used in task A was administered. This time however there was nothing missing: each sentence was either completed with the determiner or not (in half of the cases the completion was wrong and in the other half it was correct).

AGRAMMATIC PATIENT BO

BO, is a 57-year-old right-handed hairdresser, with 7 years of education. She suffered from a hemorrhagic infarction in September 2000, after which she developed a severe left hemiplegia and aphasia. The CT scan showed a large area of hypodensity in the left fronto-temporal area extending deeply to the basal nuclei with a compression and dislocation of the left lateral ventriculum. A first language assessment was performed four weeks after the onset of the disease. The Aachener Aphasie Test classified her profile as Broca's aphasia and indicated a severe agrammatic production. Despite her effortful output she had relatively mild articulation problems and produced very few phonetic paraphasias. She produced instead, many morphological errors in both spontaneous and constrained production (repetition, reading, and writing). The large majority of these errors consisted of the omission of inflectional and derivational suffixes. This is a very unusual pattern for agrammatism in Italian, where substitution with the unmarked form is rather the rule: this aspect of the patient's performance will be however reported elsewhere. BO's performance in the Token test was poor (26/50 errors) whereas auditory and written comprehension were almost

TABLE 1
BO's Performance in Sentences Completion and Verification Task

	Completion task			Verification task	
		% Error			% Error
	N	T1	T2	*N*	T2
Surname (argumental position)					
Females	30	10	6,7	30	10
Males	30	90	90	29	79.3
Common names (argumental position)					
Grammatically female	30	3,3	10	29	3,4
Grammatically male	30	6,7	3,3	30	6,7
Geographical names (argumental position)					
Cities	30	80	83,3	23	69,6
States	30	3,3	10	24	12,5
Geographical names (locative context)					
Cities	20	80	50	10	80
States	20	30	20	15	33,3

preserved where syntactic and morphological factors were not crucial. Only mild difficulties emerged in naming as well as in both reading and writing. Her digit span was 5, and her Babcock story recall was normal.

Bo's Performance

Table 1 summarizes BO's performance on task A performed in two different sessions, at five (T1) and eight (T2) weeks after the stroke, and on task B (only at T2).

In both tasks, BO was impaired with surnames of males and names of cities while she was almost perfect with surnames of females, names of countries, and common names required the determiner. She produced many more errors with cities, requiring the proposition ''a'' (to) in the locative complements, with respect to countries that required the preposition ''in.'' No difference was found with respect to the subject, direct object, and prepositional object position. BO's failing performance was not at chance, but it rather indicated that she actively made the wrong choice.

ALZHEIMER'S PATIENTS AND CONTROLS

Fifteen Alzheimer's patients (10 females and 5 males) and fifteen age- and education- matched nonneurological, chronically diseased patients also participated in the experiment, just taking task A only. The admission criteria for Alzheimer's participants were that: (a) they should know at least four famous people or places per condition; (b) they should show a mild medium deterioration on the Mini Mental Test and no more than a mild comprehension deficit on the Token Test.

Alzheimer's Patients' and Controls' Performance

Table 2 summarizes the performance of Alzheimer's patients and of controls. Control subjects performed almost at ceiling and did not show any difference between movement-requiring and non-movement-requiring sentences in the surname sentences and in the geographical sentences. No difference was also found between the

TABLE 2
Alzheimer's Patients and Controls Performance in
Sentences Completion Task

	Alzheimer's patients % Error	Controls % Error
Surname (argumental position)		
Females	18	3
Males	24	3
Common names (argumental position)		
Grammatically female	15	5
Grammatically male	10	4
Geographical names (argumental position)		
Cities	25	6
States	9	2
Geographical names (locative context)		
Cities	11	1
States	5	0

geographical sentences requiring ''a'' and those requiring ''in.'' Also with the Alzheimer's patients the surname test did not yield significant effects. The same happened with geographical sentences requiring prepositions. However, with geographical names, a significant difference ($p < .0042$) in the expected direction was found. In this case most of the Alzheimer's patients, individually, seemed to answer at chance with the names requiring movement. No difference was found with respect to the subject, direct object, and prepositional object position.

CONCLUSIONS

The results suggest that movement from N-position to D-position may indeed reflect some actual psychological computation, and, as such, require processing resources. The agrammatic patient seemed to ignore the special rule that applies to proper names, just behaving as they were common names. Alzheimer's patients, instead, performed at chance, as if missing the necessary resources to consistently apply the correct rule. The failure to find significant effects in the surname test in the Alzheimer's group may be due to the patients' dialect. A repetition of the experiment with speakers of a regional variation closer to standard Italian is required.

In conclusion, linguistic theories stating that PN are able to move to D-position, that could obviously stand without this evidence, receive nonetheless experimental support and appear plausible as a base for a psychological algorithm.

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Behavioral Disorganization in Schizophrenia during a Daily Activity: The Kitchen Behavioral Scoring Scale

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Executive dysfunction has been extensively described in schizophrenia and has been found to correlate with the negative symptoms of the disease. However, executive dysfunction is usually assessed by cognitive tests, and these are not necessarily good predictors of an individual's daily functioning. This study aimed to discover whether executive dysfunction in schizophrenia can be measured by analyzing a daily routine such as cooking a meal. Behavior was scored on the basis of the optimal sequence of macrostructures (order of dishes) and micro-steps (order of actions) that must be performed to prepare the meal in a minimum of time and with the smallest delay between the completion of the first and last dishes. The results showed that patients with schizophrenia make macrostructure but not micro-step sequencing errors. The number of repetitions and omissions and the delay between the completion of the first and last dish were all greater in patients than in control subjects. In patients with schizophrenia, but not in normal controls, these behavioral malfunctions were significantly correlated with both negative symptoms and performance on the executive tasks. Poor performance on the memory tests was not correlated with the behavioral malfunction. Therefore, daily functioning in schizophrenia may be specifically influenced by executive dysfunction in schizophrenia, and this can be quantitatively assessed with a behavioral scale of action sequences.

INTRODUCTION

Cognitive dysfunctions have been extensively described in schizophrenia (Pantelis, Barnes, Nelson, Tanner, Weatherley, Owen, & Robbins, 1997; Seltzer, Conrad, & Cassens, 1997; Weisbrod, Kiefer, Marzinzik, & Spitzer, 2000). These cognitive deficits are characterized mainly by memory disturbances and executive dysfunctions, including intellectual slowness (bradyphrenia), and by some specific attentional impairments that may induce shifting deficits or planning difficulties. Among the clinical features of the illness, the negative symptoms (blunted affect, social avoidance, etc.) are found to be more closely associated with these executive dysfunctions than the positive symptoms (delusions, hallucinations, etc.) (Mahurin, Velligan, & Miller, 1998; Poole, Ober, Shenaut, & Vinogradov, 1999).

Until now, executive dysfunctions have been measured using neuropsychological tests, and negative symptoms are still assessed with clinical scales. However, these measures are not necessarily good predictors of the behavioral disorganization of schizophrenic patients in their everyday life. No methods have yet been developed to directly assess how executive dysfunctions or negative symptoms in schizophrenia may affect daily activities.

Studies showing the detrimental impact of executive deficits or negative symptoms in everyday life have been limited to indirect estimations of the patients' integration into their social, familial or professional community (Addington & Addington, 2000; McFarlane, Dushay, Deakins, Stastny, Lukens, Toran, & Link, 2000). Some authors (Velligan, Bow-Thomas, Mahurin, Miller, & Halgunseth, 2000) have shown that verbal memory may predict the community integration of patients with schizophrenia, and that neuropsychological tests of executive functions may predict their daily living. However, the most commonly used method for evaluating daily functioning or community integration is limited to the time spent in the community without hospitalization. For instance, the therapeutic efficacy of different neuroleptics is frequently compared based on patients' ability to keep a job without interruption for at least six months. Such methods do not allow one to specify which cognitive or behavioral functions are specifically involved in this ability.

This study is an attempt to develop a behavioral scale that could be used to quantify the ability to carry out a daily activity such as cooking a meal. We predicted that the executive dysfunctions and negative symptoms, but not the memory impairment, associated with schizophrenia would be correlated with the severity of the behavioral disorganization during this daily activity.

METHOD

Subjects

Seventeen subjects with schizophrenia (7 females and 10 males) and 14 control subjects (6 males and 8 females) participated in the study. The control subjects were healthy volunteers recruited from the general population, who did not have any neurological or psychiatric condition. Patients with schizophrenia were diagnosed based on the DSM-IV criteria for the paranoid, residual, undifferentiated, or disorganized forms of the syndrome. These patients were not institutionalized and were known to be autonomous in their everyday life. None of the patients had a diagnosable neurological disease and none suffered from substance abuse. Following a description of the experiment, informed consent in writing was obtained from all subjects.

Procedure

Clinical symptoms were assessed with the Positive and Negative Symptoms Scale (PANSS) (Kay, Opler, & Lindenmayer, 1988). Planning and shifting deficits were assessed with the Porteus Maze (Porteus, 1965) and Trail Making Tests (Reitan & Wolfson, 1985). Attentional functions were assessed with the Stoop Interference Task (Chatelois, Pineau, Belleville, & Peretz, 1993) and the Ruff 2 and 7 Selective Attention Test (Ruff, Evans, & Light, 1986). The Wechsler Memory Scale—Revised (Wechsler, 1987) was also administered to assess episodic memory, and subtest scores were derived from the Logical Memory, Visual Reproduction, and Verbal Pair Associated tests, with both immediate and delayed recall. These tests have previously been found to highlight the memory and executive deficits in schizophrenia (Frith, 1992).

All subjects were videotaped in a hospital kitchen during a behavioral script task: cooking a meal. Subjects were required to completely prepare, simultaneously and within one hour, the four dishes that constitute the meal. The script was designed to allow for the scoring of behaviors according to macrostructure subdivisions of actions, which in turn may be subdivided into micro-step sequences of actions (see Fig. 1). Macrostructures comprise the separate dishes that must be prepared successively, such as the dessert and vegetables, followed by the meat and the soup. Micro-steps include the sequence of actions within the preparation of a specific dish, such as opening the can of soup, pouring it into a saucepan, measuring and adding milk, heating, stirring, and regularly checking the cooking. The scoring scale was constructed on the basis of an optimal sequence of micro-steps of actions, both within and between the macrostructures, that is, the best possible sequence of actions that must be performed to complete the meal in a minimum of time, and with the least delay between the completion of the first and last dish. This optimal sequence of actions involves beginning with the dishes that take the most time to be completed,

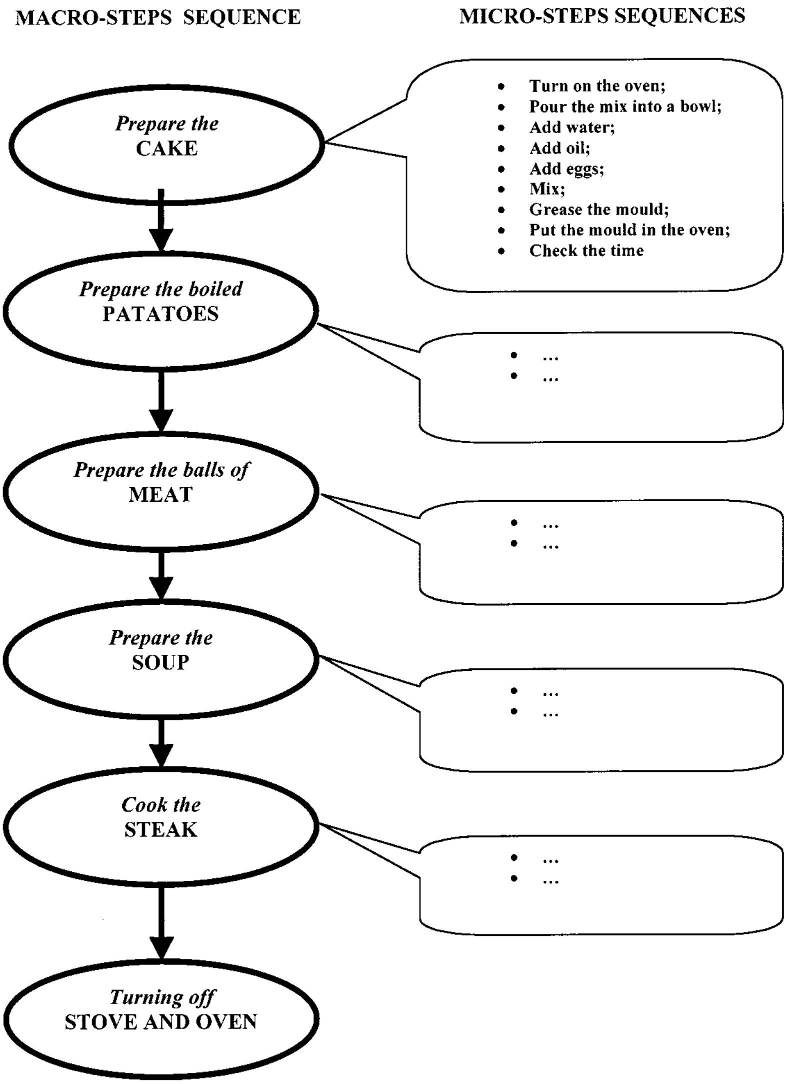

FIG. 1. The macro- and micro-steps of actions in the kitchen behavioral scoring scale.

and interrupting the preparation of one dish at a specific critical moment in order to begin or continue the preparation of another one. For instance, the preparation of the soup must be interrupted just before it is heated up, in order to prepare the meat, which takes less time to be cooked.

Each subject's actual sequences of actions were contrasted to the optimal sequences and scored according to the number of disorganized behavioral events that occurred within the macro- or micro-sequences of actions. These behavioral events included:

(1) *Omissions:* A micro-step or a macrostructure was forgotten (example of micro-step omission: not pouring water into the soup);

(2) *Repetitions:* A micro-step or macrostructure was repeated (example of a micro-step repetition: adding the same ingredient twice). Checking the progress of the cooking was not considered as a repeated step, and was counted separately;

(3) *Sequencing Errors:* These were divided into two categories:

(A) *Micro-step sequencing errors:* Nonoptimal sequence or inversion of micro-steps in a macrostructure (example: putting the meat in the frying pan before turning on the stove during the meat preparation, which lengthens the cooking time). Inversions were tolerated for some specific steps, if they did not affect the optimal performance (example: turning on the oven either before or after opening the cake mix box);

(B) *Macrostructure sequencing errors:* Wrong ordering of the macrostructures or inappropriate micro-step shifts from one macrostructure to another (example: interrupting the optimal sequence of actions for the preparation of the potatoes to begin preparing the meat and then going back to the potatoes or to another dish).

RESULTS

The schizophrenic and control groups were compared to each other on all variables, using the Student *t* test. In both groups of subjects, relationships were also assessed between the behavioral scale on the one hand and the clinical and neuropsychological measures on the other hand.

There was no difference between the two groups in terms of age (controls: 27.2 ± 9.6; schizophrenic patients: 26.9 ± 7.9) and education (controls: 10.5 ± 1.1; schizophrenic patients 11.4 ± 2.31. Two patients did not complete the Stroop Interference Task and one refused to bake the dessert for the behavioral task. Their scores were excluded from the result analysis.

The number of micro-step sequencing errors and verifications during the behavioral script task did not differ between the two groups. The other measures derived from the behavioral task, that is, the number of omissions, repetitions, and macrostructure sequencing errors, were all significantly higher in patients with schizophrenia than in the control group (see Table 1). In addition, compared to normal controls, patients with schizophrenia let almost triple the amount of time elapse between the completion of the first and last dish, and this difference is statistically significant.

