Semantic Proximity and Shape Feature Integration Effects in Visual Agnosia for Biological Kinds

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Category specific visual agnosia (CSVA) for biological objects appears to be caused by a deficit in retrieving structural knowledge. We investigated the case of IL, a patient who suffers from CSVA, in order to examine the relationship between structural and semantic knowledge. Two experiments involving synthetic shapes, a visual classification task and a picture–word matching task, were conducted with IL and 5 neurologically intact subjects. Compared to normals, the patient's results in the first task showed no perceptual categorization deficit, but in the second task they revealed interactive effects of visual structure and of semantic category. The category specificity of CSVA is explained by the greater semantic proximity between visually similar biological objects compared to artefacts.   © 1999 Academic Press

Introduction

Category specific visual agnosia (CSVA) for biological objects is a rare disorder usually caused by left or bilateral inferior-temporal brain damage (Saffran & Schwartz, 1995). Typically, patients with this form of CSVA have difficulty visually recognizing most biological objects, but preserved ability to recognize most man-made objects. Researchers generally agree that an impairment affecting stored structural (i.e., visual) knowledge is at the root of the disorder. Recent findings suggest that the disorder can be attributed to a deficit in integrating shape features from stored structural knowledge which is modulated by semantic proximity (Arguin et al., 1996; Dixon et al., 1997). In the present study, we examined CSVA patient IL in an attempt to further investigate the interaction of visual and semantic processing in the disorder.

Methods and Results

Subject. IL is a 75-year-old francophone man who contracted herpes encephalitis in July 1995. Initially, IL complained of memory and visual recognition problems. Testing revealed a full-scale IQ of 81 and deficits in long-

term memory, executive functions, and spatio-temporal orientation. Tests also showed that he suffered from prosopagnosia and visual object agnosia. However, his linguistic, visual discrimination (matching geometric shapes or faces), auditory recognition, reasoning, and short-term memory capacities were all spared.

Experiment 1: Visual object naming. IL named line drawings of biological objects ($n = 75$) and artefacts ($n = 75$) matched pairwise on visual complexity, familiarity, and name frequency. Error rates were 65% for biological objects and 20% for artefacts.

Experiment 2: Reality decision. The patient decided whether pictorially represented objects were real or not. Half of the images represented existing objects and half nonexisting objects (constructed by exchanging parts of real objects). The categories tested were animals, fruits and vegetables, and artefacts. Error rates were 46% for animals, 48% for fruits and vegetables, and 28% for artefacts.

Experiment 3: Shape categorization. Stimuli were three sets of 12 synthetic shapes each, which were generated by transforming an ellipsoid along the dimensions of elongation, curvature, or tapering. For each set, the shapes corresponding to the extremes of the continuum were recognizable depictions of a fruit or a vegetable (elongation: cucumber/asparagus; curvature: cucumber/banana; tapering: cucumber/carrot). The other 10 stimuli of each continuum corresponded to equally spaced changes on the dimension of interest. Shape sets were tested separately, each in five blocks of 12 trials. On each trial, one shape was shown by itself and the subject indicated which end of the tested continuum it resembled most. Five neurologically intact subjects aged between 25 and 27 years old were each tested on half as many trials as IL. Results showed accurate categorization performance, with stimuli at the extremes of each continuum receiving the appropriate labels. IL's response distribution was significantly different from chance and showed an abrupt response category switch along the stimulus continuum, which also occurred in our normal observers.

Experiment 4: Visual picture-to-auditory word matching. Visual stimuli were synthetic ellipsoids varying on elongation, curvature, and tapering. The patient indicated whether an auditory word and a visual shape presented simultaneously referred to the same target-object. On positive trials, the picture closely matched the shape of the target-object referred to by the word. On negative trials, the picture differed from the target-object on one (elongation, curvature, or tapering), two (elongation–curvature, elongation–tapering, or curvature–tapering), or three (elongation–curvature–tapering) shape dimensions. A total of 1008 trials, half positive and half negative, were run with IL in 18 experimental blocks including all conditions in random order. Two semantic conditions were tested, one in which the auditory words referred to biological objects (banana, carrot, cucumber, eggplant) and one in which they referred to artefacts (canoe, cigar, tentpeg, snowshoe). Reference

to the stimuli as biological objects or artefacts was done in separate sessions. Five neurologically intact subjects aged between 25 and 27 years old were each tested on half as many trials as IL.

IL's overall error rate on negative trials was 33% (chance level = 50%) compared to 0.01% for normal controls. Only results with our patient indicated a clear semantic category effect with error rates of 46% for fruits and vegetables compared to 19% for artefacts [IL: $\chi^2(1) = 44.29$; $p < .01$; Controls: $\chi^2(1) = 3.42$; ns]. Contrary to normal control's performance who showed no difference between conditions on negative trials [$\chi^2(2) = 5.41$; ns], IL's performance was an inverse function of the number of dimensions by which the picture differed from the target-object: error rates were 41% with a difference on one dimension, 27% with a two-dimension difference, and 24% with a three-dimension difference. Moreover, IL's results revealed an interaction between semantic category and degree of shape difference. While the effect of number of dimensions by which the picture differed from the target object was significant with biological terms [$\chi^2(2) = 9.61$; $p <$ .1], it was not for artefact names [$\chi^2(2) = 3.68$; ns]. No such interaction was apparent in normal controls.

Discussion

IL exhibits a visual object recognition disorder that may be explained in terms of an impaired access to stored structural knowledge. This access problem is more severe for biological objects than for artefacts (cf. Experiments 1–2). Since IL was able to categorize biological items on the basis of a single-shape dimension (Experiment 3), it appears that his main difficulty is not simply one of processing some shape features. Rather, these observations suggest that basic visual information required to represent biological objects is still available to the patient.

The visual picture-to-auditory word matching task (Experiment 4) showed an interaction between semantic category and the degree of shape difference between the picture displayed and the target-object. The main effect of shape difference in IL suggests a deficit in processing the full range of features necessary to specify the shape of a particular object uniquely relative to others that share some of its properties (i.e., shape integration deficit). Even though the shapes used in the two semantic conditions were the same, feature integration was markedly worse with shapes labeled as fruits and vegetables than with shapes labeled as artefacts.

Semantically, fruits and vegetables are related objects, whereas the artefacts used here are semantically distant. Our results suggest that semantic distance prevents confusions between structurally related objects in CSVA. Therefore, the disorder is conceived as a shape integration impairment modulated by semantic proximity. This is congruent with previous findings from CSVA patient ELM and indicates that category selectivity in the disorder is

a function of the greater visual similarity of semantically related biological than nonbiological objects.

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Impaired Awareness of Social and Emotional Competencies Following Orbital Frontal Lobe Damage

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The frontal lobes have been hypothesized to be involved in mediating certain forms of awareness, including social self-awareness. However, there has been little investigation of the relative contribution of different frontal lobe regions in the process of social self-awareness. Our earlier studies suggested that the orbital frontal lobe may provide the neural substrate for this special form of awareness. To test this hypothesis, we compared five patients with focal, orbital frontal lobe damage to six patients with restricted posterior ventromedial (PVM) frontal lobe damage on a self-awareness measure. Results indicated that the orbital frontal group has difficulty estimating their social and emotional competencies compared to cognitive or instrumental abilities. In contrast, the PVM group demonstrated no alterations in any form of awareness. Findings support a crucial role for orbital frontal regions in monitoring social self-awareness.   © 1999 Academic Press

Introduction

Alterations in awareness of physical, perceptual, sensory, and cognitive deficits have been well documented in the neuropsychological literature. More recently, the possibility has been raised that patients with acquired cerebral damage may demonstrate a specific impairment in *social self-awareness* (e.g., Grattan et al., 1994; Prigatano et al., 1990; Prigatano and Altman, 1990). *Social self-awareness* has been defined as a specialized form of knowledge and insight about the self, particularly as it applies to one's own behavior in social circumstances (Grattan et al., 1994). Accurate social self-

awareness involves a realistic appraisal of processes such as how one affects others or how well one manages strong emotions in interpersonal situations. Accurate social self-awareness is important for the selection of those interpersonal behaviors which are contextually and socially appropriate thus facilitating the maintenance of positive relationships over time. Inaccurate social self-awareness may result in tactless comments as well as other inappropriate, bizarre, or disinhibited behaviors. Inaccurate social self-awareness may also result in a decrease in motivation for, or responsiveness to, treatment for interpersonal problems or a failure to implement necessary compensatory strategies.

Isolated difficulties in social self-awareness have been previously documented in patients whose neurologic illnesses or injuries disrupt the frontal lobes. Preliminary studies suggest altered awareness of social and emotional competencies independent of other forms of altered awareness (i.e., cognitive, instrumental) in patients with cerebral damage as a result of head trauma (Prigatano et al., 1990) and frontal lobe strokes and tumors (Grattan et al., 1994). However, the directionality of the altered awareness (over- vs underestimating problems) and precise frontal lobe clinical-neuroanatomic correlations remain to be specified. Historically, damage to the orbital frontal lobe sector has been strongly associated with difficulties in social judgment and applying social knowledge (cf. Phineas Gage). Patients with damage to this region may recover to the point of having normal measured intelligence, language abilities, learning and short-term memory, structured problem solving, and perception. However, patients with orbital frontal damage have been reported to develop marked difficulties in adjustment and adaptation, disproportionate to any degree of cognitive or neurologic disability. Therefore, the possibility was raised that the orbital frontal lobes could potentially represent a neural substrate for social awareness.

The *purpose* of this investigation is twofold: first, to determine whether or not patients with *focal* and *orbital-polar* frontal lobe damage demonstrate alterations in social self-awareness compared to patients with restricted posterior ventromedial frontal lobe damage. Second, if alterations in social self-awareness exist, to determine their directionality, i.e., the extent to which orbital frontal patients are more likely to over- or underestimate their social competencies.

Method

Subjects. Five volunteer men and women with acquired, CT/MRI verified lesions restricted to the orbital or orbital/polar frontal lobes comprised the experimental group. Lesions were the result of tumor ($n = 2$); surgical correction of AVM or aneurysm ($n = 2$); and gunshot wound ($n = 1$). Six patients with restricted posterior ventromedial (PVM) frontal lobe damage as a result of surgical correction of anterior communicating artery aneurysm

made up the comparison group. Lesion area was determined using a standardized template system by two investigators blinded to the neurobehavioral data. All participants were studied 4 to 6 months after hospital discharge. There was no difference between the groups with respect to age, sex, education, or race, WAIS-R Verbal, Performance or Full scale I.Q., verbal fluency (COWA), naming (Multilingual Exam Visual Naming Test), memory (WMS-R Logical Memory, Visual Retention Test), or cognitive flexibility measures (WCST) ($p > .05$).

Experimental measure. Social self-awareness: The Patient Competency Rating Scale (PCRS, Prigatano et al., 1986) was used to assess social self-awareness. The PCRS is a 30 item self-report instrument which measures patient comptencies in cognitive, instrumental, social, and emotional domains. A parallel form completed by a patient nominated family member was also used. The patient was asked to rate, on a five-point scale, how easy or difficult it is to form a wide variety of tasks and behaviors. This includes activities such as dressing oneself or remembering names of people. Patient and Relative versions of the PCRS were administered and discrepancy scores for each domain were calculated for each subject and used for data analysis.

Results

(1) Based upon analysis of discrepancy scores between ''self'' and ''relative's'' report, patients in the orbital lesion group demonstrated a specific alteration in social self-awareness ($t = -3.54$, $p = .02$) and no alteration in awareness of cognitive or instrumental abilities. The PVM group demonstrated no awareness deficits.

(2) All of the patients in the orbital lesion group (100%) *overestimated* their *social* and *emotional* difficulties compared to their ''significant others.'' The patients consistently reported having more difficulty in such areas as handling arguments, accepting criticism from others, and acting appropriately around friends than their relatives observed.

Discussion

Altered awareness of social competencies may occur independent of other forms of reduced awareness in patients with orbital or orbital polar frontal lobe damage. This raises the possibility that the orbital and polar frontal lobe regions may play an important, specialized role in monitoring social self-awareness. It appears as though patients with orbital or orbital frontal lobe damage tend to overestimate or have an exaggerated sense of their social and emotional difficulties. In light of these results, difficulties in social judgment previously reported in some patients with orbital frontal lobe damage may be partially related to (1) a heightened sensitivity to social problems, (2) difficulty distinguishing positive social interactions from negative interactions, and/or (3) the inability to adequately manage their perceived difficul-

ties in a social context. Future studies should examine the role of mediating factors such as premorbid personality in disturbances of social self-awareness after cerebral damage and the role of the other frontal lobe sectors such as the dorsal lateral frontal lobe.