Patients with schizophrenia were consistently impaired on all the executive and memory tests compared to the control group (see Table 2). In addition, the patients' performance on most of the executive tasks was significantly correlated with their poor performance on the behavioral script task (see Table 3). More specifically, the Stroop Interference Task showed a significant correlation with the number of macro-sequencing errors, the number of repetitions, and the delay between the completion of the first and last dish. The Trail Making Test correlates with the number of omissions.

In the memory tests, the performance of patients with schizophrenia did not corre-

TABLE 1
Scores on the Kitchen Behavioral Scale

Variables	Patients with schizophrenia	Control subjects	DF	*t*
Macro-sequencing errors	9.36 (4.15)	5.88 (1.64)	22	3.48**
Micro-sequencing errors	3.18 (1.72)	3.13 (1.13)	22	1.26
Number of omissions	3.91 (3.5)	0.75 (0.46)	22	3.51**
Number of repetitions	6.91 (6.46)	0.20 (0.45)	22	3.24**
First/last dishes delay	35.05 (18.46)	11.44 (5.80)	22	4.86**
Number of checks	17.55 (7.03)	24.38 (13.61)	22	1.50

Note. Values are means and standard deviations (in parentheses).
** $p < .01$ level.

TABLE 2
Results on the Neuropsychological Tests

Variables	Patients with schizophrenia	Control subjects	DF	*t*
Immediate recall (WMS)				
Logical memory	12.94 (5.30)	26.38 (10.47)	23	4.31**
Visual reproduction	31.06 (7.38)	36.25 (2.31)	23	2.10*
Verbal pair associated	18.00 (5.23)	21.75 (2.19)	23	2.58*
Delayed recall (WMS)				
Logical memory	9.29 (5.44)	22.63 (10.38)	23	3.42**
Visual reproduction	24.50 (11.00)	33.63 (2.77)	23	3.43**
Verbal pair associated	7.25 (1.06)	8.00 (0)	23	3.16**
Executive functioning				
The Ruff Selective Attention Test	219.25 (67.8)	295.38 (61.08)	23	2.67*
Stroop Interference Test	145.27 (47.02)	108.63 (24.31)	21	2.46*
Trail Making Test (B-A)	123.06 (122.59)	47.88 (50.71)	23	2.17*
Porteus Maze Test	10.94 (2.98)	14.75 (2.25)	23	3.54**

Note. Values are means and (standard deviations).
* $p < .05$.
** $p < .01$.

late with any measures in the kitchen behavioral task (see Table 3). Clinical symptoms, as measured with the PANSS, showed that the negative, but not the positive, subscale correlated well with the number of macro-sequencing errors, and with the delay between the completion of the first and last dish. There were also significant correlations between the negative symptoms of patients with schizophrenia and the scores obtained on all the executive tests ($p < .05$).

TABLE 3
Correlations between Cognitive, Psychiatric, and Behavioral Measures

Cognitive and psychiatric measures	(KBSS) Macrosequencing errors	(KBSS) Microsequencing errors	(KBSS) Omissions	(KBSS) Repetitions	(KBSS) First–last dish delay
Memory					
Immediate Recall					
Logical memory	.10	−.14	−.37	.03	−.06
Visual reproduction	−.17	−.56	−.53	−.01	−.56
Verbal pair associated	.17	−.21	−.36	−.07	.07
Delayed Recall					
Logical memory	−.05	−.12	−.38	−.01	−.09
Visual reproduction	−.09	−.46	−.48	.24	−.23
Verbal pair associated	.04	−.27	−.51	.20	−.15
Executive Functioning					
The Ruff Selective Attention Test	−.05	−.46	−.43	.81	.28
Stroop Interference Test	.87**	.13	.54	.73*	.76**
Trail Making Test (B-A)	.26	.62*	.62*	−.14	.19
Porteus Maze Test	−.24	−.61*	−.47	−.20	−.47
PANSS					
Negative symptoms	.72**	.43	.14	.59	.80*
Positive symptoms	−.14	−.08	−.53	−.12	.06

Note. KBSS = Kitchen Behavioral Scoring Scale.
* $p < .05$.
** $p < .01$.

DISCUSSION

The high number of macrostructure sequencing errors in patients with schizophrenia may indicate poor planning, that is, a wrong ordering of dishes. In point of fact, patients with schizophrenia do not always begin the meal preparation with the dessert or potatoes, even though these take more time to cook than the two other dishes (soup and steak). All the normal subjects started preparing the dessert and potato dishes at the very beginning. This kind of planning deficiency has previously been described in patients with schizophrenia (for a review, see Heinrichs & Zakzanis, 1998), and our study shows that this may contribute to the disorganized behavior seen in their everyday life. The high number of macrostructure sequencing errors cannot be attributed to the patients' unfamiliarity with meal preparation given that all of them were known to be autonomous and to prepare their own meals regularly.

Macrostructure sequencing errors not only affect the ordering of dishes but also indicate inefficient and redundant shifting between the micro-steps included in different macrostructures. In other words, patients with schizophrenia tend to shift from one macrostructure to another macrostructure at the wrong micro-step location. The higher number of omissions and repetitions may also be related to the high number of macrostructure sequencing errors, in that changing from one dish to another requires remembering the dish (macrostructure) and action (micro-step) that have been set aside, in order to come back to them later. This corresponds to the definition of prospective memory (remembering to do an action later). Prospective memory involves multiple executive functions, in that it requires one to maintain an intention to do an action that must be accomplished in the future, and to share attention between the planned action and routine activities (Okuda, Fujii, Yamadori, Kawashima, Tsukiura, Fukatsu, Suzuki, Ito, & Fukuda, 1998). A failure of prospective memory would produce inappropriate sequencing of actions, which would prolong the preparation time for the entire meal. In our study, this was demonstrated by the delay between the completion of the first and last dish, which was found to be three times higher in patients with schizophrenia than in normal controls.

Out of all the neuropsychological tests administered in this study, the Stroop attentional task was found to be the best predictor of performance on the Kitchen Behavioral Scale. Given that the Stroop is known to measure sensitivity to interference, one might suggest that omissions, repetitions, and inappropriate sequencing of actions may result from excessive distractibility, that is, poor resistance to interference during the course of a daily activity. Such distractibility is observed in attention deficit hyperactivity disorder (ADHD). Subjects with ADHD show dysfunctions in goal-directed behaviors. These patients' actions are frequently interrupted and uncompleted. There are also numerous shifts from one action to another, resulting in behavioral disorganization. A similar distractibility in schizophrenia could explain why so many patients left some dishes unfinished during the Kitchen Behavioral Script task.

Previous studies have described patients with frontal cortical lesions who were completely disorganized in daily activities that involve multitasking, such as cooking a meal (Burgess, 2000; Penfield & Evans, 1935) or shopping for multiple items (Shallice & Burgess, 1991). However, the authors have always reported this evidence anecdotally, without quantitative measures. Our study showed that it is possible to measure such behavioral disorganization during the preparation of a meal. The behavioral disorganization observed in schizophrenia in the Kitchen Behavioral Scoring Scale might also be observed in patients with frontal lobe lesions or any other clinical population with executive dysfunctions. For instance, preliminary data obtained in our laboratory shows that patients with Parkinson's disease—who are known to be affected in executive-sensitive tasks—produce an abnormal number of macrostructure sequencing errors in the Kitchen Behavioral Scoring Scale, and this correlates well with their performance on the executive neuropsychological tests (Paquet, Chouinard, Cohen, & Bédard, 2000). It seems therefore that executive or frontal lobe dysfunctions affect daily activities, and that this may be measured both quantitatively and ecologically.

The present experiment also demonstrated that the severity of the negative symptomatology correlated well with the patients' impairment on the Kitchen Behavioral Scoring Scale and with their dysexecutive syndrome as estimated by the neuropsychological assessment. Our results therefore provide an ecological validation of earlier studies demonstrating that patients with negative symptoms have executive deficits and significant disorganization in their everyday life.

In conclusion, executive (or frontal lobe) dysfunction in schizophrenia may have a real detrimental impact on daily activities such as cooking a meal. Negative symptoms and cognitive tests sensitive to executive functions are the best predictors of this behavioral disorganization. However, the latter does not correlate with the poor performance observed on memory tests. Measuring behavioral disorganization as it occurs in the patient's natural setting can lead to a better evaluation of the real impact of the illness, and of its treatment.

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Time Estimation Could Be Impaired in Male, but Not Female Adults with Attention Deficits

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The ability to judge the passage of time is critical to behavioral regulation and planning and can be impaired among individuals with attention deficit. Time estimation was tested in young adults screened for attention deficit, based on scores of a self-report questionnaire for attention problems (CAARS), using a prospective reproduction paradigm. Four time intervals (3, 6, 12, and 24 s) were tested in two conditions: (1) reproduction of the duration of a visual stimulus and (2) reproduction of an empty time interval. A significant interaction between gender and group was found suggesting that males, but not females, with attention deficits made larger errors than controls. Males with attention deficits and both groups of females made larger underestimations of time judgement than control males.

INTRODUCTION

Time estimation is critical to most sensorimotor tasks and appears to involve widespread areas of the brain, depending on the particular task. Working memory and self-regulation (e.g., internalization of speech) are executive functions that contribute to the development of a sense of time (Barkley, 1997). These functions are delayed in children with ADHD (Barkley, 1997) and may affect the child's ability to plan behavior and defer reinforcement.

Time judgement has been found to be impaired in both children (Cappella et al., 1977; Barkley et al., 1997) and adolescents (White et al., 1979) who had been diagnosed with attention problem. A nonsignificant trend toward impaired time estimation was found in young adults with ADHD (Barkley et al., 1996). The cumulative results of these studies suggest that ADHD individuals are less accurate in their sense of time than controls. The direction of the discrepancy appears to be a function of the paradigm tested. ADHD participants tend to overestimate verbal estimates of time durations but to underestimate time interval in reproduction tasks (Barkley, 1997). This tendency may be related to internal counting, as this strategy is commonly used for intervals greater than one second (Wearden et al., 1997) and has been shown to be unrelated to motor impulsivity (Sonuga-Barke et al., 1998).

In the present study, time estimation was tested in young adults with and without attention problems. A reproduction paradigm was used, similar to that used by Barkley et al. (1997) in their study with ADHD children. Durations ranging from 3 to 24 s were chosen based on Barkley et al.'s (1997) findings of greater error on time estimation for intervals below 24 s.

We hypothesized that participants with attention deficit (AD) would tend to make larger underestimations of time and show greater within-subject variability than controls in experiments using interval or duration measures. In addition, since time estimation is variously studied by replication of the duration of appearance of a sensory stimulus (e.g., Barkley et al., 1997) or by replication of an ''empty'' interval marked by two stimuli (e.g., White et al., 1979), we compared time estimation within subjects using both types of stimulus presentation. Finally, we examined whether there would be an interaction between gender and attention deficit. A recent meta-analysis of gender differences in ADHD revealed that girls scored lower on intellectual ability, hyperactivity and externalizing behavior (Gaub & Carlson, 1997). However, gender differences in time judgment have not been explored.

METHODS

Subjects

Forty-three students of Ben-Gurion University of the Negev, ranging in age from 18 to 29, participated in the study. The participants were divided into two groups (attention-deficit or controls) based on their performance on the Conners' Adult ADHD Rating Scale (CAARS) (Conners et al., 1999) (long self- report version translated to Hebrew). Since there are no norms for this scale in Israel, 2 different criteria for inclusion in the AD group were used. The criteria involved the four following profiles: (1) profile E—DSM-IV Inattentiveness Type; (2) profile F—DSM-IV Hyperactive Type; (3) profile G—DSM-IV Combined Type; (4) profile H—ADHD Index. First, the raw scores on the four profiles were considered and participants scoring at least 1 *SD* above the mean on at least two profiles were assigned to the AD group. The second criterion was based on the average *T* scores above 65 on the four profiles. The groups comprised 7 male and 5 female participants in the AD group ($X \pm SD$ age 23.39 $\pm$ 2.23) and 14 male and 17 female participants ($X \pm SD$ age 24.63 $\pm$ 1.8) in the control group.

Procedure

All participants were tested in a laboratory after removing their watches and any other external time cues. Each participant performed two experiments, under the ''duration'' or ''interval'' conditions. The order of the two experiments was counterbalanced among participants. Each experiment lasted approximately 15 min. The CAARS questionnaire was administered during a break between the experiments.

Duration experiment. A visual stimulus, a yellow square ''smiley'' face 2.3 $\times$ 2.3 cm on a gray background, appeared for a given time (3, 6, 12, or 24 s). At the termination of the duration, the stimulus disappeared and a question mark appeared cueing the participant to reproduce the time interval by pressing the space bar for the estimated time duration. The stimulus appeared on the screen for the duration of the bar press.

Interval experiment. The participants were instructed to reproduce an empty time interval (a blank screen for 3, 6, 12, or 24 s) marked by the appearance of a ‘‘smiley’’ stimulus for 2 s at the beginning and end of the interval. Following the offset of the second stimulus, a square smiley with a question mark appeared on the screen cueing the participant to reproduce the time interval. The reproduction of the interval was performed by pressing the space bar for the duration of the estimated interval. With the press of the bar, the cue was replaced by a blank screen for the duration of the bar-press, mimicking the interval condition.

In each experiment each of the four time stimuli was presented 10 times (40 trials) in a quasi-random order, such that no interval appeared more that twice consecutively. Before each experiment, the participant performed three practice trials, which consisted of time intervals of 2, 10, and 15 s appearing randomly. The experimenter determined the onset of the next trial by pressing the ENTER key following the participant’s response.

Scoring

The mean and standard deviations of the participant’s reproduction of the four time intervals were computed in the two experiments. Trials in which the time estimation deviated by more than 2 standard deviations from the mean were excluded.

The raw time reproductions were converted into three different scores, in order to attain the maximum information:

Absolute discrepancy score. This measure was the absolute value of the magnitude of the discrepancy between the participant’s time reproduction and the interval presented (in milliseconds). Absolute values are calculated so that if a particular participant tended to err in the direction of both over- and underestimation, the average error would not tend towards zero (erroneously indicating perfect time reproduction) (Barkley et al., 1997).

Accuracy coefficient score. The direction and magnitude of the reproduction error was measured as the quotient of the participant’s time reproductions divided by the duration of the interval presented. Since this score is a ratio score, it is proportional to the magnitude of the time interval, i.e., a 2-s error for 3-s interval is equivalent to a 16-s error for the 24-s interval. Thus, scores of 1.00 equal perfect reproductions of the sample interval, scores above 1.00 reflect overestimations, and scores below 1.00 reflect underestimations (Barkley et al., 1997).

Coefficient of variance. The participant’s internal consistency was measured using the quotient of the standard deviations/10 trials of each time interval divided by the mean.

Statistical Analysis

Three separate analyses of variance were conducted for each of the dependent variables mentioned above in a four factor design: 2 (male, female) $\times$ 2 (control, AD) $\times$ 2 (duration, interval) $\times$ 4 (3, 6, 12, or 24 s) with repeated measures on the last two factors using the Statistica program. All data were subjected to the Levene’s test for homogeneity of variance. The Greenhouse–Geisser correction was used to adjust degrees of freedom for repeated measures. The p value was adjusted using the Bonnferoni correction for 3 dependent measures to .017; however, due to the exploratory nature of the study effects that are significant at the level of $p < .05$ are reported as approaching significance. Planned comparisons were used for the group and gender effects and post-hoc tests for all other effects.

RESULTS

Absolute Discrepancy Scores

The analysis revealed an almost significant main effect for group ($F_{1,39} = 3.95$, $p < .0541$) with attention-deficit participants showing a trend toward higher absolute discrepancies than normal controls. A significant interaction of Group × Gender ($F_{1,39} = 8.63$, $p < .0055$) showed that this difference was due to the males. Male AD participants had significantly higher absolute discrepancies compared to the normal controls and the female attention-deficit participants, while the difference between female controls and AD participants was not significant.. The comparisons were confirmed by t tests for unequal variances. In all cases except the 24-s time interval in the duration experiment, the AD males were significantly different from controls, whereas there were no differences between females. The Greenhouse–Geisser adjusted three-way interaction Gender × Group × Time ($F_{1,50} = 4.06$; $p = .04$) suggested that the AD males had significantly larger discrepancies than the AD females on all time measures, with the largest differences observed at 24 s (Fig. 1).

Coefficient of Accuracy Scores

The variances for this measure were not homogenous for the 3-s intervals in both experiments and the 6-s interval in the duration experiment. Nonetheless, to test for group × gender interactions an ANOVA was conducted. A two-way interaction between gender and group ($F_{1,39} = 5.15$, $p < .03$), which is close to significance using the Bonnferoni correction ($p < .017$), was found. This interaction suggested that, although all subjects underestimated the passage of time, both control females and males with AD made significantly greater underestimations than control males. Contrasts showed that the difference between both groups of females and the difference between the males and females in the AD group were not significant. There was no main effect of time in this measure, suggesting that the degree of underestimation was not related to the duration (Fig. 2).

Coefficient of Variance Scores

A significant main effect of time ($F_{3,104} = 22.17$, $p < .000001$) was found on this index of response consistency (SD/M). Post-hoc Scheffé tests indicates that participants were least consistent for 3 s time duration.

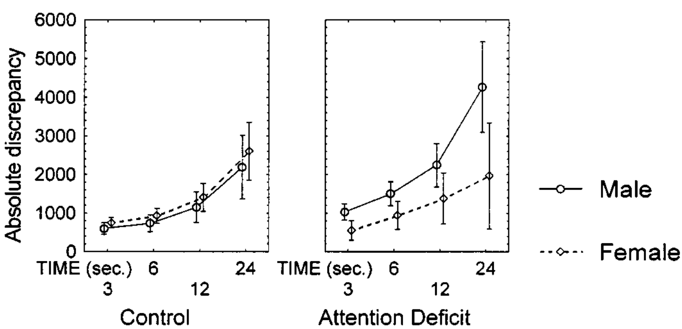

FIG. 1. Three-way interaction: Group × gender × time of the mean absolute discrepancies ($M \pm$ SD). $F(1.3, 50.1) = 4.0648$, $p = .04$.

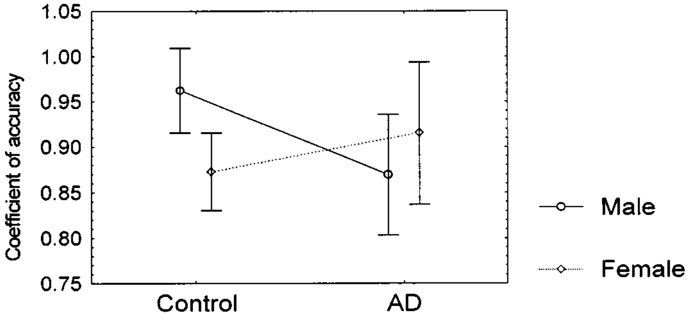

FIG. 2. Two-way interaction: Gender × group of the coefficient of accuracy (M ± SD). $F(1, 39) = 5.1493$, $p = .02887$.

DISCUSSION

In the present study, male, but not female young adult participants who reported attention problems on a self-report questionnaire showed a greater tendency to underestimate time intervals than control males. Larger discrepancies in time estimations among subjects with attention deficits were observed in prior studies with children (Cappella et al., 1977; Barkley et al., 1997), and adolescents (White et al., 1979) and a nonsignificant trend was found among adults (Barkley et al., 1996). However, none of these studies investigated the possibility of a gender difference in the time judgement tasks. It is important to note that our definition of ''attention deficit'' does not constitute a clinical diagnosis; therefore, the study should be replicated on a clinical population of adults with residual ADHD.

The coefficient of accuracy variable confirmed previous findings that adults tend to underestimate time in reproduction tasks. Control females did not differ from AD males in the magnitude of underestimation, suggesting that females might perform this task more poorly, while control males appeared to make the most accurate judgements. It remains to be determined whether these differences are due to experience with similar tasks (e.g., males might have had more experience with time judgement in the army) or to the use of different cognitive strategies. No significant differences were found between AD and control females on any of the dependent measures. It should be noted that the sample of females with attention problems was small and thus, further research with a larger AD sample should be conducted. Finally, almost all subjects reported using a counting strategy when questioned at the end of the experiment. The greater variability at the 3-s interval suggests that some time might be required to set the pace for accurate counting. It remains to be determined if retraining can benefit time estimation in people with attention deficits.

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Deficit in Understanding Sarcasm in Patients with Prefronal Lesion Is Related to Impaired Empathic Ability

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INTRODUCTION

Irony is a common feature of everyday discourse used to convey feelings in an indirect way, characterized by opposition between the literal meaning of the sentence and the speaker's meaning (Winner, 1988). Sarcasm is a form of ironic speech used to convey implicit criticism. Evidence from brain-injured (TBI) patients suggests that indirect speech in general and sarcasm in particular may pose special difficulty to the patients' interpretation of interpersonal communication (McDonald, 1992; McDonald & Pearce, 1996). It has been suggested that the poor performance of these patients on sarcasm tasks relates to their executive dysfunction and lack of cognitive flexibility (McDonald & Pearce, 1996), functions that are usually associated with prefrontal damage (Lezak, 1995). The prefrontal cortex is also known to play an important role in abstract interpretation and indirect forms of communication (Alexander et al., 1989). Moreover, human patients with damage to the prefrontal cortex (PFC) are likely to show altered emotional and social behavior, such as misinterpretation of social situations (Stuss & Benson, 1986). Tasks which require understanding of sarcasm demand inferences about the protagonist's perspective (McDonald, 1999). Another ability that relies heavily on perspective taking in social situations is empathy. Therefore, it might be speculated that the deficits in communication patterns displayed by patients with prefrontal damage are due to an impaired empathic ability. Empathy is broadly defined as a set of constructs having to do with the responses of one individual to the experience of another (Davis, 1994). Contemporary accounts of empathy have emphasized the multidimensional facets of the construct of empathy. It appears to include emotional aspects of experience sharing and emotional processing, as well as the ability to perceive cognitively the other's emotional state and make inferences regarding the other person's knowledge. This latter ability has been termed Theory of Mind (TOM, Baron-Cohen et al., 1985). Eslinger (1988) has suggested recently that empathic processes may be especially impaired after lesions to the prefrontal cortex (PFC). This was based on the well-documented impairment of social behavior, including self-awareness, loss of insight, impaired judgement and impaired decision making (Stuss & Benson, 1986, Damasio et al., 1991), all of which were observed following prefrontal damage. Thus, an inability to infer mental states and use empathy may account for the deficit in understanding sarcasm in patients suffering from brain damage.

The present study was designed to examine the effects of PFC lesions and lesion asymmetry on the understanding of sarcastic utterances. We also tested the hypothesis that deficits in one aspect of empathic ability (i.e., the ability to engage in the cognitive process of adopting another's psychological point of view) mediate the difficulty in understanding sarcasm, which is displayed by brain damaged patients.

To test our hypothesis we compared the degree of understanding sarcasm of patients with unilateral lesions in either the prefrontal or posterior cortex and examined how the degree of empathy displayed by these patients relates to understanding sarcastic utterances.

METHOD

Subjects

Patients with well-defined, localized, acquired cortical lesions (brain contusions and hematomas following traumatic head injury, or brain tumors), who were referred for a cognitive assessment at the Cognitive Neurology Unit, were recruited for participation in this study. The demographic description of the sample is summarized in Table 1. All patients gave informed consent for participation in the study. Patients were divided into Frontal (PFC, $n = 18$) and Posterior (PC, $n = 14$) subgroups, on the basis of the location of the lesion. Wherever available, anatomical classification was based on current (within 3 months) magnetic resonance (MR) or computerized axial tomography (CT) data. For 4 patients, whose lesion onset was more than 10 years prior to cognitive testing, the latest available imaging data were used (5.7 ± 2.9 years before testing, and at least 5 years post injury). The lesion analysis was conducted by a neurologist who was blind to the behavioral data. The PFC subgroup consisted of 18 patients with unilateral lesion: 8 had left sided lesion (dorsolateral = 2, orbitofrontal = 5 and dorsolateral and medial = 1); 10 patients had a right hemisphere lesion (dorsolateral = 6, orbitofrontal = 4). The PC subgroup included 14 patients with unilateral parietal lesions (left hemisphere = 7, right hemisphere = 7). Fourteen aged-matched healthy volunteers served as controls. As Table 1 shows, the three groups did not differ in age, education, and estimated overall level of intellectual functioning (as measured by the Raven's Progressive Matrices score). The two patient

TABLE 1
Demographic Description of the Sample

	Frontal lesion ($n = 18$)	Posterior lesion ($n = 14$)	Normal control ($n = 14$)
Sex			
Male	15	9	11
Female	3	5	3
Age			
Mean (*SD*)	33.39 (11.46)	44 (15.7)	36.64 (14.39)
Education			
Mean (*SD*)	12.39 (.98)	13.78 (2.42)	14.4 (3.3)
BDI			
Mean (*SD*)	12.94 (9.87)	12.5 (12.15)	4.92 (6.49)
Raven (percentile)			
Mean (*SD*)	38.68 (26.52)	41.67 (31.26)	54 (29.06)

groups were significantly more depressed than controls, but did not differ from each other in the severity of depression.

Testing and lesion localization were undertaken at least 6 months (average time: 41.8 ± 98.7 months) after the acute onset. All subjects were free of history of significant alcohol or substance abuse, psychiatric disorder, or other illness affecting the CNS. All patients were living in the community at the time of testing and none were aphasic or suffered from visual or motor impairment (as indicated by neurological screening prior to cognitive testing).

Tasks

The ability to understand *ironic meaning* was assessed using a task devised by Lapidot et al. (1998). It consists of 8 brief recorded stories presenting an interaction between two characters. At the end of each interaction one of the characters makes a comment directed at the other character. Each story is presented in two versions: a sarcastic and a neutral version (total 16 stories, presented in randomized order). Whereas in the sarcastic version the literal meaning of the speaker's comment is positive but the speaker's true meaning is negative, in the neutral version both the literal meaning and the speaker's intended meaning are positive. For example:

A sarcastic version item: Joe came to work and instead of beginning to work he set down to rest. His boss noticed his behavior and said: ''Joe, don't work too hard!''

A neutral version item: Joe came to work and immediately began to work. His boss noticed his behavior and said: ''Joe, don't work too hard!''

Following each story, two questions were asked:

1. A factual question (assessing story comprehension): Did Joe work hard?

2. An attitude question (assessing comprehension of the true meaning of the speaker): Did the manager believe Joe worked hard?

A measure of *cognitive empathy* was derived by using the Interpersonal Reactivity Index (IRI), an instrument that consists of four seven-item subscales, each tapping a separate facet of empathy (Davis, 1980). Two scales from the IRI were utilized: The *perspective taking subscale* measures the reported tendency to adopt spontaneously the psychological point of view of others; the *fantasy scale* measures the tendency to imaginatively transpose oneself into fictional situations.

In addition, all subjects completed the Raven's Progressive Matrices to assess reasoning and obtain an estimate of general intellectual functioning. Since depressive symptoms are seen in a large number of patients following brain injury, especially among patients with frontal and parietal lesions (Robinson & Manes, 2000), the Beck Depression Inventory (BDI) was also administered, to control for the patients' depressive state.

RESULTS

The level of empathy displayed by the three groups was compared using one-way ANOVA. Patients with lesions in the PFC had significantly lower empathy scores, compared to patients with posterior lesions and healthy controls. Post-hoc analysis revealed that PFC patients were significantly different from the two other groups (Duncan, $p < .05$), but the PC and healthy controls did not differ from each other.

The same pattern was noted for the performance in the sarcasm task: the error scores for the 3 groups were: PFC = 1.3 ± 1.6; PC = 0.2 ± 0.41; and healthy controls = 0.14 ± 0.36 ($F[2, 58] = 6.73$, $p < .002$). The Post-hoc analysis revealed

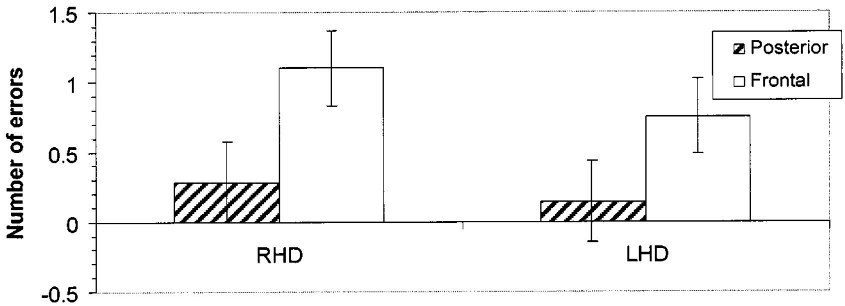

FIG. 1. The effect of frontal damage on sarcasm scores: significant effect of lesion site (PFC vs posterior) but not lesion side (RHD vs LHD).

that PFC patients were significantly different from the two other groups (Duncan, $p < .05$), whereas the PC and healthy controls did not differ from each other.

A two-way ANOVA (lesion location × hemisphere) was conducted to examine the effect of lesion location and lesion asymmetry on understanding of sarcastic utterances. To control for possible influence of the wide range of ages (19–67), the subject's age was used as a covariate. As Fig. 1 shows, there was a significant effect of lesion location on sarcasm scores ($F[1, 32] = 5.665$, $p < .025$), indicating that PFC lesions are associated with difficulty in the comprehension of sarcasm as compared to posterior lesions. Neither the lesioned hemisphere nor the interaction between hemisphere and location had significant effect. These findings suggest that whereas lesion in either the left or right prefrontal cortex results in impaired understanding of sarcasm, a lesion in posterior cortical areas in either hemisphere will not result in reduced understanding of sarcasm.

No correlation was found between patients' performance on sarcasm tasks, BDI score, Raven Progressive Matrices score and years of education, indicating that the observed impairment in the performance of the sarcasm task is independent of the severity of depression, the overall intellectual ability and formal education.

The contribution of empathic ability to the understanding of sarcasm was emphasized by an analysis of linear regression, which indicated that 20.3% of the variance in scores in the sarcasm task could be accounted for by the empathy score. The model of prediction coefficient of sarcasm scores by empathy scores was highly significant [$F(1, 31) = 8.878$, $p < .006$], suggesting that cognitive empathy scores may predict to a significant degree the performance on the sarcasm task.

DISCUSSION

The significant difference in sarcasm scores between patients with prefrontal and posterior cortical lesions suggests that the PFC plays an important role in understanding sarcastic utterances. The present results highlight the importance of the prefrontal cortex in mediating indirect communication and add to previous clinical observations of profound disturbances in social interactions associated with PFC lesions (Eslinger & Damasio, 1985). In the present study, patients with PFC lesions were significantly impaired in empathy, compared to patients with PC lesions and healthy controls. Recently, developmental studies as well as studies of patients with TBI, emphasized the importance of the speaker's perspective when understanding sarcasm (Happe at al., 1996; Levine et al., 1993). These findings provide further support for the notion that the contribution of empathic ability to understanding sarcasm is mediated by the PFC. Sperber and Wilson's (1981) *relevance theory* advocates that the interpretation of ironic utterance may require recognition of the speaker's attitude and thus requires shared knowledge. The present study supports the relevance theory by emphasizing the role of shared knowledge (reflected by empathy scores) in understanding sarcastic utterances.