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Semantic-Autobiological Memory Interactions in Severe Semantic Dementia: A Case Study

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We analyzed the residual knowledge of a patient (GC) with severe semantic dementia who presented, in 1994, a category-specific disorder affecting animals. In 1997, semantic representations for animals were lost but GC could still perform some tasks concerning animals on the basis of autobiographical memory. The assessment of contemporary and past autobiographical vs semantic memory (faces and places) showed a continuum with loss of semantic informations and relative preservation of ''contemporary'' autobiographical informations with regard to ''past'' ones. We discuss the existence of a dynamic semantic system with a continual interaction between autobiographical and semantic memory. © 1999 Academic Press

Introduction

Semantic dementia can be considered as a model of longitudinal loss of semantic knowledge. We report here a case of a patient (GC) who received in 1994 a clinical diagnosis of semantic dementia with a category-specific disorder affecting the category of animals (Cardebat et al., 1996). The aim of this paper is twofold: (1) to assess, 3 years after, the neuropsychological and, more specifically, the ''semantic'' profile of GC (i.e., category-specific disorder) despite very poor performance (MMS = 9) and 2) to evaluate the autobiographical memory with regard to residual semantic knowledge.

Neuropsychological Profile

GC, a 75-year-old woman, right-handed retired secretary was noted at the age of 69 to have word-finding difficulties. In 1994, MR imaging revealed a cortical atrophy restricted to the left temporal lobe and especially to the medial and posterior portions of T3 and T4.

Language deficit progressed dramatically over the following 6 years, whereas there was no evidence of elementary visual, spatial, or praxic difficulties. Moreover, GC remained well oriented in time, she negotiated her environment without becoming lost, and she was able to recall some recent autobiographical events.

In 1997, on language examination, her spontaneous speech was effortless but empty and stereotyped in content without phonological nor syntactic disturbances. We noted a reading disorder with pattern of surface dyslexia (16/20 hits on regular words, 0/20 on irregular ones) and a profound impairment of semantic memory causing severe anomia (I/40 hit), very impaired word comprehension, no production on verbal fluency tests. Semantic deficit was so important that it contaminated phonological processing as shown by GC's performance both on word repetition task and on word-span task from Patterson et al. (1994) that included either two ''known'' words referring to handmade objects or two ''unknown'' words referring to animals. Indeed, phonological errors appeared for unfrequent items (7/20 errors) in the repetition task and predominated for ''unknown'' words in the span task (5/28 errors, i.e., 5 phonemic paraphasias for handmade objects vs 21/28 errors, i.e., 21 phonemic paraphasias for animals). The category-specific disorder was also evidenced by a dissociation in performance with variability of errors for handmade objects (visual and auditory naming: 2/30 hits, picture–word matching; 8/20 hits but picture classification: 18/20 hits) contrasting with error constancy for animals (visual and auditory naming: 0/30 hits, picture–word matching; 0/20 hits, picture classification: nil).

Despite the apparent loss of semantic representations of animals, we tried to assess whether some autobiographic traces could subsist and compensate for the dramatic deficit related to this category. Then, GC was evaluated in a visual functional matching task, resembling the Pyramid–Palm Tree test, which included only animals (hits: 5/10). This performance, contrasted with profoundly severe impairment in other semantic tests, seemed to reflect autobiographical experience. For example, GC, who still likes fishing, was able to match a fish with a fishing rod. In the same way, GC was able to produce 7 hits in a word-categorization task according to the ''edible'' criterion of animals (*N:* 26, 19 ''I don't know'' responses), correct responses concerning animals like ''snail'' or ''prawn,'' items occasionally appearing in her menu.

Autobiographical and Semantic Memory

The purpose of the following section was to evaluate differential knowledge of contemporary, past, and semantic informations concerning names

of personal acquaintances vs celebrities and names of personal places (i.e., places where GC has been living) vs famous places.

Celebrities (*N:* 50, 15 ''contemporary'' and 35 ''past'') and acquaintances (*N:* 23, 17 ''contemporary'' and 6 ''past'') were evaluated from photographies. Since naming was almost impossible, responses were regarded as correct if they indicated functional or contextual information. Results showed that (1) the only famous face GC recognized was Jacques Chirac: ''That is the one who people . . . He's the one who commands people . . . He's in Paris . . . Everybody tells him something . . . Things aren't good for him . . . (GC was evaluated after President Chirac decided new general elections) and (2) that names of contemporary acquaintances were recognized (17 correct identifications, 5 correct naming) better than those relevant to the past (6 correct identifications but no naming).

The protocol of identification of names of places included 8 famous places, for example Bordeaux and Marseille (0/8 hits), 7 personal contemporary places (2/7 hits), and 8 personal ''past'' places (6/8 hits).

Discussion

This study focuses on the role of autobiographical experience in maintenance of concepts. Despite the importance of semantic deterioration that now affects the phonological level, GC's performance indicates that deficit still affects preferentially the animal category with a loss of semantic representations. However, this loss is not to be considered in Yes/No terms because some long-term representations still exist, which seem to reflect their current relevance for the patient. It would even seem possible to interpret the relative preservation of knowledge of handmade objects in terms of ''episodic'' trace continually reactivated in daily life.

More generally, GC's residual knowledge, which helps her to understand the world, seems to be nourished by autobiographic episodes temporally graded, since they need constant reactivation to assure a cognitive function. Indeed, results showed a continuum between an ''abolished'' semantic memory, an impaired autobiographical memory of the past, and a relatively preserved autobiographical current memory. Evidence for double dissociation between semantic memory and autobiographical memory has been reported by several authors (see for example Hodges & McCarthy, 1993, for loss of autobiographical memory and Snowden et al., 1996, for the reverse pattern) and can be related to bilateral lesions of the mesial temporal cortex and left-sided lateral temporal regions, respectively. The lesion observed in GC was congruent to the latter topography and is very well consonant with a specific deficit of semantic memory and relative sparing of autobiographical knowledge.

To conclude, this case study, despite its limits, suggests a bidirectional interaction between autobiographic and semantic memorizing and emphasizes the dynamic nature of the semantic system, with meaning constantly being updated through personal experience.

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Interhemispheric Cooperation Facilitates Response Times in a Primed Lexical Decision Task

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Within- and crossed-field priming were examined in a lateralized lexical decision experiment. Both left and right visual field primes (LVF, RVF) facilitated reaction times to LVF and RVF targets. Thus priming information is transferred and equally effective for both hemispheres. Also, for related and unrelated primes, and word and nonword trials, responses were fastest in the cross-field condition. This effect disappeared in a second experiment in which priming words were replaced by a string of letter-like nonsense forms. Thus, when two sequential words must be processed, there is a strong advantage for splitting the load between the hemispheres. © 1999 Academic Press

Introduction

The differential specialization of the cerebral hemispheres is well established, but the ways in which the hemispheres interact and the conditions under which interhemispheric integration is advantageous are less well understood. Interhemispheric integration can be studied by investigating how stimuli presented to one hemisphere affect processing of stimuli presented to the other.

Lexical decision tasks in which priming words precede the target letter strings can yield insights into whether the hemispheres share information about primes. Although lexical decisions are typically faster in the right than in the left visual field (RVF/LVF), studies with split-brain patients have indicated that both cerebral hemispheres can make lexical decisions, and both can benefit from semantic priming (Zaidel, 1983).

There are many lexical decision studies with lateral primes and targets presented in the same visual field (within-field trials). Only two reports con-

cern crossed-field conditions for word–word pairs; these studies found that related primes speeded responses between as well as within fields (Zaidel, 1983; Abernethy & Coney, 1993). Zaidel (1983) also found that reaction times were facilitated when targets and primes, whether related or unrelated, were in opposite visual fields, but this effect was absent from the Abernethy and Coney study. The studies differed in the nature of the prime–target relationship and the magnitude of priming in the two fields, and so the conditions under which the crossed-field advantage will emerge, and what this phenomenon indicates about interhemispheric cooperation, is unclear. To determine if the crossed-field advantage found by Zaidel reflects a processing deficit when both prime and target are projected to one hemisphere, within- and crossed-field priming effects on a lateralized lexical decision task were investigated.

Methods

A primed lexical decision experiment was run with 33 right-handed adults. On related trials, primes were both similar to and associated with the matched target (e.g., inch/foot); these primes have been shown to yield equivalent priming for within-LVF and within-RVF trials (Chiarello et al., 1990). Orthographically legal nonwords were created by changing a single letter in each target (e.g., foot became folt). Stimuli were shown for 150 ms, and appeared 1.2° (primes) or 1.9° (targets) to the left or right of fixation. The prime–target interstimulus interval was 200 ms. All stimuli were oriented vertically and appeared equally often in LVF and RVF. Half the trials were words and half were nonwords, and primes were related to targets on half of word trials. In a second experiment with 24 right-handers, priming words were replaced with a string of letter-like nonsense forms. For both experiments, subjects responded to words with one hand and to nonwords with the other, and hand signaling ''word'' was counterbalanced across subjects.

Results

In the experiment with word primes, subjects made word decisions 50.8 ms faster when the word was preceded by a related prime (related-primes mean = 508.4, unrelated-prime mean = 559.2 ms; main effect of relatedness of prime: $F(1, 31) = 40.96$, $p < .0001$). The relatedness of the prime did not interact with either field of target or field of prime, so primes in either field are equally effective for targets in either field. Subjects were also 15.8 ms faster to identify targets in the RVF than in the LVF (main effect of target VF: $F(1, 31) = 5.66$, $p = .024$). A crossed-field advantage also emerged: responses were 32.2 ms faster when the prime and target were in opposite field (interaction of field of prime with field of target: $F(1, 31) = 13.83$, $p = .0008$).

Word and nonword responses were analyzed for both experiments in an

ANOVA with study and hand used to identify word as between group factors, and target type, VF of target, and VF of priming stimulus (word or nonsense string) as repeated measures. There was a trend for responses to be faster when nonsense strings rather than words preceded the targets (main effect of study: $F(1, 53) = 3.49$, $p = .0675$; mean response times of 595.7 ms versus 655.5 ms), and word decision were made 127.2 ms faster than non-word decisions (main effect of target type: $F(1, 53) = 130.11$, $p < .0001$). A RVF advantage (20.9 ms) also emerged ($F(1, 53) = 24.67$, $p < .0001$).

A three-way interaction of study with VF of prime and VF of target ($F(1, 53) = 7.69$, $p = .0076$) indicated that the crossed-field effect, which was significant for the word trials in the first analysis, was also present for non-word trials in this experiment, but was not present for the nonsense prime experiment. This was confirmed in separate analyses with both word and nonword trials for both experiments. The interaction of prime and target VFs was significant for word primes ($F(1, 31) = 29.38$, $p < .0001$; average crossed-field advantage $= 36.5$ ms) but not for nonsense primes ($F(1, 22) = 2.42$, $p = .134$). In the nonsense prime study, there was virtually no difference in reaction times to RVF targets preceded by LVF versus RVF primes (584.1 ms versus 588.2 ms) and the difference for LVF targets (613.1 ms versus 597.5 ms) was considerably smaller than that observed in the first experiment.

Discussion

In an experiment with semantically and functionally related prime–target pairs, the magnitude of the priming effect was equivalent for LVF and RVF targets, and for within- and crossed-field conditions. However, the occurrence of a word in one visual field resulted in a moderate slowing of reaction times to subsequently presented word targets within that same field, whereas the occurrence of a nonletter string in the prime location did not. The crossed-field advantage for word–word or word–nonword trials clearly reflects the imposition of word processing demands on a receiving hemisphere, demands that interfere with that hemisphere's ability to process a letter string presented 350 ms later.

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Storage or Parsing of Morphologically Complex Words?
A Case Study in Agrammatism

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We analyzed the performance of a patient (M.B.) affected by agrammatism and phonological dyslexia. M.B. was tested with a series of tasks requiring lexical retrieval of simple and morphologically complex words. The patient presented a pattern of errors that is interpreted as the result of the prominent use of the lexical routine. This pattern of errors was characterized by frequency effect more than by a difference between types of suffixes (inflectional versus derivational) or types of word. It seems that high-frequency morphologically complex items will meet stored representations, thus avoiding more costly parsing that is required for less frequent items. These results are in keeping with dual-route models of lexical representation of morphologically complex words.   © 1999 Academic Press

Introduction

Are morphologically complex words stored in the mental lexicon or are they subject to parsing? Neuropsychological investigations on this issue focused mostly on a peculiar pattern of morphological errors shown by patients is justified by the fact that they are disturbed in reading via the sublexical routine. Their performance would therefore result from reading through the lexical system. Deep and phonological dyslexics show typical lexicality effects in reading but have also been demonstrated to experience difficulties with affixes in morphologically complex words. This finding has been interpreted either as evidence of a morphological decomposition of complex words (Job & Sartori, 1984) or of a basic weakness of the representation of bound morphemes (De Bleser & Bayer, 1990). The present investigation in an Italian-speaking patient affected by agrammatism and phonological dyslexia, a combination of symptoms that appears rather regularly, leads to a different conclusion.

Case Report

M.B. is a 24-year-old Italian male who sustained a left fronto-insular vascular lesion determining a Broca's aphasia with severe agrammatic speech production. Reading was severely impaired, especially for nonwords, function words, and verbs, thus showing the typical pattern of phonological dyslexia.