Our results indicate that the degree of cognitive empathy may predict the degree of deficits in sarcasm. Cognitive empathy requires the ability to make inferences regarding the speaker's knowledge and intentions. This definition is very similar to the definition of Theory of Mind (TOM). However, the concept of ''empathy'' emphasizes the *emotional* aspects of experience sharing, whereas discussions of TOM focus on knowledge, intentions, and beliefs (Baron-Cohen et al., 1985) and say very little about the role of emotions. The present study did not examine directly the contribution of analysis of emotional cues to the understanding of sarcasm. In real life situations, people may rely on additional social cues (such as facial expression and prosody). The processing of such information has been shown to be impaired in patients with right hemisphere lesions (Heilman et al., 2000). Indeed, it has been suggested that the right hemisphere may play an important role in mediating the ability to understand sarcastic utterances (Winner et al., 1998). Surprisingly, we did not find any differences in the performance of the sarcasm task between patients with right and left hemisphere lesions. Neither the lesion side nor the interaction between lesion location and side had a significant effect on the comprehension of sarcasm. However, the exact location of the lesion within the right hemisphere was not reported in earlier studies that found a deficit in the understanding of sarcasm among patients with RHD. It is possible that those lesions were localized to the right prefrontal cortex, or that within a mixed group of RHD the difficulty in comprehension of sarcasm was more pronounced in those with prefrontal, as compared to posterior, right hemisphere lesions.

Further research is needed to evaluate the relative contribution of specific cognitive skills to understanding sarcasm (as well as to the different components of empathy) and assess how deficits in those skills (resulting from specific brain lesions) interfere with the comprehension of sarcasm.

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Conditions of Visual Verbal Extinction: Does the Ipsilesional Stimulus Have to Be Identified?

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Six left-neglect patients were presented with four-letter words in the left and/or right hemifield, in different contextual conditions: unilateral, bilateral-x in which one word appears on one side and a string of ‘‘x’’ appears on the other side (the side of ‘‘x’’ was not predictable), and bilateral-word (presentation of one word in each hemifield). In Experiment 1, left extinction occurred even if the right stimulus was an easily discriminable string of ‘‘x.’’ Experiment 2 showed that increasing the size of the left stimuli reduced extinction when a string of ‘‘x’’ was presented on the right hemifield. However, extinction was stronger with bilateral-word presentation. These results indicate the presence of an early component in the extinction phenomenon, i.e., a ‘‘magnetic’’ attraction toward the ipsilesional hemifield, but are also in favor of some additional deficit, at a later stage of information processing.

INTRODUCTION

Visual extinction is a common phenomenon in patients suffering from a posterior lesion, especially in parietal areas. Patients can report a stimulus presented in the hemifield contralateral to their lesion when presented alone, but they cannot report this stimulus when another stimulus of the same type is simultaneously presented in the hemifield ipsilateral to the lesion (Bender & Furlow, 1945). Visual extinction has been related to the syndrome of hemineglect, although it can sometimes occur without the other clinical signs usually found in spatial hemineglect. The basic explanation of the extinction phenomenon is a pathological bias in the distribution of spatial attention (see, for example, Friedland & Weinstein, 1977; Posner, Walker, Friedrich, & Rafal, 1984).

There have been many studies showing that extinction is not a constant phenomenon in which the contralesional stimulus is completely lost in every situation. For example, Volpe, Ledoux, and Gazzaniga (1979) showed that unidentified left-sided stimuli can still be compared to right-sided stimuli in patients suffering from a right parietal lesion. Others have also argued that the task can influence left extinction (locate or count targets: Vuilleumier & Rafal, 1999). Several studies have shown that an extinguished stimulus can affect the processing of a subsequent or simultaneous stimulus presented in the center of the screen or in the ‘‘good’’ ipsilesional hemifield (Audet, Bub, & Lecours, 1991; Danckert, Maruff, Kinsella, De Graaff, & Currie, 1999; McGlinchey-Berroth, Milberg, Verfaellie, Grande, D’Esposito, & Alexander, 1996). Also, letters in the extinguished hemifield can be better identified in a single word display than in a two-word display even if both displays subtend the same visual angle (Siéroff & Michel, 1987).

Other studies have investigated the influence of the ipsilesional stimulus on the extinction phenomenon, for example when these stimuli are potential targets (Mark, Kooistra, & Heilman, 1988; Eglin, Robertson, & Knight, 1989). The nature of the ipsilesional stimulus itself can affect the extinction: it seems that an ipsilesional face produces more extinction on a contralesional shape than an ipsilesional word, supposedly because faces have a stronger power in attracting attention (Vuilleumier, 2000). Other questions remain unresolved: is it crucial that the patient actually identifies and reports the ipsilesional stimulus to elicit the extinction phenomenon, or is the simple presence of an easily discriminable stimulus in the ‘‘good’’ hemifield sufficient? If the deficit is located at a very early stage of processing, any stimulus in the ipsilesional side should produce an extinction, even if this stimulus does not have to be identified. On the other hand, if the deficit is located at a later stage of processing, the need to identify and/or to report the ipsilesional stimulus should provoke (or increase) the extinction. Karnath (1988; see also Di Pellegrino & De Renzi, 1995) has shown, in three left neglect patients, that the extinction phenomenon with simple shapes is reduced or even abolished when patients do not have to identify the right-sided stimulus. However, in his study, this right-sided stimulus was constantly ignored over the whole experiment, so that patients may have developed the strategy to orient endogenously their attention toward the left side.

In the present article, we present new data on left visual extinction with words in patients suffering from a lesion in the right hemisphere. We examine whether or not left extinction occurs in trials in which the right stimulus does not have to be reported, and patients cannot predict before the trial if the right stimulus will have to be ignored.

EXPERIMENT 1

Method

Participants. Six right-handed patients (two women and four men) suffering from a vascular accident (5 ischaemic and 1 hemorragic) in the right hemisphere (sylvian territory) were tested. Mean age was 60.2 years (min. 49, max. 72). All the patients had a left hemineglect (tested with the procedure developed by Bartolomeo and Chokron, 1999: visual and tactile extinction, copy, three cancellation tests, line bisection, overlapping figures). No patient had a clinically detectable complete hemianopia. They were tested between 1 and 9 months after the ictus.

Eleven normal participants, all right-handed, were tested as controls (7 women and 4 men). Their mean age was matched with mean age of patients (55.5 years; min. 44, max. 73; $t(15) = .97$, ns) and cultural level [$t(15) = 1.43$, ns].

Stimuli. We used 120 four-letter words (only nouns), distributed in 6 lists of 20 words. Lists were equivalent for word frequency (min. 1829, max. 1959 per 100 millions) and imageability. They were presented lower-case in black on a white video screen (font Courier 18), and subtended a visual angle of 1.2° horizontally and .4° vertically (participants were seated at a distance of 50 cm from the screen). The closest extremity was .9° from the fixation item (plus sign).

Procedure. The experiment was conducted on a Macintosh Powerbook, using Psychlab 2.3 (Bub & Gum, 1988). The fixation item appeared in the center of the screen; one or two words appeared 500 ms later for a duration time adapted to each patient and control. This duration was determined in a pre-experiment in order to obtain approximately the same level of errors in each participant: it ranged from 200 to 600 ms for patients and from 150 to 200 ms for controls. Words were immediately followed by a patterned mask (made of irregular lines of different orientation) covering a visual angle of $6.7 \times 2.7°$. Participants were required to fixate the fixation item, and to orally report the letter string. They were encouraged to give a response even if they did not identify the whole word; they sometimes spelt some letters or pronounced a nonword.

There were three contextual conditions, using 40 words each, 20 on the left and 20 on the right, corresponding to the 6 lists of words. The first contextual condition was a unilateral presentation. The second was a bilateral presentation: one word was presented simultaneously with a string of four ‘‘x’’ (Courier 18) in the other hemifield (same distance from the fixation item) = bilateral-x condition. The third was the presentation of two words, one in each hemifield = bilateral-word condition. Each of the three contextual conditions were blocked and presented twice, in two sessions (separated by between 1 and 8 days), using half the lists each time. The block order was changed over sessions. Participants were informed of the type of presentation condition before each block. For example, in the bilateral-x condition, they were informed that they did not have to report the string of ‘‘x’’ but only the word. Most importantly, they knew that the string of ‘‘x’’ could appear on the left as well as on the right side, so they could not develop a long-term strategy ignoring stimuli on one side of space.

If the extinction phenomenon is related to a deficit occurring at an early stage of processing, the simple presence of an easily discriminable string of ‘‘x’’ on the right side should decrease the level of performance for the left-sided word compared to the unilateral condition. If the extinction phenomenon occurs at a later stage of processing, there should be poorer performance for the left-sided word in the bilateral-word condition compared to the bilateral-x condition.

Results and Discussion

An ANOVA with Group (patients, controls) as between-subjects factor, Hemifield (left, right) and Context (unilateral, bilateral-x, bilateral-word) as within-subjects factors, was calculated on the number of correctly identified letters. We preferred this type of measure rather than a measure of correct identification of the whole word, because it gives more precise indications about performance level. This scoring method has already been described in other articles (see for example Siéroff, Pollatsek, & Posner 1988) and consists in evaluating the inclusion of each letter of a stimulus in participants' responses whatever their response mode (letter-by-letter spelling or pronouncing a real word or not). Results are shown in Fig. 1.

Normal controls showed only a rather expected decrease in performance for the right-sided words in the bilateral-word condition compared to the unilateral condition [$F(1, 15) = 11.54$; $p < .01$], very likely due to the order of report.

Patients showed better results with right-sided words compared to left-sided words in every contextual condition: unilateral [$F(1, 5) = 38.44$; $p < .001$], bilateral-x [$F(1, 5) = 54.98$; $p < .001$] and bilateral-word [$F(1, 5) = 31.06$; $p < .001$]. Thus, our patients showed an asymmetry in performance even in the unilateral condition. This could have been caused by some low-level visual deficit, although no clinically detectable hemianopia was found. This could also have been caused by some particularly strong hemineglect.

The most interesting result is that patients' performance for the left-sided word was significantly better in the unilateral condition than in the bilateral-x condition [$F(1, 15) = 19.86$; $p < .001$], and this difference was stronger in patients than in normals [$F(1, 15) = 7.01$; $p < .05$]. Thus, patients were abnormally affected by the simple presence of an easily discriminable stimulus, a string of four ''x,'' in the right hemifield. Apparently, a task requiring the identification of the right-sided stimulus is not necessary to elicit the extinction phenomenon.

The performance for the left-sided word did not differ significantly between the bilateral-x and the bilateral-word conditions, but there was some floor effect. Because of this floor effect and also because of the asymmetry obtained in the unilateral condition, we conducted a second experiment with the same patients, in which we ''en-

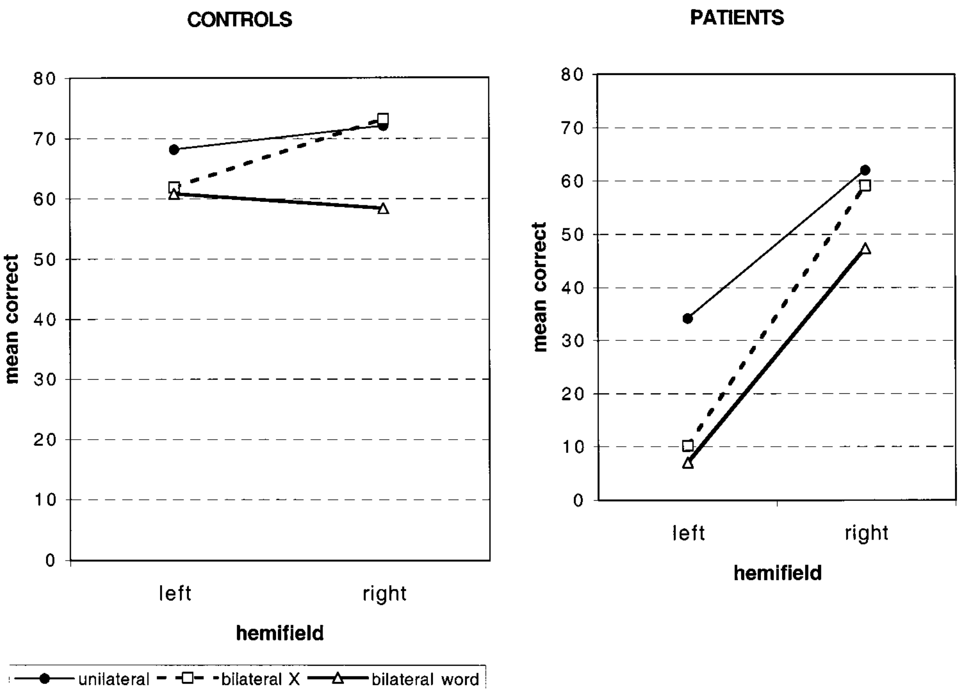

FIG. 1. Mean number of correctly identified letters (max. 80) in four-letter words presented in the left and right hemifields for the three contextual conditions in controls and patients; letters are the same size in both hemifields.

hanced'' the level of performance in the left hemifield by increasing the size of the letters only on this side.

EXPERIMENT 2

Method

Participants. Participants were the same 6 patients as in Experiment 1.

Stimuli. 120 four-letter words different from those used in Experiment 1 were distributed in six lists of equal frequency (min. 1804, max. 1912 per 100 millions) and imageability. Words presented in the right hemifield used a Courier 18 font and subtended the same visual angle as in Experiment 1. Words presented in the left hemifield used a Courier 36 font and covered 2.5° horizontally, and .8° vertically. The closest extremity was .9° from the fixation item. Strings of ''x'' were also scaled on the same principle.

Procedure. The procedure was similar to that in Experiment 1.

Results and Discussion

An ANOVA with Hemifield (left, right) and Context (unilateral, bilateral-x, bilateral-word) as within-subjects factors was calculated on the number of correctly identified letters. Results are shown in Fig. 2.

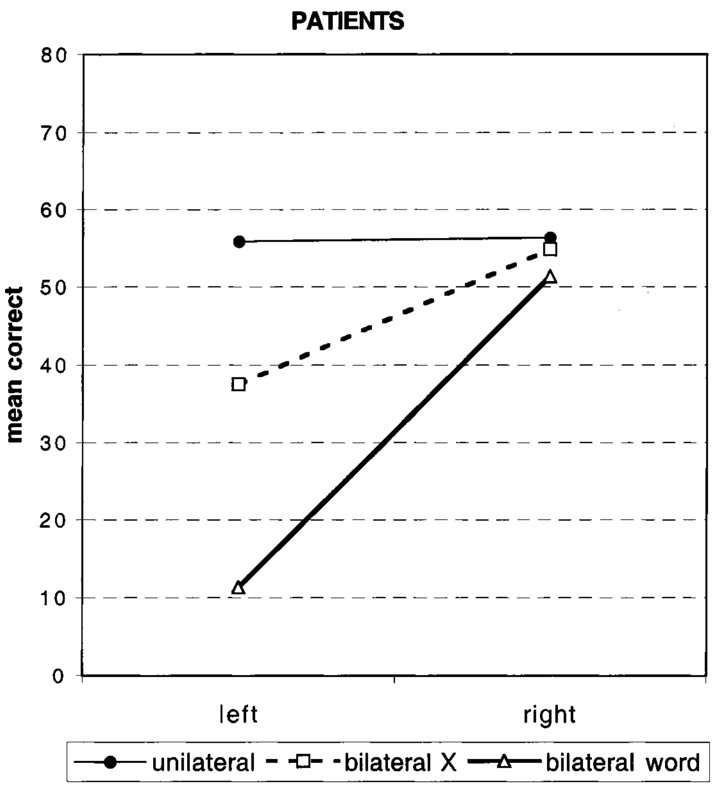

FIG. 2. Mean number of correctly identified letters (max. 80) in four-letter words presented in the left and right hemifields for the three contextual conditions in patients; letters are twice as large in the left hemifield compared to the right hemifield.

Asymmetrical performance between left and right words was found only in the bilateral-word condition [$F(1, 5) = 16.90$; $p < .01$], and not in the unilateral [$F(1, 5) < .1$] or the bilateral-x condition [$F(1, 5) = 2.15$; ns].

Although the number of correctly identified letters in the left word seemed lower in the bilateral-x condition than in the unilateral condition, the difference was not significant [$F(1, 5) = 3.11$; $p = .14$]. Possibly, the difference in size between the left and right stimuli lessened the ‘‘magnetic’’ attraction toward the string of ‘‘x’’ in the right hemifield.

More interestingly, the difference between bilateral-x and bilateral-word conditions on the left-sided word performance was significant here [$F(1, 5) = 9.58$; $p < .05$], showing that the identification of a word in the right hemifield contributed to the extinction phenomenon.

GENERAL DISCUSSION

Two experiments were conducted in order to specify the conditions of extinction in neglect patients, and specifically the influence of the task on the ipsilesional stimulus. The most important result is that the phenomenon of verbal visual extinction occurs even if the bilateral display consists of one word to identify on the left side and one easily discriminable string of ‘‘x’’ on the right side. The simple presence of a stimulus in the ‘‘good’’ hemifield is sufficient to elicit the extinction. This indicates that part of the extinction phenomenon is due to a deficit occurring at a very early stage of processing. Patients are abnormally attracted to the side of space ipsilateral to their lesion. This ‘‘magnetic’’ attraction towards the ipsilesional events can be the expression of a bias in exogeneous attention (Gainotti, 1996). This result is different from the one obtained by Karnath (1988) on three patients. However, the patients, in his study, may have developed a strategy to prepare endogenous orienting of attention toward the left hemifield, since the task consisted in ignoring the right-sided stimulus constantly on every trial. Indeed, recent studies have shown that neglect patients are able, in some circumstances, to develop such an endogenous orientation of attention toward the left side (Bartolomeo, Siéroff, Decaix, & Chokron, in press).

In our Experiment 2, we obtained equivalent performance for the left and the right words in the unilateral condition: performance was enhanced on the left side by increasing the size of the stimulus. Apparently, performance for the left-sided word was also enhanced in the bilateral-x condition and extinction was no longer significant. We suppose that, with such a ‘‘distorted’’ display (left stimulus twice as large as the right stimulus), the left stimulus was rendered more attractive. Consequently, the spatial bias (‘‘magnetic’’ attraction to the right) was compensated in this condition. However, it is difficult to conclude and more data are necessary.

Finally, we obtained a significant difference between the bilateral-word condition and the bilateral-x condition on the identification of the left-sided word only in Experiment 2, where the floor effect has been eliminated. Thus, part of the extinction phenomenon occurs because patients have to identify and/or report the ipsilesional stimulus. This result could be in favor of a deficit occurring also at a somewhat later stage of processing: in the identification process or at the stage of responding to stimuli.

In conclusion, these two experiments show that the phenomenon of visual verbal extinction can be the expression of two impaired operations, one at an early stage of processing and another at a later stage of processing. First, patients are abnormally attracted towards the ipsilesional stimulus even when this stimulus is easily discriminable and does not have to be identified and reported. Second, extinction is even stronger when the right-sided stimulus has to be identified and/or reported.

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Concept Driven Color Experiences in Digit-Color Synesthesia

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In digit-color synesthesia, black digits elicit conscious experiences of highly specific colors (photisms). This paper describes C, an undergraduate student who experiences digit-color synesthesia. We evaluated whether C's photisms could occur even in the absence of an externally presented digit. C was shown simple arithmetic problems (e.g., 5 + 2) followed by a color patch. C was significantly faster at naming the color of the patch when it was congruent with the photism associated with the *answer* to the problem than when the color patch was incongruent with the answer. These results replicate previous findings (Dixon, Smilek, Cudahy, & Merikle, 2000) and strongly suggest that for C, an externally presented inducing stimulus is *not* necessary to trigger a photism—activating the concept of a digit is sufficient.

INTRODUCTION

This case report describes C, a 22-year-old, undergraduate student who experiences digit-color synesth esia. When shown standard black digits, her identification of each digit is accompanied by a photism—a conscious experience of a highly specific color. Our previous investigations of C have shown that her photisms are both consistent and automatic (Dixon, Smilek, Cudahy, & Merikle, 2000).

Until recently, one issue regarding synesth etic experiences that remained unclear was whether an external stimulus was necessary for photisms to occur. For example, Cytowic (1989) states that ''Synesthesia is unsuppressable but cannot be conjured up at will. There must be an objective stimulus.'' (Cytowic, 1989, p. 64) ''Synaesthsia is involuntary but elicited. It is a passive experience that happens to someone. It is unsupressable, but elicited by a stimulus that is usually identified without difficulty. It cannot be conjured up or dismissed at will . . .'' (Cytowic, 1997, p. 23). These statements suggest that synesth etic photisms can only be elicited by an externally presented stimulus. Despite these statements, Cytowic (1989) reports the case of FKD who perceives nouns, verbs, and proper names as blobs of color and claims that each of his synesth etic experiences ''comes involuntarily and cannot be altered and is most often the result of hearing the word or *thinking* of the person so named.'' (Cytowic, 1989, p. 41). Likewise, C, the synesth ete who we have studied, reports that her photisms can be triggered simply by thinking of digits. Subjective reports such as these are interesting because they suggest that, at least for some synesth etes, photisms occur as a result of activating the meaning of an inducing stimulus and that the inducing stimulus does not have to be externally presented in order for the photism to be activated (see, Grossenbacher, 1997).

In our previous brief report (Dixon et al., 2000), we provided the first empirical evidence supporting the idea that photisms can be activated without a physically present inducing stimulus. We presented C with simple arithmetic equations (e.g., 5 + 2) followed by a color patch that was either congruent or incongruent with the *answer* to the arithmetic problem. C's task was to calculate the answer to the arithmetic problem and then to name the color of the patch as quickly and as accurately as possible. The rationale underlying this experiment was that if a photism was an automatic consequence of simply thinking of the answer to the arithmetic problem, then the photism should interfere with her ability to name the color of the patch on incongruent trials compared to congruent trials. The results showed that on average, C's reaction times were 236 ms faster on congruent trials than incongruent trials. This large congruent/incongruent difference is striking because 8 nonsynesth etes showed a mean difference of only1 ms. C's large congruent/incongruent difference suggested that photisms were elicited even though the answer to the arithmetic problem was never physically presented. Consonant with C's first person report that just thinking of a 7 elicits a yellow photism, these data shows empirically that activating the concept of a digit is sufficient to induce a photism.

The preset paper has two objectives. The first objective is to report a replication of the findings reported by Dixon et al. (2000) in order to show the robustness and reliability of these finding. The second objective is to provide a detailed description of the methodology used by Dixon et al. (2000) to demonstrate concept-driven photisms in digit–color synesth esia. Due to the brevity of the report of our initial findings, we were unable to give a detailed presentation of the methodology.

In the present experiment, we once again presented C with simple arithmetic equations (e.g., 5 + 2) followed by a color patch that was either congruent or incongruent with the *answer* to the arithmetic problem. As before, C's task was to calculate the answer to the arithmetic problem and then to name the color of the patch as quickly and as accurately as possible. Based on our previous findings, we predicted that C's photisms would interfere with her ability to name the color of the patch on incongruent trials compared to congruent trials. Empirically, this interference would result in slower reaction times for naming the color of the patch on incongruent trials compared to congruent trials.

METHOD

Participants

C and eight nonsynesth etic undergraduate students at the University of Waterloo each participated in a 45 min session for $8.00.

Apparatus

All testing was conducted using a 200 MHz Pentium processor interfaced to a ViewSonic 17PS monitor. Stimuli were presented and reaction times were recorded using Micro Experimental Laboratory software (Schneider, 1990).

Procedures

On each trial, participants were presented, in sequence, with a fixation cross (250 ms), a digit (250 ms), an arithmetic operator (250 ms), a second digit (50 ms), and finally a color patch (until response). The intervals between the stimuli were 250 ms except for the interval between the second digit and the color patch which was 200 ms. The stimuli were approximately 0.5 cm (0.40°) in height and 0.5 cm (0.40°) in width, and they were presented against a gray background in the center of a computer monitor at a viewing distance of approximately 57 cm. The two digits and the arithmetic operator presented on each trial constituted an arithmetic problem to which the answers were 2, 4, 5, or 7. There were eight possible arithmetic problems that yielded each of the four possible answers (e.g., 1 + 4, 2 + 3, 3 + 2, 4 + 1, 6 − 1, 7 − 2, 8 − 3, and 9 − 4 all yield 5).

There were two types of trials: congruent and incongruent. On congruent trials the color of the patch was congruent with the color of C's photism for the answer to the arithmetic problem, whereas on incongruent trials the color of the patch was a color

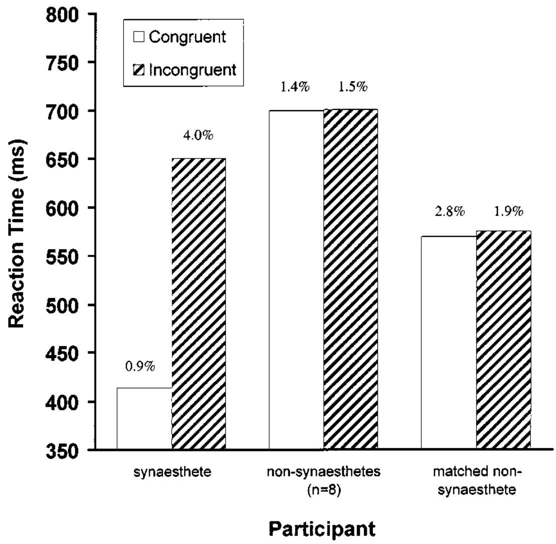

FIG. 1. Mean color naming reaction times and percent errors on congruent and incongruent trials for C, eight synesthaetes, and for the nonsynesthaete most similar to C in terms of overall reaction times.

other than the color of C's photism for the answer to the arithmetic problem. Participants were instructed to name the color of the patch as fast as possible while maintaining high accuracy and then to report the answer to the arithmetic problem. Naming the color of the patch triggered a voice key, which recorded RTs with millisecond accuracy. In order to calculate response accuracy, the participants' responses to the color patch were recorded. Following 8 practice trials, the participants were presented 108 congruent and 324 incongruent trials in random order.

RESULTS AND DISCUSSION

Before the reaction times (RTs) for the correct responses were analyzed, the outliers in each cell were removed using a recursive procedure (see Van Selst & Jolicoeur, 1994). After outlier removal, the mean RTs for C's performance on congruent and incongruent trials were calculated. These means are shown on the left side of Fig. 1. As can be seen from the figure, C was much slower at naming the color of the patches on incongruent trials (mean = 646 ms) than on congruent trials (mean = 418 ms), $t(405) = 12.71$, $p < .001$. C also made marginally more errors on incongruent trials (4.03%) than congruent trials (0.9%) indicating that the reaction time results were not due to speed–accuracy tradeoffs. These results clearly replicate the findings reported by Dixon et al. (2000) and indicate that the effect is both robust and reliable. The fact that C was slower at naming the color of the patch on incongruent trials than on congruent trials indicates that the photism associated with the single-digit answer to each arithmetic problem was elicited by her mental calculation of the answer. Thus, an external stimulus was not required to trigger a color photism. Rather, activating the *concept* of a digit by a mental calculation was sufficient to induce the photism associated with that digit.

The middle and the right side of Fig. 1 depicts the result of a group of eight nonsynesth etes and the one nonsynesth ete most similar to C in overall RTs, respectively.[1] In contrast to the large congruent/incongruent difference (228 ms) found for C, the nonsynesth etes who were tested using the identical procedures showed minimal congruent/incongruent differences. For the eight nonsynesth etes, these congruent/incongruent differences ranged from −29 ms to +26 ms (all $ps < .05$), with the mean difference being 1 ms. The congruent/incongruent difference found for C (228 ms) was 19.3 standard deviations away from the mean congruent/incongruent difference (1ms) for the nonsynesthaetes.

While the present results demonstrate that for C an externally presented digit is not necessary for a photism to occur, the present results do not rule out the possibility that some forms of synesth esia require an external stimulus to elicit a photism. We agree with Grossenbacher (1997) that there may be different subtypes of synesth etes—those who require an exogenous eliciting stimulus in order to generate photisms and those, like C and FKD, who can trigger photisms merely by thinking of, or imagining, the inducing stimulus. Grossenbacher (1997) speculates that ''imagined inducers'' tend to be higher level concepts like people, words or familiar objects, rather than lower level concepts like sounds. The current results indicate that for C, digits qualify as such higher level concepts.

We contend that for synesth etes like C, the concept of a digit like 7, includes typical semantic attributes such as value (larger than 6, smaller than 8), luckiness, the fact that it is an odd number and that it is prime. Crucially, however, for C, the concept of 7 also contains the attribute yellow. For C, each time the concept of 7 is activated so too is the attribute of yellowness. For C the semantic association between 7 and yellow leads to the experience of the color yellow.

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[1] These results were briefly reported by Dixon et al. (2000).

The Right Hemisphere as an Anomaly Detector: Evidence from Visual Perception

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V. S. Ramachandran (1998) has suggested that the right hemisphere, which tends to be specialized for the analysis of global-level information, serves as an anomaly detector. Its role is to judge whether a given percept is possible and whether there are elements of that percept that seem incongruent with the other elements. In contrast, the left hemisphere tends to create a ''story'' to make sense of the incongruities. In the current study, pictures of possible or impossible objects were displayed for brief exposure durations to either the left visual field/right hemisphere or to the right visual field/left hemisphere). The results provide tentative support for the work of Ramachandran. In male participants, the right hemisphere was superior to the left in detecting impossible objects.

INTRODUCTION

It is well known that the two hemispheres of the brain serve different functions in the interpretation of visual information (Springer & Deutsch, 1998). However, some of the specific specializations are still not agreed upon, particularly those related to the analysis of complex visual images. Ramachandran (Ramachandran & Blakeslee, 1998) has suggested that the right hemisphere, which tends to be specialized for the analysis of global-level information, contains an anomaly detector. This anomaly detector analyses information (e.g., verbal material, information pertaining to body image, perceptual items) for the presence of features that render this information logically impossible, or incompatible with memorial representations pertaining to this information.

Ramachandran uses two lines of evidence for the anomaly detector being located in the right hemisphere. First, his own work with anosognosic patients (Ramachandran, 1995) implies that the right hemisphere is critical in detecting anomalies. Left hemiplegic patients who have damage to the right parietal lobe often do not consciously admit to having any sort of paralysis; rather, they adamantly claim to be fully mobile—often confabulating a story to account for the incongruity between their claims of being healthy and their inability to move the left side of their body (e.g., ''I'm just really tired''). Of note is the fact that this anosognosia only occurs for right parietal-damaged patients. Patients with left hemisphere damage are fully aware of being paralyzed on the right side of their body. Thus, the right hemisphere can detect anomalies in body image whereas the left hemisphere cannot. Second, research by Gardner (1993) has shown that patients with right hemisphere damage have difficulty recognizing the incongruities in ''garden path sentences.'' In these sentences, there is an unexpected twist at the end of the sentence that contradicts the beginning. The resulting sentence makes grammatical sense but is logically anomalous. Ramachandran (in Ramachandran & Blakeslee, 1998) suggests that the inability of right hemisphere patients to notice the resulting absurdity is another failure of the anomaly detector.