Experimental Investigation

A series of single-word processing tasks, aimed at assessing morphological abilities, was administered to M.B.: lexical decision on spoken and writ-

ten input, reading aloud, and repetition. M.B. performed flawlessly in lexical decision on spoken input but he showed both a concreteness and a grammatical class effect on written input (concrete vs abstract nouns, $\chi^2(1) = 11.93$, $p < .001$; concrete nouns vs function words, $\chi^2(1) = 9.52$, $p < .01$). Reading aloud also revealed marked lexicality, concreteness, and grammatical class effects with dramatic results on inflected and derived words (concrete simple nouns vs simple nonwords, $\chi^2(1) = 29.44$; $p < .0001$; concrete vs abstract nouns, $\chi^2(1) = 15.52$; $p < .001$; concrete nouns vs function words, $\chi^2(1) = 19.88$; $p < .001$; simple words vs derived words, $\chi^2(1) = 16.08$; $p < .001$; simple words vs inflected words $\chi^2(1) = 60.47$; $p < .0001$).

A further experiment on reading aloud was performed by having M.B. read suffixed and pseudosuffixed words. The suffixes used in this task have an evaluative function (e.g., diminutive: -ino, -etto, -ello; pejorative: -accio; augmentative: -one), a peculiar feature of Italian morphology. Four classes of real words were presented: (1) suffixed words with transparent meaning (e.g., lettino = little bed), (2) suffixed words with opaque meaning (e.g., lampada = lamp; lampadina = bulb), (3) pseudosuffixed words where the pseudoroot is an independent word in Italian (e.g., cervello = brain, but cervo = deer), and (4) pseudosuffixed words where the pseudoroot does not exist in Italian (e.g., carbone = coal; carbo is a nonword). M.B. was impaired on transparent evaluative suffixes with respect to the other three categories (see Table 17), thus showing an authentic morphological effect (if these errors were determined by lack of sufficient visual analysis pseudowords with existing root should have been read as badly).

The frequency effect if singlar vs plural form was also studied: M.B. read better singular than plural forms of words where the singular is more frequent; the inflections of words that are more frequent in the plural were instead read just above chance (see Table 17).

Discussion

M.B.'s performance is best interpreted as the result of reading via the lexicon. M.B.'s impaired performance on bound morphemes also varied according to word frequency and seems revealing about the processing of morphologically complex words. Evidence from the errors tells how M.B. first accesses (most) information in the proper lemma representation, even when made complex by features specification (e.g., plural or diminutive). He seems to retain information about markedness, being able to distinguish whether he has to read the base form (the singular of a noun, masculine and singular of an adjective, infinitive of a verb), or an inflected form whose meaning he retains. In the same way, he seems to access the meaning of derivational suffixes he cannot properly retrieve. M.B.'s problem can be attributed to the stage of activation of the phonological output. This is by no means an uncommon finding in aphasia. M.B.'s performance, however, is informative about the lemma representations of inflected and derived words, which seem

TABLE 17
Reading of Evaluative Suffixes and of Singular- and Plural-Dominant Nouns

Reading of evaluative suffixes

	N	+	(%)	Strip
Suffixed nouns, transparent (1)	62	21	34	17
Suffixed nouns, opaque (2)	52	32	62	4
Pseudosuffixed nouns (3)	43	23	53	3
Pseudosuffixed nouns (4)	32	22	69	—

(1) noun + evaluative suffix, transparent meaning (lettino)
(2) noun + evaluative suffix, opaque meaning (lampadina)
(3) real root + pseudo-evaluative suffix (cervello)
(4) pseudo-evaluative suffix (false root) (carbone)

suffixed (1) vs suffixed (2): $\chi^2 (1) = 6.02$; $p < .05$;
suffixed (1) vs pseudosuffixed (3): $\chi^2 (1) = 5.57$; $p < .05$

Reading of singular- and plural-dominant words

Dominance	Number	N	+	(%)	+infl.	vis	neol
Singular > plural	singular	71	62	87	0 +infl	3	5
(e.g., nose)	plural	71	40	56	21 −infl	4	5
Plural > singular	singular	65	46	71	12 +infl	4	3
(e.g., eyes)	plural	65	42	65	16 −infl	1	6

to match what the lemma theory predicts. Subsequent processes of word form (lexeme) retrieval are also made transparent by M.B.'s performance in reading singular and plural forms. The interaction between frequency and markedness tells how lexeme retrieval can be envisaged as a race among possible competitors. High-frequency morphologically complex words seem to meet stored representations, thus avoiding more costly parsing that is required for less frequent items. This account seems to accommodate both theories mentioned in the Introduction and is in keeping with dual-route models of lexical representation of morphologically complex words (Burani & Caramazza, 1987; Baayen et al., 1997).

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Specific Impairment in Written Number Name to Arabic Transcoding: A Case Study

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Within McCloskey's cognitive model of numerical processing, all the transcoding and calculation operations are performed via a unique semantic route. This model has been challenged through several case studies showing for example impaired number transcoding with preserved calculation skills. We present a brain-damaged patient (RR) who showed a specific impairment in a written number name to arabic transcoding task. Other number processing skills, including numeral recognition, numeral comprehension, and calculation, were unimpaired. McCloskey's model cannot account for RR's performance and it is suggested that the number processing system should include semantic and nonsemantic pathways. © 1999 Academic Press

Number processing skills allow adult subjects to carry out arithmetical operations, but they also allow subjects to execute transcoding operations between the different numeral codes. There are different ways to conceptualize the cognitive architecture of number transcoding and calculation mechanisms. Different models of number processing have been recently proposed following the important conceptual work realized by McCloskey and his collaborators (McCloskey, 1992; Macaruso, McCloskey, & Aliminosa, 1993). To account for the performance of dyscalculic patients in calculation and transcoding tasks, these authors have developed a modular model of number processing and calculation. In this model, the numerical skills rely on several distinct functional components, including separable systems for numeral comprehension, numeral production, and calculation. An outline of this model is given in Fig. 32.
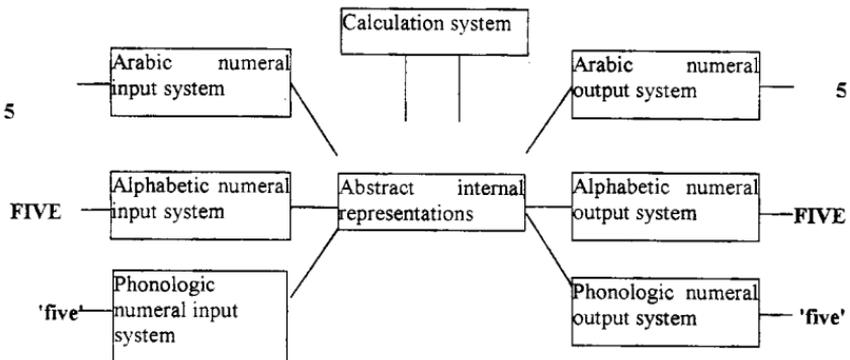

FIG. 32. McCloskey's model of numerical cognition.

According to McCloskey's propositions, the numeral processing abilities depend on a central semantic component that underlies all the transcoding and calculation operations. This important assumption of the McCloskey model is controversial and has been recently challenged through several case studies (Cohen, Dehaene, & Verstichel, 1994; Cipolotti, 1995). Within the McCloskey model, it is for example very difficult to explain the performance of the patient S.A.M. reported by Cipolotti and Butterworth (1995). While S.A.M. performed flawlessly on number recognition, number comprehension, and calculation tasks, his ability to read aloud and to write from dictation arabic numerals and written number names was impaired. Cipolotti and Butterworth (1995) argued that this pattern of performance could be explained by resorting to a multiroute model of number processing. In this model, number transcoding can be performed through independent semantic or nonsemantic routes, according to the modality-specific number codes or to the task demands.

The present study describes a single patient whose performance in a specific transcoding task also challenged McCloskey's model of number processing.

Method

Case Report. RR is a 70-year-old right-handed bank manager. He suffered a cerebrovascular accident in February 1997 resulting in language impairments. A CT Scan revealed the presence of 4 ischemic lesions in the left occipital area, in the left inferior and posterior parietal area, in the right front-parietal area, and in the right caudate nucleus.

Language examination. Speech output was fluent with moderate anomia. Auditory and reading comprehension were preserved. Spelling was canonical of surface agraphia.

Neuropsychological examination. Neuropsychological examination showed normal general intelligence and unimpaired frontal lobe functions. RR's scores on the Wechsler Memory Scale–Revised stood below the normal range, but short-term memory in the verbal and visual modalities was normal. The patient complained about difficulties in writing arabic numerals.

Experimental Investigation

The different routes and processing components were evaluated with an acalculia test battery comprising tasks of transcoding, numeral recognition, numeral comprehension, and calculation.

Transcoding tasks. An identical set of 135 numerals constructed in order of magnitude from 1 to 6 digits was used in the different transcoding tasks. The set was composed by all the French lexical primitives and by numerals equally divided into the following subgroups: numerals ending in zeros (100; 40,000; . . .), numerals without internal zeros (6435; 14,912; . . .) and numer-

TABLE 18
Percentage of Error Responsibles in the Transcoding Tasks

Transcoding tasks	Number of errors	Percentage of errors
Arabic → Phonological (reading)	22/135	16%
Arabic → Alphabetical	15/135	11%
Alphabetical → Phonological (reading)	8/135	6%
Alphabetical → Arabic	64/135	47%
Phonological → Alphabetical (writing from dictation)	3/135	2%
Phonological → Arabic (writing from dictation)	7/135	5%

als with internal zeros (107; 43,002; . . .). Table 18 presents RR's error rate in the transcoding tasks. Repetition and copying were flawless.

Except for the alphabetical to arabic transcoding task, the transcoding abilities of RR appeared to be relatively unimpaired. The majority of RR's errors in this particular task were syntactic errors (e.g., 2140 → 200140), whereas most of RR's errors in the other transcoding tasks were of the lexical type (e.g., reading aloud arabic numerals: 29 → 49). The spatial ordering of the written numerals had no incidence on RR's performance (upright presentation = 44% of errors).

Numeral recognition. Some of the stimuli used in the transcoding tasks were presented to RR in matching tasks. The recognition of numerals appeared to be largely preserved: matching a spoken number name to arabic numerals (50/50), matching a spoken number name to written number names (44/49), matching a written number name to arabic numerals (83/100), matching an arabic numeral to written number names (81/100).

Numeral comprehension and calculation. RR's ability to comprehend arabic and verbal numerals was largely intact: magnitude comparison, number positioning on an analogic scale, and grammaticality judgment tasks were well performed in all the presentation formats. RR's responses for simple calculation problems pointed to the good preservation of the calculation system.

Discussion

Considered in isolation, all the components of the number processing system (see Fig. 32) seemed to be unimpaired and RR's numerical impairments were limited to a deficit in the alphabetical to arabic transcoding operations. According to the model proposed by McCloskey (1992), such a pattern of performance can arise from a deficit in the alphabetic numeral input system, from a deficit in the abstract internal representations, or from a deficit in the arabic numeral output system. These three possibilities have been ruled out since RR's performance was unimpaired in reading aloud written number

names, comprehending numerals regardless of the presentation code, and also in writing arabic numerals to dictation. RR's transcoding deficit seemed to be dependent on the surface features of the number representations (i.e., number code). It is suggested, as already proposed by Cipolotti (1995) and Cipolotti and Butterworth (1995), that the number processing system should include semantic and nonsemantic routes, the latter being code dependent.

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Rotation of a Complex Figure by Children[6]

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Rotated drawings have been considered ''normal'' in very young children (up until age 7), but a sign of brain damage in older children and adults. We report two older children (10.8 and 8.10 years) who spontaneously rotated the Rey complex figure by 90° during copy and recall. However, extensive testing revealed no further abnormalities associated with perceptual or developmental dysmaturations. We conclude that the misorientation of drawings is a developmental phenomenon which extends to a higher age than was previously expected and can occur in ''normal'' older children.   © 1999 Academic Press

Introduction

Recent studies have demonstrated that rotated drawings can be a symptom of a far more pervasive perceptual disorder: agnosia for object orientation (e.g., Turnbull, Beschin, & Della Salla, 1997). The affected patients are in the paradoxical situation of being able to reliably name objects which they
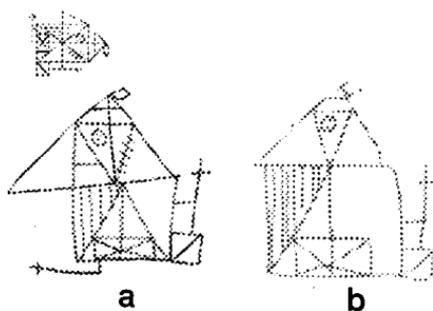
FIG. 33.   DS's spontaneous rotation of the Rey figure in (a) copying and from (b) memory.

cannot correctly orient. The study of significantly rotated drawings was first covered in the developmental literature. The prevailing view during the 1970s was that children were indifferent to orientation (Rock, 1973), and perceived form and orientation ''independently'' (Weiss, 1971). This suggested that rotation may be normal in preschool children (Rock, 1973) but a sign of developmental dysmaturation after the age of 7 (Lyle, 1969).

However, recent findings suggest that by 3 months of age children are as sensitive to orientation as adults (Manny, 1992). In light of the findings that normal infants *can* perceive orientation, it would be reasonable to deduce that creating rotated drawings could be regarded as ''abnormal,'' especially at older ages. However, we present two cases which question this suggestion. The Rey Osterrieth complex figure was administered in the traditional manner (see Lezak, 1983; page 395) as part of a larger battery testing arithmetic and visuo-spatial skills.