In applying the notion of the anomaly detector to visual perception, Ramachandran's theory finds some support in neuroimaging and hemispheric specialization studies. Using positron emission tomography (PET) scans, Frith and Dolan (1997) have demonstrated, using neurological patients, that a small area of the right parietal lobe becomes activated when there are discrepancies between a patient's movement and the visual image of that movement. This finding is consistent with the literature on the hemispheric specialization of visual perception. When perceiving visual information, the right hemisphere tends to be more efficient at processing global features containing low spatial frequency information (see Hellige, 1995, for a review). In other words, the right hemisphere is superior to the left at processing ''the big picture.'' In contrast, the left hemisphere is more efficient at processing local information containing high spatial frequency information. The focused nature of left hemisphere perception may interfere with its ability to detect how individual features make an entire object anomalous.

The current study is an extension of the idea that the right hemisphere is superior to the left in detecting anomalies. In this study, two types of objects were used, line drawings of familiar objects (Snodgrass & Vanderwart, 1980) and line drawings of novel shapes (Williams & Tarr, 1997) that were based on sets of irregular polygons. Line drawings were briefly displayed to either the left visual field (which projects to the right hemisphere) or the right visual field (which projects to the left hemisphere). For both familiar and novel objects, half of the objects were rendered impossible. The familiar items were altered on the computer such that they became anomalous items (e.g., a car with square wheels). For the unfamiliar objects, logically possible polygons were altered so that they became structurally impossible. We predict that, consistent with the work of Ramachandran, the right hemisphere will be superior to the left in impossible objects.

METHOD

Participants

Twenty-four students (14 females and 12 males) participated in this study in exchange for course credit in an introductory psychology class. All participants were right-handed (as confirmed by the Waterloo Handedness Questionnaire) and had normal or corrected-to-normal vision.

Stimuli and Apparatus

Two sets of objects, one familiar and one unfamiliar, were used. The familiar items were taken from the Snodgrass and Vanderwart (1980) set of line drawings. Items were altered into ''impossible objects'' using Adobe Photo Editor such that changes rendered the objects functionally unusable and thus anomalous (e.g., a car with square wheels). Figure 1 contains an example of a possible and an impossible object from both the familiar and unfamiliar object sets.

The unfamiliar items were taken from a set of irregular polygons used by Williams and Tarr (1997). One set of forty line drawings was constructed such that the resulting polygon could exist in real space (i.e., it was a *possible* object). The other set of forty line drawings was based on the possible objects; however, each of these objects contained three alterations of structural features. The resulting irregular polygon could not exist in real space (i.e., it was an *impossible* object).

These stimuli were presented on a 12″ color monitor connected to a Macintosh 650 Centris computer. The experiment was run using Psyscope software. The polygons were presented to the left or to the right of the center of a screen. The side of presentation and the type of object being presented was randomized with the constraint that all participants were to receive an equal number of possible and impossible figures in both the left and right visual fields. The presentation of each stimulus was

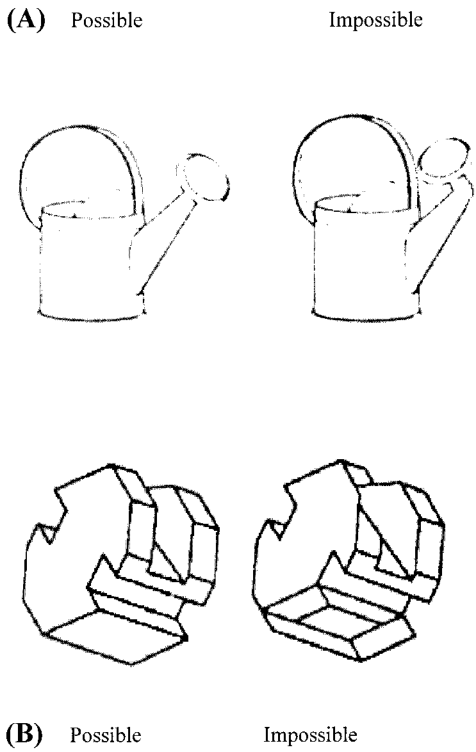

FIG. 1. Displayed in (A) are two sample stimuli based on Snodgrass and Vanderwart (1980). The right object is a picture of a normal watering can, whereas the left object has been structurally altered to such that its functional usefulness has been reduced. These are *familiar object.* In (B) are two samples of stimuli based on Williams and Tarr (1997). The left item represents the possible version while the left represents the impossible version. These are *unfamiliar objects.*

in a 9 $\times$ 9 cm area the center of which was 4.5 cm from fixation. The line drawings were black and were presented on a white background. These stimuli were viewed from a distance of 35 cm. Participants indicated whether the presented stimuli were possible or impossible stimuli by pressing one of two buttons on a Button Box connected to the computer with their index fingers. The hand of response was counterbalanced so that the left and right index finger were each used to respond to both types of items (possible and impossible) and both stimulus sets (familiar and unfamiliar). Participants were instructed to keep their fingers on the response keys for the duration of the trial and to respond as quickly and as accurately as possible.

Procedure

Before beginning the computer task, participants were asked to complete the Waterloo Handedness Questionnaire and the Waterloo Footedness Questionnaire (Elias, Bryden, & Bulman-Fleming, 1998). Participants were also asked to confirm that they were able to clearly see the computer screen. Upon completion of the questionnaires, participants were given instructions for the computer task.

Each of the four blocks of trials on the computer task was preceded by a set of eight practice trials characteristic of the test trials described below. Each test trial began with a fixation cross that was displayed for 500 ms. After the fixation cross disappeared, a possible or an impossible object was presented to the left or right of fixation. The object remained on the computer screen for 150 ms (the approximately duration of an eye saccade). Participants responded as quickly and as accurately as possible to the stimulus. No feedback was given on the test trials. After each trial, there was a 1000 ms delay before the next trial began automatically.

RESULTS

Mean accuracy and response times were calculated for each subject within each factor. Response times were analyzed for outliers using a trimming method that removed outliers more than three standard deviations away from the individual participant's response-time means. Error rates were high for some participants and were approximately 30% across the anomalous conditions and 25% across the normal conditions. However, no error rates approached chance and all data collected was used in the analysis.

A repeated-measures analysis of variance was conducted on response time and accuracy. The effect of gender was treated as a between-subjects variable. There were no main effects of or interactions with reaction time for males or females (all F's < 1). In regard to the accuracy data, there was a significant main effect object type (impossible vs possible) for both the familiar and the unfamiliar items, $F(1, 26) = 74.64$, $p < .001$ and $F(1, 26) = 4.245$, $p < .05$, respectively. Possible objects

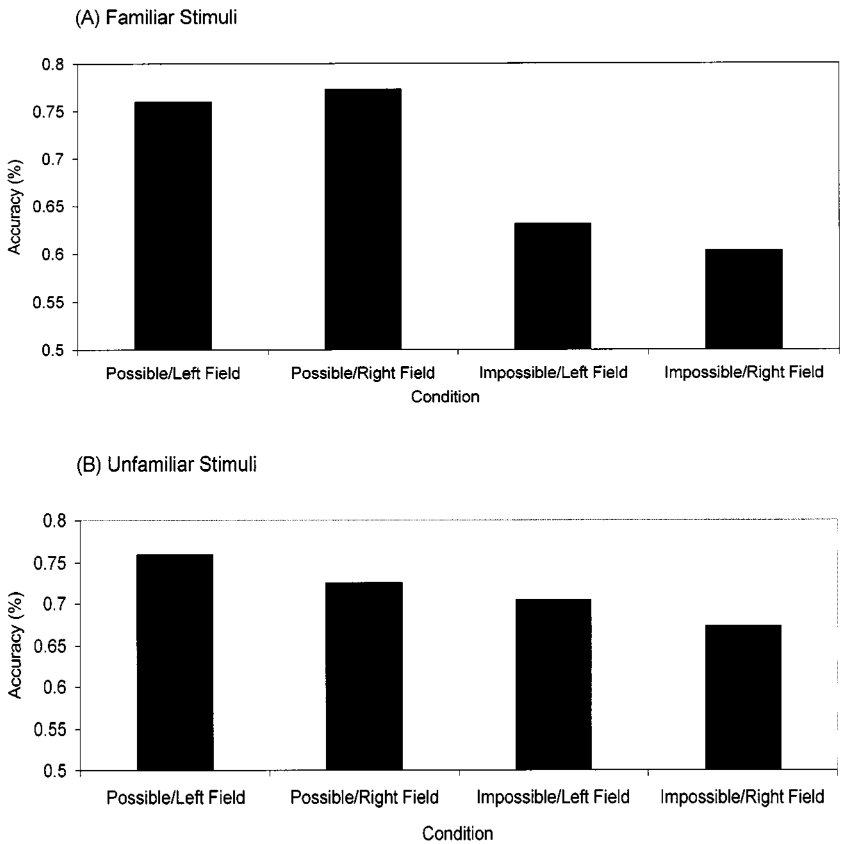

FIG. 2. A graphical representation of means found for male subjects. Graph (A) displays corresponding data from male subjects when tested using possible and impossible familiar stimuli presented in the left and right visual field. Graph (B) shows male subjects' accuracy scores in test trials presenting possible and impossible polygon line drawings in the left and right visual field.

were generally responded to more accurately than impossible objects, both for the familiar (Snodgrass & Vanderwart, 1980) and unfamiliar (Williams & Tarr, 1997) figures. A significant interaction of object type $\times$ visual field $\times$ gender was also found for the unfamiliar objects, $F(1, 26) = 5.278$, $p < .03$. This result suggests that the males were showing larger effects than the females.

Given the fact that females tended to show smaller effects than males, we hypothesized that the anomaly detector may be more lateralized in males than in females. Therefore, we analyzed the data from males separately. The means for these data are presented in Fig. 2. The resulting analysis was a 2 (object type) $\times$ 2 (visual field) $\times$ 2 (familiarity) repeated-measures ANOVA. There was a main effect of familiarity, with the familiar items resulting in more errors than the unfamiliar items, $F(1, 11) = 5.29$, $p < .05$. As well, the main effect of object type (possible vs. impossible was significant, $F(1, 11) = 22.00$, $p < .001$. Critically, a marginally significant object type x visual field interaction was found for males, $F(1, 11) = 2.945$, $p = .057$. Male participants detected anomalous stimuli presented in the left visual field more accurately than in the right visual field.

DISCUSSION

The results of this experiment provide tentative support for the notion of a right-hemisphere anomaly detector. In male participants, there was a tendency for the right hemisphere to be superior to the left detecting impossible objects.

It is possible that the tendency for males to be better than females at detecting impossible objects is due to a general superiority in visuospatial skills. However, males performed at slightly higher levels than females when dealing with *familiar* objects (i.e., objects for which participants have semantic and memorial representations). Thus, the effect cannot be entirely accounted for by a gender difference in basic visuospatial abilities.

One of the more salient aspects of the data was that the anomaly detector appears to be more lateralized to the right hemisphere in males than in females. For both the familiar and the unfamiliar objects, males showed a larger right hemisphere advantage than did females. This gender difference could be due to the fact that, in general, males show stronger lateralization of function than do females (Springer & Deutsch, 1998). Given this fact, it is not surprising that the predicted right-hemisphere advantage was marginally significant in males but was not significant in females.

Previous work (Dolan & Frith, 1997; Ramachandran, 1995) has demonstrated that the right hemisphere appears to be able to detect incongruities between the visual perception of a movement and the biofeedback related to that movement. However, all of this previous research has involved multiple sensory modalities (Ramachandran, 1995) or semantics (Gardner, 1993). The current experiment extends the scope of the anomaly detector from higher level cognitions to lower level visual perception. Whether this lower level anomaly detector influences performance on other perceptual tasks has not yet been studied. This, along with the possibility of multiple anomaly detectors for different levels of analysis, is an issue to be settled empirically.

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Movement in the Ipsilesional Hand Is Segmented Following Unilateral Brain Damage

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Unilateral stroke results in hemiplegia or hemiparesis of the contralateral side of the body. The ipsilateral side of the body, the so-called ''good'' side, is often assumed to have no deficit. However, there is increasing evidence that the function of the unaffected limbs, especially the upper extremities, is different from that of normal age-matched controls. In the present study, we examined the motor control of both hands of chronic stroke subjects, 6 with left hemisphere brain damage (LHBD) and 5 with right hemisphere brain damage (RHBD). The control group consisted of 5 normal age-matched subjects. The task of the subject was to move a handle by flexing his/her fingers until the target position was reached. The target position was set as 33% of the range of each subject. No time constraints were imposed. The movements of the normal subjects were basically smooth, with few hesitations. In contrast to this, the movements of both hands in the two stroke groups were segmented and characterized by multiple starts and stops. As compared to normals, the time to reach the target, the number of pauses during the movement, and the percent of time spent in pauses, were significantly greater for both hands of the LHBD group. In the RHBD group, the percent of time spent in pauses was significantly greater than the control group for the ipsilesional hand. The increased segmentation seen in the movements of the ipsilesional, as well as the contralesional, hands of the hemiplegic subjects suggests that the motor deficits in stroke patients may be due to a global inability to correctly plan and carry out movements.

INTRODUCTION

Following a unilateral cerebrovascular accident, the clearest evidence of sensory-motor deficits is typically seen in the limbs contralateral to the side of the lesion.

The affected limbs of the stroke patients suffer from a multiplicity of deficits such as weakness (Colebatch et al., 1986), abnormal muscle tone (Becher et al., 1998), abnormal patterns of muscle activation (Bourbonnais et al., 1989; Dewald et al., 1995) and abnormal interjoint coordination (Levin, 1996). In addition to the above, movements of the affected limb tend to be segmented, with velocity profiles which are skewed and disrupted, rather than smooth and bell shaped (Levin,1996; Cirstea & Levin, 2000; Krebs et al., 1999).

There is also increasing evidence of subtle defects in the function of the ''unaffected'' hand and arm ipsilateral to the damaged hemisphere—particularly in tasks demanding dexterity and coordination. For example, defects in the sensori-motor function of the ipsilateral hand have been found in tracking tasks (Carey et al., 1998; Jones et al., 1989; Halaney & Carey, 1989), in aiming and reaching movements (Baskett et al., 1996; Fisher et al., 2000; Fisk & Goodale, 1988; Winstein & Pohl, 1995) and in a wide variety of functional tasks (Desrosiers et al., 1996; Marque et al., 1997; Okuda et al., 1995; Smutok et al., 1989; Sunderland et al., 1999).

The ipsilesional hand shows prolonged movement times (Bell et al., 1994; Fisk & Goodale, 1988; Harrington & Haaland, 1992; Sunderland et al., 1999; Winstein & Pohl, 1995), and decreased accuracy (Carey et al., 1998; Sunderland et al.,1999; Velicki et al., 2000) as well as deficits both in the planning and execution of skilled motor tasks (Fisk & Goodale, 1988; Fisher et al., 2000). However, detailed kinematic analysis of the movements of the ipsilesional arms has revealed smooth, basically, bell-shaped velocity profiles. This was true even when the movements were defective in other ways (Fisk & Goodale, 1988; Fisher et al., 2000).

In the present study, we investigated the smoothness of motion and movement time during a finger movement step tracking task in subjects with stroke, as compared to healthy age-matched controls. In contrast to previous studies, we found that this task elicited a choppy and segmented movement not only in the affected contralateral hand, but also in the ostensibly unaffected ipsilateral hand. This suggests an additional ipsilateral defect in addition to those previously described.

MATERIALS AND METHODS

Subjects

There were 3 groups of subjects: left hemisphere brain damaged (LHBD), right hemisphere brain damaged (RHBD), and normal controls. The LHBD group consisted of 6 subjects, 4 men and 2 women, aged 49–70 (59.7 $\pm$ 5.5). The RHBD group consisted of 5 male subjects aged 62–81 (72.4 $\pm$ 7.6). The control group consisted of 5 normal, right handed, age matched subjects, 4 men and 1 woman, aged 56–86 (67.4 $\pm$ 10.4), who did not suffer from any discernable neurological impairment. All of the stroke subjects were premorbidly right handed, and none was aphasic. Brain damage in all cases was due to stroke, with a clinical picture consistent with unilateral middle cerebral artery involvement. Subjects were between one and three years post stroke, with an average of 21 months. All patients had some degree of hemiparesis contralateral to the lesion. One subject in each stroke group was hemiplegic, as opposed to hemiparetic, and had no active movement in the fingers of the contralesional hand. All subjects were able to comprehend the experimental task and complete it satisfactorily in a single session of less than 20 min. All signed informed consent forms prior to participation in the study.

Apparatus

The apparatus used in this experiment was designed to study finger flexion and extension in the horizontal plane and evaluate the quality of the movement. The apparatus consisted of a handle that slid on a very low friction track. The subject's forearm rested on a support and was stabilized in mid-position between pronation and supination. A vertical post stabilized the heel of the palm, limiting movement to the metacarpophalangeal and interphalangeal joints of the hand. The subject grasped the handle with his/her fingers and used his/her finger flexor muscles to draw the handle in the direction of the post. A weight resistance in the direction of finger extension acted to pull the handle open. The position of the handle was measured by a linear potentiometer. The apparatus was interfaced with a computer via an analogue/digital converter (DAQ 1200, National Instruments). Data was sampled at 40 Hz.

Procedure

The subject was seated facing the experimental apparatus and the computer screen, with his/her forearm resting in the support and the heel of his/her hand placed firmly against the vertical post. The handle was grasped with all 4 fingers. While the subject grasped the handle, we measured the range of motion of the subject's hand by measuring the excursion of the handle from full flexion of the hand (fingers completely closed) to full extension (hand open). Full extension was defined as that point at which the distal phalanx of the 5th digit (little finger) could just grasp the handle. Past that position, the handle could be grasped by only 3 fingers. A brake was applied, so that the handle could not open past that point. This was now the starting point for each movement. The fully opened position of the hand was defined as 100 normalized units (N.U.), with other positions defined as a percentage of the fully opened position. We used normalized units instead of centimeters because hands vary considerably in size between individuals.

The position of the handle was displayed on the computer screen together with the target position that the subject was supposed to match. The task of the subject was to pull the handle of the test apparatus from the initial position, in which the hand was almost completely open, to the target position, which was always set as 33% of the range of the subject (33 N.U.). The task was repeated 10 times for each hand; the first 2 times were not included in the analysis. Except for the 2 subjects with no active movement in their affected hands, all the subjects were tested on both their right and left hands.

Data Analysis

A specially commissioned computer program, written using Labview (National Instruments), was used for data collection. Velocity of movement was derived using differentiation, and was low pass filtered using a dual pass Butterworth filter with a cutoff frequency of 10. A custom software program was used to analyze the following kinematic measures: movement time (MT), the number of pauses in the movement, and the percentage of time in each trial spent in pauses.

Movement time was measured from the beginning of the movement until the subject came within 12% of the target and stayed there for more than 0.30 s. In other words, if the movement ended with an extended, hesitating, homing in movement, or if there were difficulties zeroing in on the target, this phase was not included in the analysis. This allowed us to concentrate on the components of the movement itself without complicating factors due to problems with fine motor control or visualization of the target. There were 2 criteria for the definition of a pause: one, the average movement velocity was less than 6 normalized units per second and, two, the low velocity interval had to last for at least 0.09 s.

Data were analyzed using nonparametric tests—Mann Whitney for between subject comparisons and Wilcoxan Sign Test for intrasubject comparisons (SPSS 10). Values are given as mean ± standard deviation, and significance was set at $p < .05$.

RESULTS

Pattern of Movement

Figures 1A and 1B show a typical example of the hand movement of a control subject. The motion is smooth with no hesitations. Notice that the movement has two distinct phases—an initial, relatively rapid phase which brings the handle close to the target and a second, slower phase in which the subject ''homes in'' on the target. The first movement segment is probably preprogrammed and is carried out in an open loop fashion. The second phase is based on visual feedback and involves moment-to-moment control. In this sense, the movement of the fingers resembles more general aiming movements of the arm which also consist of 2 stages, an initial

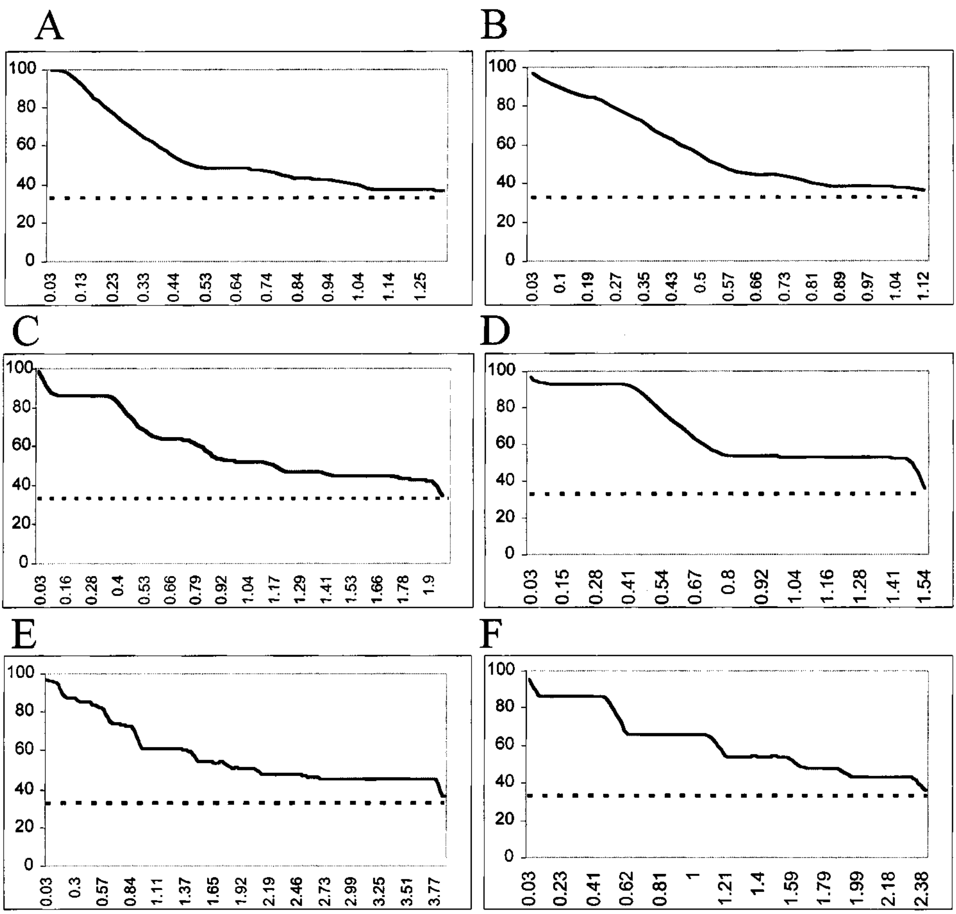

FIG. 1. Typical examples of the movement toward the target. The graphs show typical examples of movements of the fingers from a fully opened position to the target. The dotted line is the target which was set at 33% of the full range of motion of each subject. The *y* axis indicates the position of the handle in normalized units. The *x* axis indicates the time in seconds: (A) left hand control; (B) right hand control; (C) left hand RHBD; (D) right hand RHBD; (E) left hand LHBD; (F) right hand LHBD. Note the segmentation of the movements of the stroke subjects (C–F) as compared to the relatively smooth movement of the controls (A, B).

impulse stage (also called ballistic or preprogrammed movement phase), and a second, current control phase, in which the subject uses visual feedback to home in on the target, making fine adjustments as needed (Meyer et al., 1988). The same basic movement pattern was seen in both right and left hands of control subjects.

In contrast to this, as seen in Figs. 1C–1F, the movements of both symptomatic and asymptomatic hands of the hemiplegic subjects tended to be characterized by multiple starts and stops. Instead of the 2-phase movement seen in normal subjects, we see a choppy, segmented movement, which is interspersed with long pauses. This gives the movement the appearance of a series of steps. Instead of one rapid velocity phase followed by a slower phase, the movements of these subjects consisted of a series of brief, rapid velocity phases with a return to zero, or near zero, velocity between bursts. The movements of the unaffected right hands of two subjects with RHBD did demonstrate 2 distinct phases. However, the first phase was generally broken up by at least one zero velocity interval and the phases were separated by a relatively long pause, thus imparting a segmented appearance to these movements as well.

Movement Time

The left hemisphere brain damaged group (LHBD) was the slowest of the 3 groups (Fig. 2). The movement time for each hand of the LHBD group (3.02 ± 1.3, left hand; 3.62 ± 1.59, right) was significantly greater than the time for the corresponding hands of controls (1.25 ± .42, left hand; 1.5 ± .44, right hand). The movement times of the right hemisphere brain damaged group (RHBD) were 1.79 ± .59 for the left hand and 1.85 ± .80 for the right hand. These values were not significantly different from controls. For both the RHBD group and controls, there was no significant difference between right and left hands. However, in the LHBD group, the average movement time for the contralesional right hand was significantly more than the movement time for the ipsilesional left hand.

There was no difference in movement time between the ipsilesional hands of the two brain damage groups.

Segmentation

In order to evaluate the degree of segmentation in the movements of our subjects, we examined two aspects of their movement: (1) the number of pauses and (2) the amount of time in each trial taken up by pauses as a percentage of total movement time.

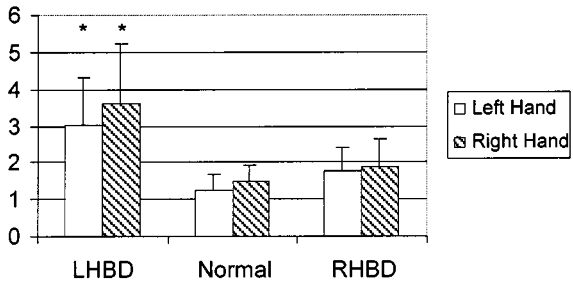

FIG. 2. Movement time: The *y* axis indicates the time in seconds to move the fingers from an open position to the target position (33% of full range of motion). Error bars indicate standard deviation. In the LHBD group the movement time for the right hand was statistically greater than the movement time for the left hand. *Statistically different from normals.

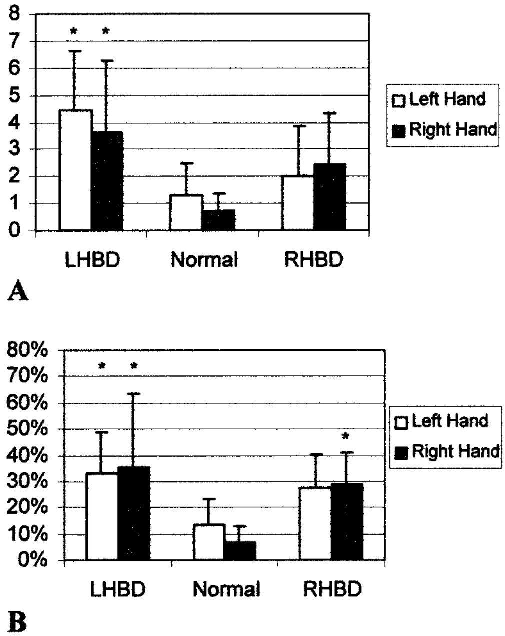

FIG. 3. Segmentation of movement: (A) The *y* axis indicates the number of pauses during the finger movement. (B) The *y* axis indicates the percentage of the total movement time spent in pauses. Error bars indicate standard deviation. *Statistically different from normals.

The LHBD group had the greatest number of pauses (Fig. 3A). The average number of pauses was 4.4 ± 2.2 for the ipsilesional left hand and 3.6 ± 2.8 for the contralesional right hand. This was significantly greater than the number of pauses for the corresponding hands of the control subjects (1.3 ± 1.1, left; 0.7 ± 0.7, right). The number of pauses in the RHBD group tended to be greater than controls (2 ± 1.8, left; 2.4 ± 1.9, right). However, this did not reach statistical significance. There were no statistically significant differences between right and left hands within any of the groups.

We next looked at the percentage of time in each trial that was spent in intervals of zero or near zero velocity (Fig. 3B). We termed this total pause time. We found that the total pause time of the LHBD group (32.84 ± 15.99, left hand; 35.23 ± 28.08) was significantly greater than that of the normal subjects (13.42 ± 9.83, left hand; 7.0 + 6.03, right hand). Surprisingly, the total pause time of the right ipsilesional hand of the RHBD group (28.79 ± 11.88) was also significantly greater than normal. Even though the total pause time (27.63 ± 12.84) of the left contralesional hand of the RHBD group was virtually identical to that of the right hand, it was not significantly greater than the normal group.

There was no difference between the corresponding hands of the LHBD and RHBD groups in either of the parameters used in evaluating the degree of segmentation.

DISCUSSION

We have shown here evidence for segmentation of movement in both left hemisphere brain damaged and right hemisphere brain damaged stroke subjects. It is important to note, however, that there were evident differences in the deficits seen in the two groups. As compared to controls, the movements of both hands of the LHBD subjects demonstrated a statistically significant increase in the number of pauses, as well as an increased percentage of movement time taken up by very low velocity intervals. The ipsilateral hands of the RHBD subjects showed a significant increase only in percentage of pause time. The movements of the contralesional hands of the RHBD subjects were also segmented; however this segmentation did not reach statistical significance, possibly because the algorithm that we used was not sensitive enough to detect it. The ipsilesional deficits seen here were more severe in the LHBD group than in the RHBD group. This is consistent with previous reports of greater bilateral deficits after left hemisphere brain damage (e.g., Haaland & Harrington, 1994; Harrington & Haaland, 1992; Okuda, 1995; Smutok et al., 1989; Sunderland et al., 1999), although some studies have found more severe, or equally severe, ipsilesional deficits after right hemisphere brain damage (e.g., Desrosiers et al., 1996; Finlayson & Reitan, 1980; Hom & Reitan, 1982). The segmented movement of both hands of the LHBD subjects may be related to the increased movement time of this group. However, the observation that the movements of the RHBD group were also segmented, despite their normal movement times, makes it unlikely that increased movement time is the only explanation for this phenomenon.

Previous studies have demonstrated segmentation of movement of the contralesional hand (Cirstea & Levin, 2000; Krebs et al., 1999; Levin, 1996; Trombly, 1992). The segmentation demonstrated in this study, however, is qualitatively different from that seen in those earlier investigations, which showed multiphasic tangential velocity profiles, or brief zero velocity crossings, but not actual pauses where the velocity approached zero and stayed there for substantial periods of time. Krebs et al. (1999) did provide strong evidence that the movements of acute hemiplegics are composed of isolated segments, but even here, the segmentation was not nearly as severe as that seen in our subjects. Moreover, in the Krebs study, the segmentation was a transient phenomenon; as recovery progressed, the segments became progressively more blended. In contrast to this, in our study, we saw that the movements of patients more than a year post stroke were still interspersed with obvious pauses of .09 s, and longer, during which movement velocity averaged close to zero.