Case study 1: DS. DS is a right-handed boy aged 10.8 years at time of test who had no history of learning difficulties. He is an ''above average'' student and did very well on the above battery. However, DS spontaneously rotated the Rey Figure during copy (Fig. 33a), and from memory (Fig. 33b). DS later copied 6 simplified versions of the Rey figure (see Turnbull et al., 1996) and the Taylor Complex figure (see Lezak, 1983; page 397) accurately and in the correct orientations. In addition, he was able to draw a bike and a clock quickly and skillfully, showing no signs of orientation difficulty or neglect.

When DS was asked if his rotated copy (Fig. 33a) differed from the original Rey he seemed unaware of the orientation discrepancies, replying ''my lines are all squint.'' When directly asked about the orientation of two figures he said they were identical. Only when the experimenter asked whether the two figures looked more alike before or after Fig. 33a had been physically rotated by 90° did DS realize his error, although he did not appear to understand why he choose such a strategy.
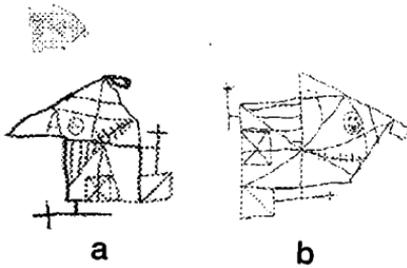
FIG. 34. RW's spontaneous rotation of the Rey figure in (a) copying and (b) correctly oriented copy of the same figure performed one week later.

Case study 2: RW. RW is a left-handed boy aged 8.10 years at time of test who had no history of learning difficulties. He is an ''average'' student and performed well on all aspects of the battery, with the exception of spontaneously rotating the Rey during copying (see Fig. 34). RW also copied 6 simplified versions of the Rey figure (Turnbull et al., 1996) accurately with no signs of orientational confusion. A week later he was asked once again to copy the original Rey figure (Fig. 34b). However, this time he did so with no orientational difficulty.

RW also seemed unaware of the orientation discrepancies between his rotated figure and his correctly copied figure. When asked for differences between the two, he replied ''[Fig. 34b] is bigger than [Fig. 34a],'' and [Fig. 34a] was done in colored pens. It was only after RW was directly questioned about the orientation of the figures that he realized his error.

Orientation investigations. Thirty-two line drawings with clear canonical orientations were presented in four orientations. RW correctly recognized, and was able to provide the correct canonical orientations for all 32 drawings. RW was also able to point to the ''odd one out'' (23/24), when three cards containing identical objects were presented with only two of the objects oriented in the same direction. As a final test, 28 line drawings were presented in four orientations with a dot on either the right or left of the object. RW was asked to state the position of the dot when the object was in its correct canonical orientation. On the first block, RW scored at chance (14/28), nevertheless, the improvement over the next three blocks ($M = 27/28$) suggested that he had no fundamental difficulty with this task.

Discussion

An interpretation based solely on the reproductions of the original rotated figures may have suggested that these children suffer from agnosia for object orientation (see Turnbull et al., 1997). However, extensive testing revealed no further additional deficits. In fact, both children scored at, or near, ceiling

on all tasks. Therefore, we conclude that these children are not agnosic for object orientation.

However, the question remains as to why apparently normal children have selective difficulties with orientating the Rey figure. Due to the fact that even very young infants can perceive orientational change (Manny, 1992), the hypothesis that children rotate drawings because they are ''indifferent'' to orientation (Rock, 1973) must be ruled out. In addition, DS and RW were both older than the suggested age for ''normal'' developmental rotation (Lyle, 1969), and yet they did not appear to suffer from any obvious developmental dysmaturations.

It is difficult to find an explanation which merges the contradictory findings that children have the ability to perceive orientation which they cannot reproduce. It seems likely that the ability to *discriminate* orientation is present in infants, but the ability to *reconstruct* correct orientation develops with age. Perhaps the age differences between these cases and previous studies is due to the high task demands of the Rey figure, explaining why the simple versions of the figure were not rotated. Nevertheless, this suggestion does not justify the absence of rotation in additional complex figures. A possible post hoc explanation is that rotation occurs spontaneously, thereby affecting some trials and not others. However, further investigation must be carried out in order for the phenomenon to be fully understood.

The present findings, along with the previous literature (e.g., Turnbull et al., 1997) suggest that the rotation of drawings can either be a developmental phenomenon (which extends to a higher age than was previously expected) or a sign of cognitive dysfunction, but that one instance of spatial rotation is not sufficient evidence to decipher between the two possibilities.

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Impairment in Auditory Verbal Processing and Dichotic Listening after Recovery of Epilepsy in Landau and Kleffner Syndrome

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In an attempt to specify the cognitive impairments associated with the poor verbal outcome usually described for epileptic aphasia, we investigated the verbal abilities and dichotic listening performances of five children with Landau and Kleffner Syndrome, several years after complete recovery of epilepsy. The five patients showed a specific impairment in the auditory verbal short-term memory involving the phonological processing system. Unilateral extinction of dichotic stimuli (contralateral to the epileptogenic focus) was also observed. These effects of unilateral extinction and reduced auditory verbal short term memory are seen as consequences of temporal cortex dysfunction.   © 1999 Academic Press

Most of the long-term follow-up studies of acquired childhood aphasia with epilepsy, a rare syndrome described by Landau and Kleffner in 1957, emphasize the poor outcome for language impairment in epileptic aphasia compared to childhood aphasia due to structural lesion of the left hemisphere. Despite an increasing number of follow-up case studies, the verbal disorders persisting after recovery of epilepsy have not yet been fully investigated. To better understand the verbal outcome in epileptic aphasia we examined the development of various verbal abilities several years after complete recovery of epilepsy in five children with Landau and Kleffner Syndrome (LKS).

All children had a normal development until a first epileptic seizure or a rapid loss of verbal abilities occurring between 3 and 6 years of age. CT and MRI examinations ruled out any structural lesion, whereas repeated EEG recordings showed a left or right temporal epileptic focus for all patients in the study. During the active period of epileptic aphasia, PET scan observations showing a regional hypermetabolism in the temporal cortex correlated well with the epileptic focus. Table 19 presents the clinical and social characteristics of these five children.

Neuropsychological Assessment

Verbal and nonverbal intellectual abilities were evaluated using the WISC-R. Verbal auditory processing was assessed via lexical discrimination tasks, the oken test, as well as word and sentence repetition. Picture naming and two verbal fluency tests were also used to assess lexical availability.

Auditory verbal short-term memory span was measured with the forward

TABLE 19
Clinical and Social Characteristics

Patients	Gender	Handedness	Age at onset of LKS	Epileptic focus	Duration of aphasia with epilepsy	Main aphasic features during active epilepsy
T.G.	M	RH (+60)	5 years 3 m	Right temporal	22 months	Severe auditory agnosia impaired oral expression
J.P.H.	M	RH (+80)	3 years	Left temporal	46 months	Auditory agnosia and severe expressive disorders
D.C.	M	LH (−80)	6 years	Right temporal	30 months	Deficit in auditory comprehension, syntax and naming
K.M.	M	RH (+60)	6 years 3 m	Right temporal	51 months	Global aphasia with severe mental deterioration
G.B.	M	RH (+100)	5 years 5 m	Left temporal	34 months	Auditory agnosia and severe expressive disorders

digit span test and compared to visuo-spatial short-term memory assessed with the Corsi block-tapping procedure (Milner, 1971). A nonword repetition test assessed the phonological store and examined the effect of length and phonological similarity on phonological memory performances. Rey auditory verbal learning test examined immediate lexical memory and verbal learning strategy.

Dichotic listening tests were also used to investigate the possible functional reorganization following LKS. Three tests involving either lexical items or digits were performed using free report and one ear focused attention procedures.

Results

The individual performances on verbal and nonverbal tests shown in Table 20 pointed to a common residual verbal impairment that appeared to involve specifically the auditory verbal memory system. The discrepancy between performances evidenced by all five patients in repetition tasks with significantly lower performances in the repetition of nonword pointed to a deficit within the phonological store system. Except for K.M., the patients showed spared nonverbal intellectual abilities. Their poorer performances on verbal tasks were probably due to reduced abilities as demonstrated in the vocabulary subtest or in tasks requiring auditory short-term memory (e.g., information, digit span, problem solving).

In the Rey auditory verbal learning test, the first report of the five patients showed both a reduced word span and a strong recency effect. Performance reached the normal learning curve following the third presentation of the fifteen-word list. Delayed free recall and recognition were within the normal range.

All five patients showed normal performance in reporting digits and nouns presented monaurally. Dichotic presentation of similar material, however, revealed a strong asymmetry in reporting similar items, associated with an almost complete monaural extinction. In the five patients, the dichotic extinction involved the channel contra lateral to side of the epileptogenic focus. The dichotic unilateral extinction persisted after increasing the stimulus intensity in the extinguished channel.

Conclusion

Several years after recovery from epileptic aphasia, the five subjects studied here still showed significantly lower levels of verbal capabilities. The verbal tasks requiring sufficient capacity in auditory short-term memory were the most impaired. Reduced digit span and difficulties in nonword repetition as well as in complex sentence repetition may result from specific disturbances in the auditory short-term memory or in the phonological processing system. In dichotic tasks, the patients also exhibited an extinction contralat-

TABLE 20
Individual Performances on Verbal and Nonverbal Tests

Patient	T.G.	J.P.H.	D.C.	K.M.	G.B.
Delay after recovery of LKS	5 years	4 years	3 years 8 months	4 years 9 months	22 months
Short-term memory span					
Auditory-verbal	3**	3**	4*	3**	2**
Corsi block-tapping	5	5	4*	3**	5
Auditory recognition test ($n = 25$)	19	21	22	17	24
Language assessment					
Confrontation naming ($n = 30$)	30	28	30	26	30
Verbal fluency test (words/min.)	8**	10**	12*	7**	10**
Real word repetition ($n = 15$)	15	15	15	15	15
Nonword repetition ($n = 15$)	10**	9**	12*	8**	6**
Sentence repetition ($n = 10$)	7*	6**	8*	6**	6**
WISC-R: Verbal IQ	106	80	83	64	76
Performance IQ	131	110	101	71	103

* 2 *SD* below Mean Score related to age.
** >2 *SD* below Mean Score related to age.

eral to the temporal auditory cortex involved in the generation of epileptic discharges. This dichotic extinction observed after complete normalization of the EEG suggests a permanent unilateral dysfunction in the auditory verbal system. In three of the patients described here, the dichotic extinction was correlated to a focal hypometabolism in the temporal cortex (Maquet et al., 1995; Metz-Lutz et al., 1997).

In normal adults, recent PET studies suggest there is a symmetrical involvement of the right and left superior temporal cortices in the phonological short-term memory (Fiez et al., 199; Grasby et al., 1993). In the outcome of epileptic aphasia, the impairment of phonological short-term memory may result from a permanent unilateral dysfunction in the auditory verbal system.

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Functional Cerebral Asymmetry for Verbal Stimuli in a Foreign Language[7]

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Ear advantage as an indicator of functional cerebral asymmetry for verbal stimuli in a foreign language (English) was studied by means of a dichotic listening test and lateralization indices, calculated from the order and accuracy of repetition, on a sample of 55 female right-handers, native speakers of Croatian. Possible effects of the attended ear were controlled. The results suggest left hemisphere dominance

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in processing foreign-language verbal material, expressed as significant right-ear advantage during divided attention and greater left-hemisphere control when attention effects are taken into consideration.   © 1999 Academic Press

Introduction

Language functions are not symmetrically represented in the brain, favoring the left hemisphere in most individuals (Johnson, 1997; Purvest et al., 1997). With respect to neurolinguistic organization of bilinguals three hypotheses have emerged: (1) left hemisphere is dominant for both languages, (2) left-lateralization is not as clear in bilinguals as in monolinguals, and (3) two languages are lateralized to the opposite hemispheres (Springer & Deutsch, 1993).

The aim of this work was to determine ear advantage (EA) as an indicator of cerebral asymmetry in processing English as a foreign language by native Croatian speakers.

Method

The subjects were 55 healthy right-handed female students, native speakers of Croatian, between 18 and 25 years of age (mean: 20), without familial sinistrality. The average period of learning English was 8 years. Mean score on a test of English was 72% (median: 70%).

Recording and reproduction were done on a Sony MiniDisc Recorder. Test material was prepared on a 486 PC (Sound Blaster 16, Creative Wave-Studio 2.01, Windows 3.1). Analog–digital conversion was at the 11025 Hz (8-bit) sampling frequency. Standard British English pronunciation was used.

Testing was performed individually, at 75 dB, using the dichotic listening method (Kimura, 1967) with modified response analysis, and was preceded by oral instructions and a training session.

Pairs of numbers (72 pairs) were presented simultaneously, with synchronized onsets and equal peak intensities. ISI was 1 s. Every third pair was followed by a pause during which the subject repeated the numbers she had registered. After every 24 pairs the attention was switched (left, right, divided) to control for possible attention effects (Mondor & Bryden, 1992).