Abnormalities in the production of visually guided movements in the ipsilesional hands have been reported in previous studies (e.g., Levin, 1996; Fisher et al., 2000; Fisk & Goodale, 1988). However, the present study is the first report of segmented movement in the ipsilesional hand. The question arises as to why this phenomenon has not been previously detected. There are several possible reasons for this. First of all, the tasks used in the Fisk and Goodale (1988) and Levin (1996) studies were either aiming or reaching movements. These tasks differ from the task used in this study in that they consist of relatively large, gross motor movements of proximal joints, while the experimental task used here required comparatively fine movements of distal joints. Second, the subjects in those studies aimed at a target that was directly in front of them. Our subjects were aiming at a virtual target situated on the computer screen and needed to perform a visuospatial transformation in order to translate the vertical position of the virtual handle seen on the computer screen to the horizontal translation of the actual handle. Therefore our task was more difficult and required a higher level of control in order to carry it out. This suggests that a deficit in information processing, as opposed to motor weakness, spasticity or sensory loss, may be the underlying cause of the segmented movement. This is in line with the study of Carey et al. (1998) which showed that deficits in the tracking ability of the ipsilesional hand in subjects with stroke were probably due to a global impairment in information processing.

The experimental paradigm in the Fisher et al. study (2000) did require the subjects to perform a visuospatial transformation. However, their analysis was limited to single peaked velocity trials in which there were no obvious trajectory corrections. Trials with multiple velocity peaks were either eliminated or else only the first peak was analyzed. In other words, trials in which there was evidence of segmentation were not included in their study.

The hypothesis that there is a global deficit in information processing is strengthened by the observation that, aside from movement time in the LHBD group, there were no significant differences in the parameters tested between left and right hands in either of the stroke groups. In other words, segmentation of movement was seen in both the affected and the unaffected hands of the subjects with stroke. This segmentation, which was characterized by the presence of short bursts of unsustained movement and long pauses between movements, may indicate that the stroke subjects were unable to preplan the entire motion and, instead, had to rely on moment to moment control of hand movements.

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Content Mazes and Filled Pauses in Narrative Language Samples of Children with Specific Language Impairment

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Linguistic nonfluencies known as mazes (filled pauses, repetitions, revisions, and abandoned utterances) have been used to draw inferences about processing difficulties associated with the production of language. In children with normal language development (NL), maze frequency in general increases with linguistic complexity, being greater in narrative than conversational contexts and in longer utterances. The same tendency has been found for children with specific language impairment (SLI). However, the frequency of mazes produced by children with NL and SLI has not been compared directly at equivalent utterance lengths in narration. This study compared the frequency of filled pauses and content mazes in narrative language samples of school-age children with SLI. The children with SLI used significantly more content mazes than the children with NL, but fewer filled pauses. Unlike content mazes, the frequency of filled pauses remained stable across samples of different utterance lengths among children with SLI. This indicates that filled pauses and content mazes have different origins and should not be analyzed or interpreted in the same way.

INTRODUCTION

Mazes refer to a number of types of nonfluencies that are not part of the intended message and that detract from its efficient communication (Loban, 1976). Specifically, mazes include filled pauses (*um, uh*), repetitions, revisions, false starts, and abandoned utterances. Mazes in spontaneous language samples have been used to draw inferences about performance factors affecting language production. Theoretical accounts have been proposed in which mazes result from the high processing demands inherent in the formulation of complex language (e.g., Levelt, 1989). In clinical assessment of children's language proficiency, high frequencies of mazes are typically interpreted as indicating a processing conflict during production (Leadholm & Miller, 1992; Nelson, 1998; Owens, 1999), such as word finding difficulty or sentence formulation problems. Given the processing and working memory limitations repeatedly documented in children with specific language impairment (SLI) (cf. Gillam, 1998), a higher than normal frequency of mazes should be expected in this population.

In normal language (NL) development, maze frequency generally increases with age and with the demands of the context, being greater in narration than conversation (Leadholm & Miller, 1992). Mazes have also been found to increase with utterance length (MacLachlan & Chapman, 1988). Thus, in general, it appears that the frequency of mazes is proportional to the overall complexity of the language being used. Previous studies of mazes produced by children with SLI indicate that they are similarly influenced by complexity as in NL (MacLachlan & Chapman, 1988; Wagner, Nettelbladt, Sahlén, & Nilholm, 2000), being more frequent in narrative than in conversational contexts. Therefore, meaningful comparison of mazes in different populations needs to examine both groups in similar, and preferably taxing contexts in which mazes are particularly likely to be observed, such as in narrative rather than conversational language samples.

Although previous studies have compared mazes of children with NL and SLI in both conversation and narration, the two groups have not been compared directly at equivalent MLU levels in narration. In MacLachlan and Chapman (1988), the NL and SLI groups were matched on MLU in conversation, but differed in MLU in narration. Interestingly, although the children with SLI and the younger MLU-matched children had similar utterance lengths in conversation, the younger NL children did not demonstrate the same ability as the children with SLI to produce long utterances in narration. Therefore, if matching had involved narrative samples, a different comparison group would have been selected. The different behavior between the groups of children across contexts illustrates the complexity of language production and associated production breakdowns. Mazes are in general related to linguistic complexity. However, the complexity of spontaneous language is itself dependent on a number of factors. In the case of the groups of children studied by MacLachlan and Chapman, it may be that the children with SLI, being older, possessing more world knowledge, and responding to age expectations, had pushed themselves to produce long utterances in their narration. The younger children with NL used shorter utterances and had fewer mazes. As has been suggested also in a study of mazes in language samples of an adult subject with memory deficits (Caspari & Parkinson, 2000), relatively maze-free speech can be achieved by highly proficient speakers or by speakers who do not attempt complex utterances. This underscores the need to compare subject groups at similar levels of linguistic complexity, such as by controlling utterance length (MLU).

Different maze types are typically interpreted to some extent as indicating different underlying factors. Thus, filled pauses and repetitions are viewed as stalling behaviors, whereas semantic or syntactic revisions are viewed as indicating deeper formulation problems. Some developmental changes have been observed in maze types among children with NL (e.g., Evans, 1985). However, there has been little systematic study of maze types or associated factors in individuals with language impairments. MacLachlan and Chapman (1988) found that the relative frequency of maze types, including stalls, repairs, and abandoned utterances, remained constant across age and conversational and narrative contexts for both children with NL and SLI with the exception of filled pauses, which showed evidence of increasing in frequency with age. Given this finding, this study differentiated filled pauses and other mazes (content mazes). The purpose of this study was to compare the frequency of mazes used by children with SLI and children with NL in narrative language samples of equivalent utterance length. The study examined groups of school-age children, including groups matched on age and on MLU. Mazes were subdivided into filled pauses and content mazes.

PARTICIPANTS

Participants were school-age children ranging in age from 5;5 to 9;8, including 50 children with SLI and 50 children with NL matched group-wise on age (SLI group: mean age in months: 93.63, *SD* 12.51; mean MLU: 7.18, SD 2.24. NL group: mean age in months 92.96, *SD* 12.15, mean MLU 9.32, *SD* 1.94). In addition, subgroups of 25 children with SLI and 25 children with NL were matched on MLU (SLI group: mean age in months 100.28, *SD* 9.18; mean MLU 8.62, *SD* 1.86; NL group: mean age in months 84.04, *SD* 8.52, mean MLU 8.61, *SD* 1.80). It should be noted that among the children with SLI, the MLU-matched subgroup had a higher mean MLU than the larger age-matched group. Thus, this subgroup included the more advanced of the children with SLI. All the children were monolingual speakers of English. This sample has been described in detail in Thordardottir and Ellis Weismer (in press).

PROCEDURE

Narrative language samples were collected as part of previous studies (Ellis Weismer & Hesketh, 1996, 1998; Ellis Weismer, Evans, & Hesketh, 1999) by a single examiner using the same protocol for each child. The samples were transcribed orthographically according to SALT conventions (Miller & Chapman, 1993). Mazes were separated from the rest of the utterance following SALT transcription conventions such that the remainder of the utterance constituted a coherent utterance. Filled pauses were those that contained nonspecific content such as *um, uh, like.* Content mazes contained meaningful linguistic material, such as words or phrases. This analysis included the middle 50 utterances of each language sample. Whereas SALT analyses typically include only complete and intelligible utterances, the analysis of mazes in the present study included all utterances, including partially unintelligible and abandoned utterances, given the focus on communication breakdowns. The maze measures obtained included: (1) number of mazes (content mazes and filled pauses), (2) number of filled pauses, (3) number of content mazes. Interrater reliability of the coding of mazes was rechecked in 10 randomly selected samples and was 95%.

RESULTS

Results were analyzed for age-matched and MLU-matched groups separately using a mixed model 2 × 2 ANOVA with group as the between subjects factor and maze type (filled pauses, content mazes) as repeated measures. For the age-matched groups, the maze type × group interaction was significant ($F(1, 98) = 7.76$, $p = .006$, $\chi^2 =$

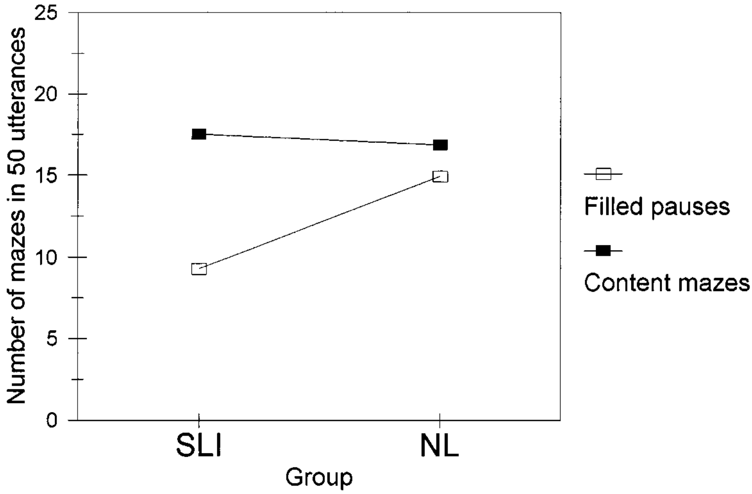

FIG. 1. Number of filled pauses and content mazes used by children with SLI and NL matched on age. The figure shows the maze type × group interaction.

.07). This interaction is displayed in Fig. 1. Post hoc Fischer LSD tests revealed that content mazes were more frequent than filled pauses for both groups. However, whereas the difference between these maze types was small and nonsignificant for children with NL, this difference was much larger and statistically significant for children with SLI. The groups differed significantly in the frequency of filled pauses, but not in the frequency of content mazes. Children with SLI had fewer filled pauses than children with NL. The main effect of maze type was significant ($F(1, 98) = 20.31$, $p = .000$, $\chi^2 = .17$), suggesting that content mazes were overall more frequent than filler mazes and the main effect of group approached significance ($F(1, 98) = 3.56$, $p = .062$), suggesting that children with SLI used fewer mazes overall than children with NL. These main effects are subsumed by the maze type × group interaction.

For the groups matched on MLU, a significant maze type × group interaction was

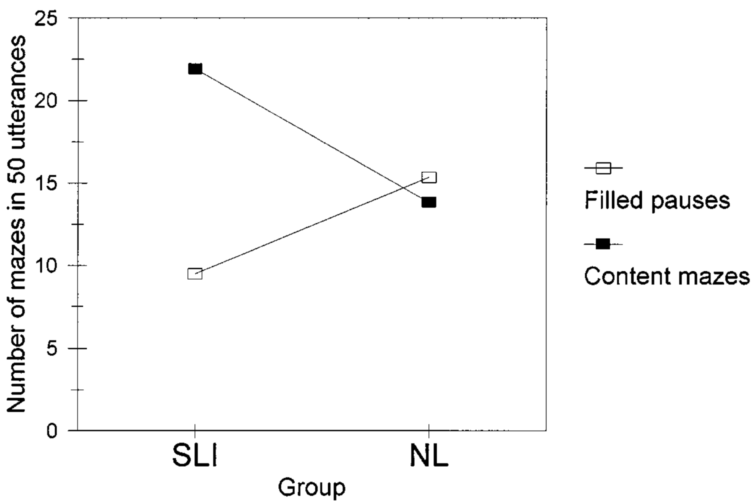

FIG. 2. Number of filled pauses and content mazes used by children with SLI and NL matched on MLU. The figure shows the maze type × group interaction.

also found ($F(1, 48) = 20.06$, $p = .000$, $\chi^2 = .30$). The interaction is shown in Fig. 2. Post hoc tests revealed that children with NL had somewhat fewer content mazes than filled pauses, but the difference was not significant. Children with SLI, however, had a large and significant difference between the two maze types, with content mazes being much more frequent than filled pauses. The groups differed significantly in the frequency of use of both maze types. Children with SLI had significantly fewer filled pauses and significantly more content mazes than children with NL. The main effect of maze type was significant ($F(1, 48) = 13.00$, $p = .001$, $\chi^2 = .20$), suggesting that content mazes were more frequent than filled pauses overall. This main effect is subsumed by the maze type × group interaction and cannot be interpreted independently. The main effect of group was not significant for the MLU-matched groups ($p > .6$).

DISCUSSION

Given previous reports that maze frequency increases with increasing utterance length and the assumption that mazes reflect processing difficulty, it was expected, that children with SLI would maze more than their MLU-matched counterparts because of their lower processing abilities. This prediction was only partly borne out in the results. Only content mazes showed this effect. The age-matched groups did not differ in the frequency of content mazes, whereas the MLU-matched groups did. In contrast, children with SLI unexpectedly used fewer filled pauses than children with NL, whether matched on age or on MLU. This suggests that these two types of mazes are not motivated by the same types of factors.

No firm prediction had been made for the age-matched groups. These groups differed significantly in MLU. Given the lower MLU of the SLI group, utterance length was expected to contribute less to the production of mazes for children with SLI than NL. In contrast, processing factors were expected to promote maze production more so for the children with SLI than children with NL. Given this trade-off of factors between the groups, the finding of similar frequencies of content mazes across groups is not surprising. The finding that filled pauses were significantly less frequent among children with SLI is, however, surprising and indicates, again, that filled pauses are influenced by other factors than are content mazes.

Although a direct statistical comparison was not made between age- and MLU-matched groups, the latter being a subgroup of the former, inspection of Figs. 1 and 2 reveals little change in the frequency of either maze type for the NL children between age and MLU matches. However, for the group with SLI, when age-matched and MLU-matched groups are compared, filled pauses remained at similar, low, levels, whereas the frequency of content mazes increased considerably from age- to MLU-matched groups. The MLU-matched subgroup with SLI includes the more advanced of the SLI children, having a significantly higher mean MLU than the larger age-matched group of children with SLI. This comparison between age-and MLU-matched groups within children with SLI strengthens the conclusion that only content mazes were influenced by length of utterance, whereas filled pauses were not.

To summarize, this study compared the frequency of mazes produced by school-age children with SLI and NL in utterances of comparable length in a narrative context. Children with SLI used significantly more content mazes and significantly fewer filled pauses than their NL counterparts. These results suggest that these maze types are not influenced by the same types of factors and that they should not be analyzed together. In fact, the main effect of group was not significant for either age- or MLU-matched groups, masking the fact that the pattern of content and filler mazes was substantially different across groups. It can be concluded that content mazes appear to be susceptible to processing factors, increasing with utterance length and being more frequent among children with lower processing abilities. However, filled pauses appear to have a different origin. MacLachlan and Chapman (1988) had previously reported that the relative frequency of filled pauses increased with age. Because MLU also increases with age, one possible interpretation might be that filled pauses are a by-product of long utterances. However, the present results show that this is not the case. Alternatively, it can be speculated that filled pauses may be motivated by pragmatic factors that are relatively independent of utterance length and that they may serve the function of indicating that the speaker still holds the floor. The frequency of this maze type may increase with age because the use of this maze type requires metalinguistic skills. More research is needed to clarify the interpretation of different maze types among speakers with normal language and language impairment. This study does indicate that filled pauses are different from content mazes and that computation of maze frequency as an indication of processing difficulty should not include both maze types.

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