EA was determined by accuracy index (IndA) and order-of-response index (IndOR). R and L stand for right and left ear, respectively (c = correct responses; e = incorrect responses).

$$\text{IndA} = \frac{\text{Rc} - \text{Lc}}{\text{Re} + \text{Le}} \leftrightarrow 100$$

$$\text{IndOR} = \frac{\text{R} - \text{L}}{\text{R} + \text{L}} \leftrightarrow 100.$$

In each triad of pairs the number repeated first scored six points, the second one five points, down to the last one, that scored one point. If a number was repeated twice, e.g., in first and fourth place, it scored the corresponding number of points for the ear to which it was presented, but it was scored as an error for the opposite ear.

Results and Discussion

In directed-left condition, the numbers presented to the left ear were repeated earlier and more accurately than those presented to the right ($p = .00$). Negative indices reflect left-ear advantage (LEA). The reverse was true for directed-right condition indicating right-ear advantage (REA). In divided-attention condition the subjects repeated earlier and more accurately ($p = .04$) the numbers presented to the right ear, with positive indices (REA) (Table 21).

Although the subjects shifted their attention as required, some degree of control over the unattended ear remained. It was greater for the right ear ($p = .01$ for IndOR; $p = .08$ for IndA), as evident from absolute values of the indices. Accordingly, in directed-left condition overall accuracy was higher than in directed-right condition, because in addition to numbers presented to the attended ear the subjects registered correctly more of those presented to the unattended ear, than in the reverse attention condition.

In directed-left condition, LEA, expressed as IndOR, was found in 90.91% and expressed as IndA in 83.64% of subjects. In directed-right condition, REA was found in all subjects (both indices). These differences indicate left hemisphere dominance and are in agreement with literature data (Kimura, 1967; Obrzut et al., 1986; Hynd et al,. 1979; Hugdahl & Andersson, 1986). In divided-attention condition, REA was found in 61.82% (IndOR), i.e., 63.64% (IndA) of subjects. The correlation between IndOR and IndA was high ($r = 0.83$) and significant ($p = .00$). These results are lower than Gordon's (1980) (64–74%), which may be higher than Wuillemin et al.'s (1994) who found right-visual-field advantage in 58% of bilinguals regardless of gender.

Fewer subjects exhibited REA in divided-attention condition than in literature for monolinguals. Kimura (1967) found REA in 94% of subjects, 1.9:1 ratio in favor of REA (1973); Rosenfield and Goodglass (1980) found REA in 85% of their (male) subjects; Hugdahl et al. (1990) found REA in 83% of their monolinguals; Hugdahl (1991) found REA in 85% of right-handed and 65% of left-handed monolinguals.

As in earlier studies of Croatian-speaking subjects learning Russian (Horga, 1992) or English (Mildner, 1992), no significant lateralization differences were found compared with native language processing in the same sample (Mildner & Rukavina, 1996), with only a trend toward greater right-hemisphere involvement in directed-left condition.

TABLE 21
Ear Advantage Depending on Attention Conditions

| Attention | Order of response (%) | | IndOR | Overall accuracy (%) | Accuracy by ear (%) | | IndA |
	Left ear	Right ear			Left ear	Right ear	
Left	69.22	30.78	−37.16	77.42	89.55	65.30	−49.15
Right	27.53	72.47	45.20	76.29	59.54	93.03	71.60
Divided	46.73	53.27	6.49	77.99	75.15	80.83	20.30

The results support the hypothesis that foreign-language processing is mainly a left-hemisphere function, with greater involvement of the right hemisphere than in monolinguals.

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A Left Hemisphere Temporal Processing Advantage for Auditory and Tactile Stimuli

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Hemispheric asymmetries for detection of brief interruptions in auditory and tactile stimuli were investigated in two groups of nonclinical dextrals. Short bursts of white noise or vibrations were delivered unilaterally to the ears or hands. Half of the stimuli contained a gap lasting between 2 and 18 ms. Participants indicated whether the stimulus contained a gap or not. The right ear/hand was associated with fewer errors and faster responses. There was a higher number of ''no-gap'' responses for the left ear/hand. These results demonstrate that the left hemisphere is more able to detect the temporal structure of auditory and tactile stimuli than the right hemisphere.   © 1999 Academic Press

Introduction

There has been a move away from characterizing the functions of the cerebral hemispheres in terms of *what* information is processed toward a description of *how* the information is processed. One such description has suggested that the left hemisphere (LH) is better suited to processing information with a fine temporal structure than the right hemisphere (RH) (Nicholls, 1996). This proposition is supported by clinical research which has demonstrated that patients with LH lesions have higher flicker-fusion thresholds (Goldman et al., 1968) and higher thresholds for the fusion of two clicks (Lackner & Teuber, 1973). Nonclinical research also suggests a LH specialization for temporal processing. Nicholls (1994) required participants to discriminate between 130-ms pulses of light which did, or did not, contain a brief interruption lasting between 8 and 14 ms. A lower level of error and response bias toward ''no-gap'' responses was observed for the right visual field. These results suggest that the LH is more able to detect fine temporal events than the RH.

The superior temporal processing capacity of the LH is thought to play an important role in other LH functions including reading (Farmer & Klein, 1993), the comprehension and production of speech (Tallal, 1976), and the production of sequential heterogenous movements (Harrington & Haaland, 1992). Bearing in mind the intermodal influence of temporal processing asymmetries, it seems reasonable to expect that the temporal processing asymmetry should also be intermodal. The present paper reports two studies which have extended the two-flash fusion study reported by Nicholls (1994) to the auditory and tactile domains.

Method

Participants. Twenty-four and 29 dextral university students participated in the auditory and tactile versions of the gap detection task, respectively.

Apparatus. Auditory stimuli were delivered unilaterally to the ears through a set of headphones. Tactile stimuli were delivered using bone-conducting vibrators. A four-button response panel was used to record bimanual responses.

Method. The auditory stimuli consisted of 300-ms bursts of broad band noise. Half of the noise bursts contained a gap in the middle lasting between 2 and 8 ms. The tactile stimuli consisted of 1000-Hz vibrations lasting 120 ms. Half of the tactile stimuli had an interruption in the middle lasting between 6 and 18 ms. The auditory and tactile versions of the gap detection task were administered as separate experiments. Stimuli were delivered unilaterally to the hands or ears. Participants indicated whether the stimuli contained a gap or not using a bimanual response. They were informed that there would be equal numbers of both types of stimuli.
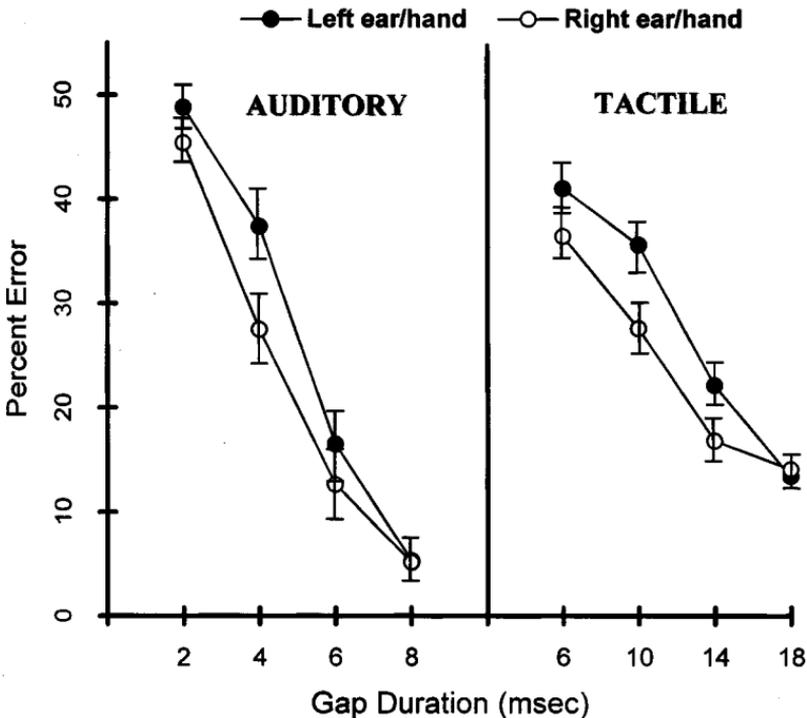

FIG. 35. Mean percentage error (and $\pm$ standard error bars) for the left and right ears/hands across the different gap times for the auditory and tactile versions of the gap detection task.

A total of 240 and 256 trials were presented for the auditory and tactile versions of the task, respectively. The four levels of gap time (2, 4, 6, and 8 ms for the auditory task) and (6, 10, 14, and 18 ms for the tactile task) were varied between blocks. The order in which the different gap times were administered was balanced. Within each block, equal numbers of trials were delivered to the left and right sides, and equal numbers of gap and no-gap stimuli were presented. The order in which the within-block factors occurred was randomized.

Results

Auditory task. Analysis of the error data with a repeated measures AN-OVA revealed significantly fewer errors for the right ear [$F(1,23) = 8.38$, $p < .01$] and for the longer gap times [$F(3,69) = 133.63, p < .001$]. Figure 35 illustrates that the asymmetry between the ears was larger for gap times of 2, 4, and 6 ms than gap-times of 8 ms [$F(3,69) = 4.62, p < .01$].

A measure of response bias was calculated by subtracting ''no-gap'' responses from ''gap'' responses. Positive scores reflect a bias toward ''no-
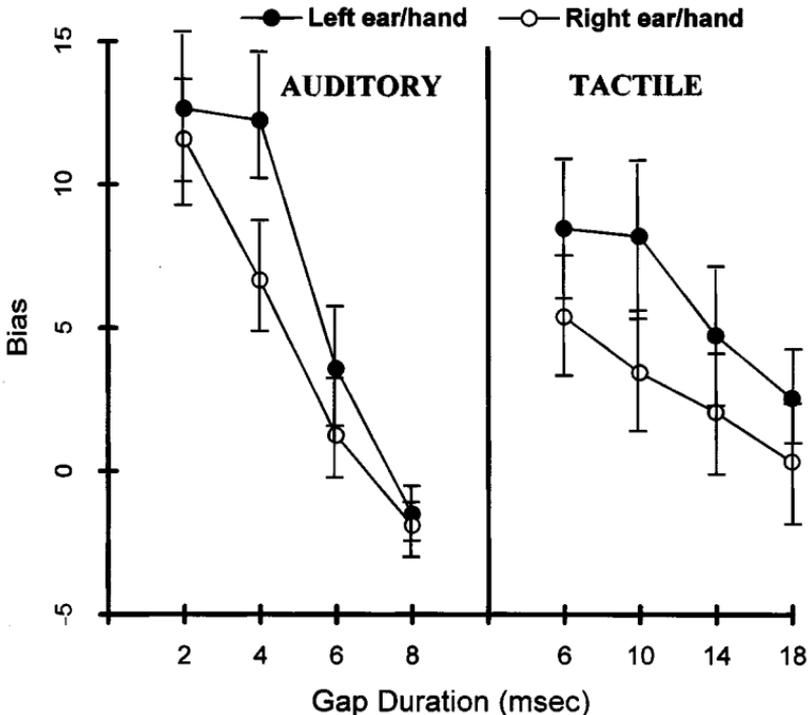

FIG. 36. Mean response bias scores (and ± standard error bars) for the left and right ears/hands across the different gap times for the auditory and tactile versions of the gap detection task.
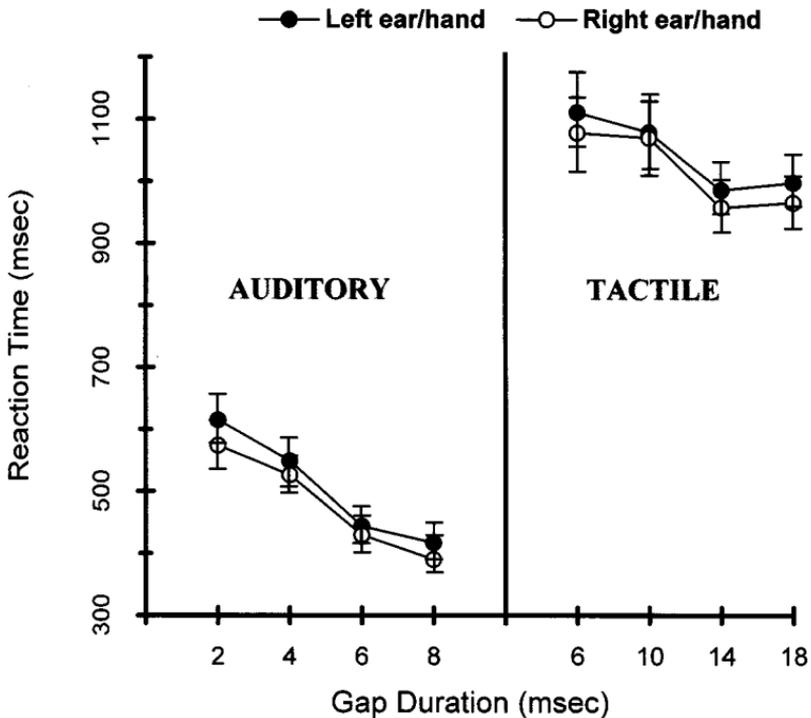
FIG. 37. Mean reaction times for correct responses (and ± standard error bars) for the left and right ears/hands across the different gap times for the auditory and tactile versions of the gap detection task.

gap'' responses, whereas negative scores reflect a bias toward ''gap'' responses. The data revealed significantly lower levels of bias for the right ear $F(1, 23) = 4.40, p < .05$] and for the longer gap times [$F(3, 69) = 23.73, p < .001$]. Figure 36 illustrates that the asymmetry was apparent for gap times of 4 and 6 ms, but was attenuated for gap times of 2 and 8 ms [$F(3, 69) = 2.82, p < .05$].

Analysis of the reaction time (RT) data revealed longer RTs for the right ear [$F(1, 23) = 5.41, p < .05$] and for the shorter gap durations [$F(3, 69) = 17.62, p < .001$] (see Fig. 37).

Tactile task. The error data revealed significantly lower levels of error for the right hand [$F(1, 28) = 6.92, p < .05$] and for the longer gap times [$F(3, 84) = 44.98, p < .001$]. Figure 36 illustrates that the asymmetry between the hands evident for gap times of 6, 10, and 14 ms was not apparent for gap times of 18 ms [$F(3, 84) = 3.09, p < .05$].

The response bias data revealed significantly lower levels of bias for the longer gap times [$F(3, 84) = 8.43, p < .001$]. The trend for the right hand to be associated with lower levels of bias than the left hand approached significance [$F(1, 28) = 3.11, p < .1$].

Figure 37 illustrates that RTs were faster for the shorter gap durations [$F(3, 84) = 4.88$, $p < .005$]. Reaction times to the right hand were slightly faster than those for the left hand [$F(1, 28) = 3.16$, $p < .1$].

Discussion

Analysis of the error data revealed a clear LH advantage for the auditory and tactile gap detection tasks. A floor and ceiling effect was evident at the hardest and easiest levels of the design, respectively. The response bias data revealed that the LH made fewer no-gap responses for the auditory and tactile tasks (though the effect only approached significance for the tactile task). The lower number of ''no-gap'' responses made by the LH suggests that the RH made more ''misses'' and was therefore less able to detect the gap. The RT data showed a similar LH advantage, effectively discounting the possibility of a speed/accuracy trade-off. These results demonstrate that the temporal processing asymmetry observed by Nicholls (1994) for the visual modality extends to the auditory and tacitle domains. The present study confounds the effect of hemisphere and hemispace; thus the asymmetry could be the result of an attentional bias directed to the right hemispace (Bryden & Mondor, 1992). Future research could investigate the effects of hemispace using midline and contralateral hand placement conditions.

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Two-Dimensional Geometry and Electromyography of Spontaneous and Imitated Parkinsonian Wrist Tremor

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The purpose was to compare spontaneous Parkinsonian wrist tremor with tremor imitations by control subjects. Tremor was recorded kinematically in two axes of wrist motion and electromyographically from two forearm muscles. Imitations were similar to spontaneous tremor in average characteristics of frequency, as well as of amplitude and morphology of the kinematic time series. Most imitations also showed approximately reciprocal bursting patterns in both muscles at the tremor frequency, like the spontaneous tremor. However, the imitations did not show the kinematic variability and electromyographic simplicity of spontaneous Parkinsonian tremor. © 1999 Academic Press

Introduction

The hand tremor in persons with Parkinson's disease (PD) is classically described as ''pill-rolling'' because of its rotational nature. The hand movement typically includes rotation of wrist, finger, and thumb joints. However, detailed measurements of tremor waveforms have been mostly limited to uniaxial measurements of the wrist or one finger. We evaluated tremor with simultaneous recordings in two axes of movement and electromyographic (EMG) recordings of forearm muscles. Our purpose was to compare spontaneous tremor in persons with PD with tremor imitations by control subjects.

Methods

From control subjects ($n = 8$) we obtained recordings of imitations of Parkinsonian tremor. From subjects with PD ($n = 6$) we obtained recordings of spontaneous tremor, both while they were trying to suppress it and while they allowed it to occur naturally.

Surface EMG recordings were obtained from the extensor communis digitorum (EDC) and the flexor carpi ulnaris (FCU). Subjects were seated with arm support under the forearm in a semi-pronated position, leaving the wrist free to move. A lightweight splint was strapped to the thumb and the subject was instructed to keep the tips of the index and long fingers in contact with the splint. The splint had two surfaces at right angles that extended several centimeters beyond the fingertips and reflected the beams of two laser systems that transduce velocity. Thus, the wrist flexion–extension and radial–ulnar deviation components of the tremor were captured, whereas the finger

and thumb components were controlled. The amplitudes of linear movement reflect the movement of a point on the splint approximately 15–18 cm distal to the wrist joint, depending upon the subject's hand size.

The two velocity signals and the EMG signals were simultaneously sampled at 1000 Hz for 10-s intervals. All time series were high-pass filtered at 2 Hz, the EMG series were then full-wave rectified and then all series were low-pass filtered at 20 Hz (Butterworth filters, fourth order, double-pass). Displacement and acceleration were obtained from the velocity signals through numerical integration and differentiation, respectively.

Results

Only one of the subjects with PD exhibited tremor comparable in amplitude to the imitations of tremor performed by the control subjects; the tremor of the other five subjects with PD was of much smaller amplitude. The present analysis is thus limited to comparison of eight trials from one subject with PD with imitated Parkinsonian tremor performed by control subjects.

The imitations of tremor resembled spontaneous Parkinsonian tremor in their average characteristics of frequency, amplitude, and morphology. The PD subject's tremor frequency ranged from 4.7 to 5.2 Hz. The eight imitations had tremor frequencies between 3.3 and 5.0 Hz. In amplitude, the PD subject's tremor was greater in flexion–extension amplitude than in radial–ulnar deviation amplitude in five of eight trials, as was also true for six of eight imitations. In the subject with PD, amplitude (root mean square) in either direction ranged from 0.32 to 6.8 mm in displacement (10.0 to 199.3 mm/s in velocity). In the control subjects, amplitude ranged from 0.92 to 3.7 mm in displacement (23.2 to 76.5 mm/s in velocity). Measurements of the morphological characteristics of the oscillations, such as wobble (Edwards & Beuter, 1996) and skewness (Timmer, Gantert, Deuschl, & Honerkamp, 1993), showed similar overlaps among the spontaneous tremor recordings and the imitations.

The subject with PD showed activation of the EDC and FCU in a reciprocal pattern modulated at the tremor frequency as expected (Shahani & Young, 1976), although the average phase relation between the signals varied across trials. The EDC burst occurred as early as 129° or as late as 212° with respect to the FCU burst. All control subjects showed modulation of

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FIG. 38. Displacement trajectory of the middle 8 of 10 s of (A, B) spontaneous tremor and (C) imitated tremor. The trajectories in (A) and (B) are from the right hand of one PD subject, while the subject was trying to (A) suppress it or (B) allowing it to occur naturally. The peak frequency in both series in (A) was 5.0 Hz, and in (B) was 5.2 Hz. Some oscillations in each are clockwise and others are counter-clockwise. The trajectory in (C) is from the right hand of a control subject. The peak frequency in both series was 3.7 Hz and all oscillations are clockwise.
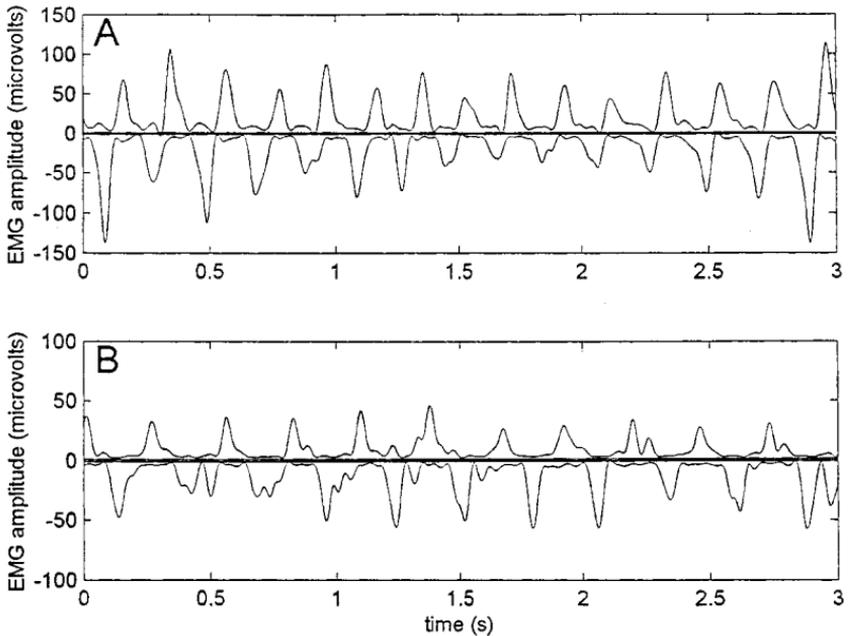
<- flexion (mm) extension ->

<- radial deviation (mm) ulnar deviation ->
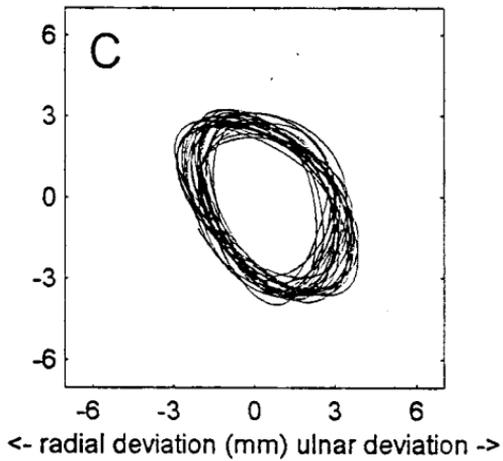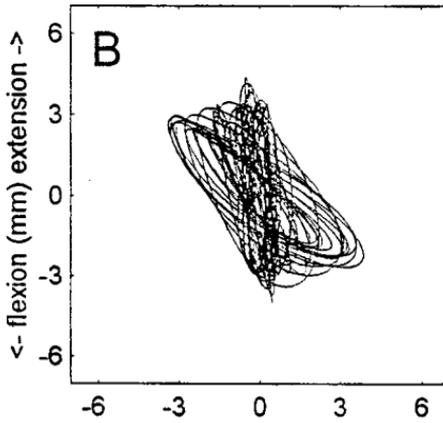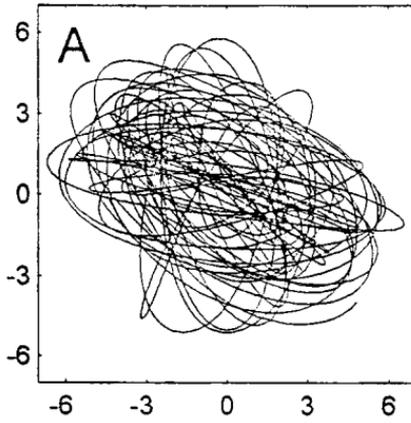
FIG. 39. Rectified and filtered EMG records from the EDC (upward traces) and the FCU (downward traces) during (A) spontaneous tremor and (B) imitated tremor. The records in (A) correspond to part of the trajectory in Fig. 38A. The records in (B) correspond to part of the trajectory in Fig. 38C.

EDC activity at the imitated tremor frequency. For six subjects who also showed modulation of FCU activity at the same frequency, the phase relation between muscles ranged from 87° to 224°.

Although the mean values of characteristics for all tremor time series were similar, an analysis of variability within trials showed differences between spontaneous and imitated tremor. The subject with PD showed a great deal of variability in flexion–extension amplitude, in radial–ulnar deviation amplitude, and in the proportion of those amplitudes in most trials. These variations, along with a variation of relative phase of the two orthogonal directions of movement created a highly variable displacement trajectory (see Figs. 38A and 38B). In contrast to this variability, the EMG records showed a relatively simple reciprocal bursting pattern (see Fig. 39A). The control subjects produced regular oscillations with trajectories such as that seen in Fig. 38C, although the shape and orientation varied across subjects. In contrast, their EMG records showed greater variability. Two subjects showed no bursting pattern in the FCU. All other EMG records from control subjects showed more irregular bursting (as measured by number of extrema per tremor period) than were found for all but one of the PD subjects' EMG records. The average number of extrema per tremor period in control sub-

jects' EMG records ranged from 2.49 to 3.41, whereas those from the subject with PD ranged from 2.04 to 2.59.

Discussion

Control subjects successfully imitated Parkinsonian wrist tremor in terms of average characteristics of frequency and geometry. However, spontaneous Parkinsonian tremor showed more variability of geometry and less variability of EMG timing and shape of bursts on a moment-to-moment basis than did imitations of tremor. We speculate that the differences are related to differences in behavioral goals of the subjects. The control subjects' goal was a movement pattern characterized by rotation at a given frequency, and the neural drive to the associated muscles was modulated throughout the recording period to produce a regular oscillatory pattern. On the other hand, the goal of the subject with PD was either to suppress or not interfere with tremor, and the variable kinematics resulted from uncompensated small modulations of a simple neural drive at the tremor frequency to both of the recorded muscles.

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Simple and Complex Motor Processing in Chronic Tic Disorders

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The hypotheses that tic disorded subjects would show greater difficulty than normal controls in initiating complex actions and suppressing automated/ballistic movements were tested using a ''countermanding paradigm.''

Eleven tic subjects recruited prior to a cognitive-behavioral tic management program, and eleven age, sex, and scholastically matched neuropsychiatrically screened nontic normal controls, were administered two replications of 52 trials of a computerized ''traffic light'' test. In this test a series of three traffic lights indicated ready–go or ready–go–stop for either a complex controlled or automated response sequence. GO time and STOP time were measured over four conditions presented in

random sequence (ready–go [complex]), ready–go [simple]), ready–go–stop [complex]) ready–go–stop [simple]).

Results indicated that tic subjects took longer than controls to inhibit both complex and automated responses, but whereas the control subjects showed slower GO reaction times for the complex response, the tic subjects showed no difference between conditions. The tic subjects also showed no practice effects over replications. The results support an elevated level of motor activation in the tic group and a difficulty, for this group, to inhibit but not to initiate and execute an action.   © 1999 Academic Press

Introduction

Motor tics are involuntary repetitive movements which occur in one muscle or in a group of muscles. The tics can be simple (involving a single muscle) or complex with a sequence of movements such as in scratching or biting nails, or pulling hair.

The neurochemistry of tic disorders implicates both cortical and subcortical neurochemical factors, which could influence both excitatory and inhibitory motor processes. ELevated dopamine has been frequently reported in some types of tic disorder, and this results in a state of overattentiveness and heightened activation. Dopamine neurons are also found in midbrain structures such as the substantia nigra and the system projects to a variety of brain structures including frontal areas. Neuropsychological models of tics generally implicate the link between the frontal lobe and the basal ganglia and suggest that the tic subject has difficulty implementing action plans stored in the basal ganglia (Lohr & Wisniewski, 1987).

Tics can be considered by their nature as repetitive automated movements. Controlled and automated styles of programming are mutually exclusive. Hence, people with chronic tic disorder may show a greater facility for initiating automated action than for controlled action and difficulty inhibiting automated motor processes in order to replace them with controlled motor processes. The key influence on whether controlled or automatic planning has priority seems to be complexity of movement and as a consequence cortical processing is more involved in controlled than automatic movements (Rosenbaum, Hindorff, & Munro, 1987).

We decided to examine directly the tic subjects' ability to initiate and suppress automated and complex responses.

Hypotheses

(1). Tic subjects will take longer to initiate a complex response sequence than controls.

(2). Tic subjects will take longer to inhibit a simple automated response sequence than controls.

Recruitment

Eleven tic subjects were recruited before beginning our program for self-control of tic disorders. Five subjects had complex tics and six had simple tics (age $\bar{\times}$ 29.0; $SD_{(n-1)} = 8.06$). *Eleven control* subjects were recruited through announcements placed in the university and the hospital. The control subjects had no tic or other neuropsychiatric problems and were matched with the tic subjects for age, scolarity, and sex (age $\bar{\times}$ 26.82; $SD_{(n-1)} = 10.15$).

Traffic Light Test

The paradigm used was a ''countermanding paradigm,'' which allowed us to compare the time to initiate a response (GO-time) with the time taken to inhibit a response (STOP-time) (Osman, Kornblum, & Meyer, 1990). Two sets of three lights appeared side by side on a computer screen in the form of traffic lights. One set signaled a simple and the other a complex response sequence.

Each trial began with one of the two yellow READY lights signaling that in four seconds the green GO light would come on and the subject would have to make either a complex or a simple response.

The *simple response* was three taps on a lever with the two fingers of the dominant hand. The *complex response* was three taps of morse code using another lever made with the same fingers. The levers were part of the same box assembly and permitted continuous analogue recording to monitor the response. The red STOP light appeared on 50% of the trials and instructed the subject to inhibit the prepared response. The STOP light onset was calculated to appear always just after the subject had begun the response (whether simple or complex). The GO reaction time and STOP reaction time were calculated automatically by the computer.

After a period of acclimatization, all subjects received two replications of 52 trials, with a short rest period between replications. The four conditions (SIMPLE + GO; SIMPLE + STOP; COMPLEX + GO; COMPLEX = STOP) were presented in random order.

Results

The ANOVA results (2-way, group by simple vs complex condition repeated over two replications) showed no significant difference between groups for the GO reaction time. So the hypothesis that tic subjects would take longer than the controls to initiate a complex response was *not* confirmed. In fact, the trend of the results was toward faster GO time in tic subjects. (Mean complex GO RT (ms): tic group, 310.00, matched controls, 330.62; median simple GO RT: tic group, 301.14, matched controls, 310.84).

We did however observe a GO time condition effect ($F(1, 20) = 7.60$; $p < .01$) and a group by condition effect ($F(1, 20) = 8.33$; $p < .009$), indicating that whereas the control subjects showed an expected quicker GO time to simple than complex responses. The tic subjects did not show this condition difference.

As regards the second hypothesis, the STOP time of tic subjects was longer than the control's STOP time, which was in accordance with the hypothesis, but the variation within the tic group was also very large and there was no overall significant group effect. The STOP times were larger in the tic group for both simple and complex conditions for both replications, and all individual one-way comparisons between groups were significant at or beyond $p < .06$ level (one-tailed). (Median complex STOP time (ms): tic group, 404.24, matched controls, 300.46; mean simple STOP time: tic group, 388.36, matched controls, 339.80).

There was also a significant replication effect ($F(1, 20) = 8.80$; $p < .008$), showing that the control group improved their STOP time with practice over replications for both simple and complex conditions. But the tic group showed no comparable decrease in STOP time over first and second replications. (Tic group: 1st replication, 401.47, 2nd replication, 391.13; matched controls: 1st replication, 351.78, 2nd replication, 288.47).

Conclusion

The study suggests there is little difference overall between tic disordered and nontic disordered subjects in time taken to initiate (GO) a (complex) controlled or a (simple) automated task. There does, however, appear to be a difference between groups in STOP time taken to inhibit an action either simple or complex, once it is in execution. However, there is clearly considerable more variability in STOP response time within the tic-disordered subjects than within the controls.

In contrast to the controls, the tic-disordered subjects did not show any slower GO time to initiate a ''complex'' than a ''simple'' response sequence. Also, tic-disordered subjects did not seem to systematically benefit from practice effects by reducing their response speed over time. Conversely, nontic-disordered subjects did show such practice effects, both for time taken to initiate and to inhibit a response.

These results would support the impulsive quality of tic disorder. Impulsivity is accompanied by a higher degree of motor activation, arousability and variability in response (Barratt, Patton, Olsson, & Zuker, 1981). This activation may lead to less selective response preparation and less likelihood of benefitting from practice effects.

Our results would also concord with other neuropsychological findings in Tourette and tic disorder which have tended to show little evidence of impairment in executive function (e.g., Bornstein, 1991). The tic sufferer

may not experience a general problem of balancing excitation and inhibition but one of regulating automated motor patterns already underway. The greater difficulty in suppressing automated activity may render the subject more susceptible to develop and maintain reflex-like automated habits such as tics.

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Left Inferior Frontal Cortex Is Involved in Probabilistic Serial Reaction Time Learning

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Cerebral blood flow was estimated using positron emission tomography and H_2O^{15} infusions in 12 volunteers while they were trained on the probabilistic serial reaction time task developed by Jimenez, Mendez, and Cleeremans (1996). Participants' reaction times to predictable and nonpredictable stimuli showed increasing sensitivity to the probabilistic constraints set by previous elements of the sequence. Analysis by statistical parametric mapping showed a significant interaction between participants' performance and time effect in the left inferior frontal cortex. Our results provide the first evidence of this cerebral area being involved in the processing of contextual information in a probabilistic sequence learning task.   © 1999 Academic Press

Introduction

The aim of this study is to explore the cerebral structures involved in implicit learning by means of a serial reaction time (SRT) task in which the sequence of stimuli was based on a probabilistic finite-state grammar, and in which random material was interspersed with structured material. Previous studies (e.g., Jimenez, Mendez, & Cleeremans, 1996) have shown with this task an increasing sensitivity, after an extended practice, to the probabilistic constraints set by two previous elements of the sequence. In the present positron emission tomography (PET) experiment, regional cerebral blood flow (rCBF) was recorded while participants were exposed without any prior practice to the aforementioned probabilistic sequence-learning task. This procedure was designed to highlight the cerebral structures associated with the early stage of the implicit acquisition of the probabilistic constraints set by only one previous element in the sequence. Learning of these constraints is expected to occur after a limited practice and to be reflected in the interaction between behavioral performance and rCBF of the participants.

Method

Twelve right-handed volunteers (7 men and 11 women, mean age 22.1 years, range 20–28 years) were exposed to a six-choice reaction time (RT) task. The session consisted of 25 blocks of 205 successive trials. For each trial, a stimulus could appear on a computer screen at one of six horizontally laid locations. The task consisted of pressing as fast and as accurately as possible with the right hand on one of six corresponding keys. Unknown to participants, the sequential structure of the material was manipulated by generating successive stimuli based on the finite-state grammar shown in Fig. 40. To assess learning, there was a 15% chance on each trial of replacing the grammatical (G) stimulus with a nongrammatical (NG), random stimulus (identity and grammatical substitutions were discarded). This procedure thus generates material such that the predictability of each stimulus depends probabilistically on the context set by previous elements of the sequence. Assuming that response preparation is facilitated by high predictability, predictable G stimuli should thus elicit faster responses than NG stimuli, but only if the context in which stimuli may occur has been encoded by participants. Jimenez et al. (1996) showed that participants can learn about the constraints set by two previous trials at most, and that this sensitivity emerged through practice as a gradually increasing difference between the RTs elicited by G and NG stimuli occurring in specific sets of controlled context of length 1 to 3. Similarly, we computed the differences between RTs elicited by G and NG stimuli in contexts defined by either one (i.e., variable L1) or two (i.e., variable L2) previous stimuli.
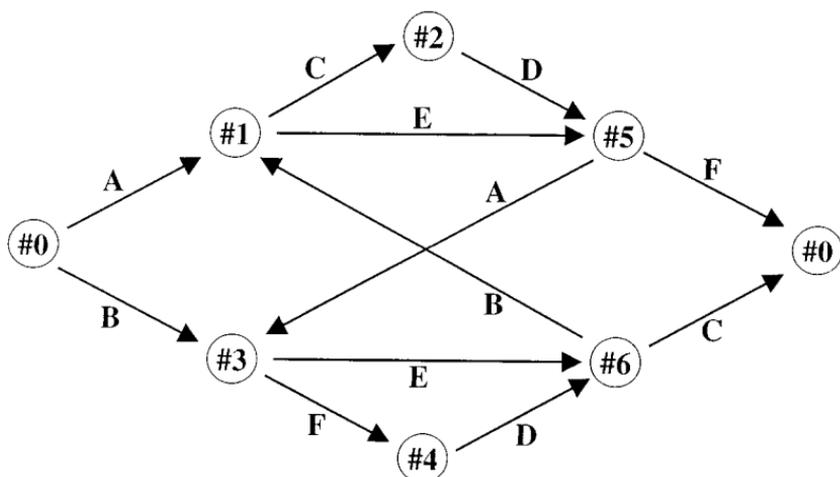
FIG. 40. The finite-state grammar used to generate the stimulus material, from Jimenez et al. (1996). Each letter corresponds to a stimulus location on the screen.

PET Acquisition

Twelve PET scans were obtained by a Siemens CTI 951 R 16/31 scanner in 3D mode. The rCBF was measured using iterative infusion of oxygen-15 labeled water (6 mCi/222 MBq in 5 cc saline). One SRT training block was given prior to the scans, and the 24 remaining experimental blocks were given during and between each scan. Data analysis was conducted using the statistical parametric mapping (SPM96) software (Wellcome Department of Cognitive Neurology, UK) and the specific rCBF response to a covariate was estimated at each and every voxel according to the general linear model, using a design matrix which included block effect and global activity as confounding covariates. The covariate of interest consisted in the interaction between L1 or L2 performance and the increasing time. The latter variables were entered as confounding covariates. The resulting foci of activation were characterized in terms of peak height over the entire volume, by reference to the theory of gaussian random fields (Friston, Worsley, Frackowiak, Mazziotta, & Evans, 1994).

Results

Median reaction time was computed for each of the 12 pairs of SRT blocks practiced during the 12 scans. A two-way analysis of variance revealed a significant main effect of Grammaticality for the L1 context only, $F(1, 11) = 5.63$, $MSE = 9047.8$, $p < .05$, indicating participants' sensitivity to the first order sequential constraints set by one previous trial. A significant main effect was also found for the global RT for L1, $F(1, 11) = 10.81$, $MSE =$
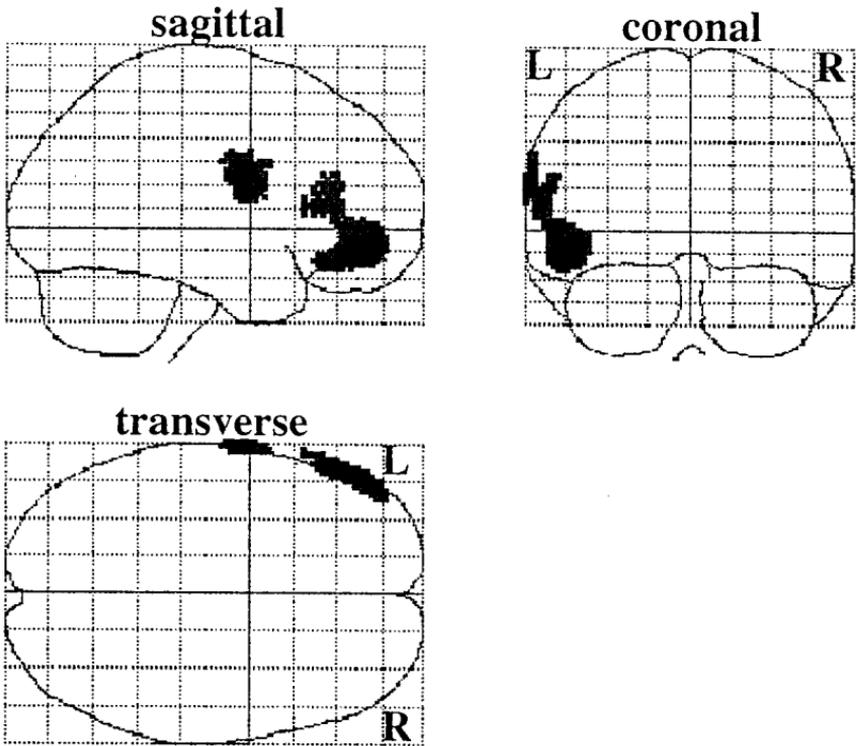
FIG. 41. SPM {Z} tresholded at $Z > 3.09$ showing rCBF significantly correlated to the interaction between performance and time effect at voxel -52, 48, -4 mm.

2054.6, $p < .0001$, and L2 context, $F(1, 11) = 8.14$, $MSE = 3404.1$, $p < .0001$, showing improvement of the global performance with practice irrespective of the grammatical status of the stimuli. A significant Grammaticality $\times$ Global RT interaction, $F(1, 11) = 2.38$, $MSE = 1023.8$, $p < .05$, for L1 context only indicates that performance for G stimuli improved more than for NG stimuli with practice. An SPM analysis revealed that the interaction between L1 and increasing time is significantly correlated ($Z = 4.82$, p corrected $< .01$) with the voxel rCBF at -52, 48, -4 mm in the Talairach and Tournoux (1988) space. This voxel corresponds to an area located in the left inferior frontal cortex (Broadmann area 47), as shown in Fig. 41.

Discussion

RT analysis are in accordance with previous studies (Jimenez et al., 1996), suggesting that with restricted practice participants are able to learn about the constraints set only by the preceding trial. Broadmann area 47 has been found mainly activated in naming and reading tasks (see Cabeza & Nyberg, 1997, for a review), but to our knowledge it is the first time that a relationship

is highlighted between the metabolic activity of this cortical area and the processing of contextual information in a sequential learning paradigm. Further studies should make precise the role of this cerebral region in the processing of more sophisticated contextual information.

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Some Acoustic Correlates of Perceptually "Flat Affect" in Right-Hemisphere-Damaged Speakers

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Data reported in an earlier study of prosody production in right-hemisphere-damaged (RHD) individuals (Pell, 1997a,b) were analyzed further to explore potential acoustic differences between normal speakers and those perceived to be emotionally "flat." Results indicated that RHD patients were significantly less reliable at transmitting emotional meanings through prosody to a groups of normal listeners than age-matched normal speakers. Furthermore, when subjects obtaining low emotional ratings were considered separately, perceptually "flat" speakers (comprising half of the RHD group and one normal subject) were shown to employ substantially fewer acoustic cues to emotional contrasts than normal speakers, a pattern consistent with the impressionistic data.   © 1999 Academic Press

Introduction

Clinicians have long noted a correspondence between acquired right-hemisphere damage (RHD) and an inability to impart affective qualities to speech. Such impressions of restricted or "flattened" prosodic variation in RHD speakers have seldom been validated through acoustic analysis, however. The present study sought to obtain perceptual indices of how well RHD and normal speakers convey emotion prosodically and then investigate potential acoustic differences between normal speakers and those judged to be emotionally "flat." Isolating some of the acoustic parameters that contribute to

impressions of emotionally uninflected speech may help address whether RHD patients are impaired in *implementing* affective-prosodic gestures in a manner consistent with normal speakers, without a loss of knowledge about affective-prosodic representations (Gandour et al., 1995; Pell, 1997a,b). The present study also furnishes important supplementary data on a group of RHD patients reported earlier in the literature (Pell, 1997a,b).

Method

Subjects. Ten patients with unilateral right-hemisphere infarcts (MCA territory) following cerebrovascular accident and ten age-matched control (NC) subjects were tested. All participants were right-handed English speakers with normal hearing (RHD8 was left-handed).

Stimuli/acoustic analyses. Stimuli comprised a subset of those elicited from RHD and NC subjects in an earlier investigation of prosody production (Pell, 1997a). In that study, recordings of short sentences (e.g., *Mary sold the teapot*) were obtained from RHD and NC subjects using a story completion paradigm. Manipulation of the story content rendered 24 productions of each utterance which presented unique combinations of prosodic features (emphasis placement, sentence modality, and emotional tone were varied) without alteration of segmental features. To characterize emotional contrasts in the acoustic signal, the mean F_0 (Hz), F_0 range (Hz), and rate (syllables/s) of each utterance was determined for the three emotions elicited (sad, happy, angry) using a speech analysis software. All measures were normalized prior to statistical inspection (see Pell, 1997a). For the current study, perceptual ratings were conducted on emotional stimuli elicited in the declarative (rather than interrogative) form, or 9 productions per speaker (180 total).

Perceptual rating procedure. Ten young normal subjects rated each utterance during a single testing session. Subjects listened to the 180 stimuli individually over headphones and then chose the emotional tone which ''mostly closely fit'' that used by the speaker for each exemplar (a push-button response was recorded). Four emotional interpretations were offered to the perceptual raters, including a ''neutral'' category. Productions elicited from the RHD and NC subjects were fully randomized within the experiment and raters were unaware of group distinctions within the data.

Results

Perceptual ratings. Perceptual ratings obtained for each of the 20 speakers are supplied in Table 22 by group. The success of NC and RHD individuals in encoding emotional distinctions varied somewhat within each group (range: NC = 42–90%; RHD = 31–83%) and was relatively low overall (mean: NC = 67.2%; RHD = 49.5%); this outcome may be attributed to the introduction of a ''neutral'' category in the rating procedure. Despite this variability, RHD patients were shown to be significantly less reliable at transmitting emotional distinctions to listeners than nonneurological control

TABLE 22
Perceptual Ratings (% Correct) Obtained for Each
Normal (NC) and Right-Hemisphere-Damaged
(RHD) Speaker

NC		RHD	
NC1	53	RHD1	34
NC2	78	RHD2	83
NC3	72	RHD3	32
NC4	59	RHD4	43
NC5	90	RHD5	67
NC6	60	RHD6	50
NC7	77	RHD7	41
NC8	80	RHD8	64
NC9	42	RHD9	50
NC10	61	RHD10	31
MEAN	67.2	MEAN	49.5
SD	±14.6	*SD*	±17.1

subjects when considered overall [$t = 3.54$, $df = 9$, $p = .006$]. Qualitative analysis of the data indicated that a substantially larger proportion of emotional utterances produced by the RHD patients were misidentified as *lacking* emotional inflection (i.e., a ''neutral'' response was recorded) than those produced by the normal speakers (for sad, happy, and angry targets, respectively: RHD = 21, 25, 18%; NC = 14, 14, 10%). This qualitative pattern, coupled with the overall group ratings, points to a ''flattening'' or blurring of affective-prosodic distinctions in the RHD patients' speech.

Normal parameters to emotion. To establish some of the acoustic attributes underlying emotional distinctions in normal speakers, measures of mean F_0, F_0 range, and speech rate derived for each of the 10 normal subjects (Pell, 1997) were submitted to further analyses. One-way ANOVAs demonstrated significant differences across the three emotional categories for each of the three acoustic variables when produced by normal speakers: mean F_0 [$F(2, 27) = 24.8$, $p < .001$], F_0 range [$F(2, 27) = 4.75$, $p = .02$], and rate [$F(2, 27) = 3.75$, $p = .04$]. To examine how the acoustic measures predicted the emotional categories used in this data set, a discriminant analysis was subsequently performed. Results indicated a significant canonical discriminant function [$\chi^2(6) = 29.27$, $p < .01$] carrying 82% of the variance in the data and highly correlated with mean F_0 ($r = .94$). This finding suggests that the relative level at which normal speakers set mean F_0 throughout their utterances served as the principal cue to the emotional contrasts investigated (see Fig. 42a). A second canonical function did not reach significance for this analysis ($p > .05$). The overall success of the analysis at predicting the three emotional tones for the normal speakers was fairly good (73%).

Parameters underlying emotionally ''flat'' speech. To highlight acoustic parameters associated with emotional distinctions in perceptually ''flat'' speakers, all subjects achieving an emotional rating inferior to 1½ standard
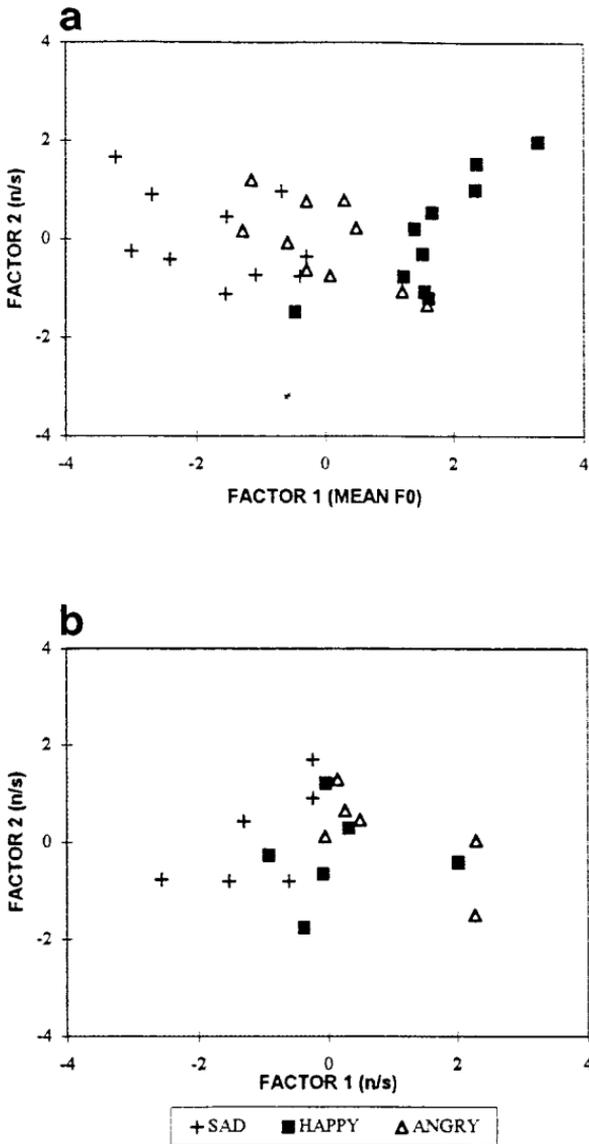
FIG. 42. Results of a discriminant analysis on the three emotional tones when produced by (a) normal speakers ($n = 10$) and (b) speakers judged to be emotionally ''flat'' ($n = 6$).

deviations of the normal group mean were considered separately. Half ($n = 5$) of the RHD speakers and one NC speaker were included in this group. One-way ANOVAs performed on each of the acoustic measures derived for these 6 subjects demonstrated significant differences across the three emotional categories for only mean F_0 [$F(2, 15) = 5.55, p = .02$]. An attempt to predict the three emotional tones from the acoustic measures produced

by ''flat'' speakers was unsuccessful, both canonical functions proving non-significant ($p > .05$; see Fig. 42b). Not surprisingly, the success of this discriminant analysis in predicting the emotional categories was very poor for the ''flat'' speakers (33%).

Discussion

Individuals perceived as lacking appropriate affective variation in their speech—a group composed of half of the RHD speakers tested in the current study, although not limited to RHD subjects—fail to provide the normal range of acoustic cues important in distinguishing among discrete emotions. Acoustically, this behavior would appear to reflect normal qualitative trends in cue usage in RHD patients, but a reduction in the number and strength of parameters implemented, leading to reduced perceptibility (Pell, 1997a,b). The data may be viewed in light of a quantitative impairment for prosody (particularly continuous aspects of prosodic contours) in many RHD individuals, as hypothesized previously (Pell, 1997a,b).

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Access and Representation of Roots, Stems, and Inflected Verb Forms in Polish[9]

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The present study is a psycholinguistic investigation of lexical access of verb forms in Polish. Using a lexical decision paradigm, we examined the recognition of word and nonword roots and stems, and of inflected forms, to probe the role of morphological structure in lexical accessing procedures. The pattern of results sup-

ports a dual-access model by providing evidence for whole-word access to known words and for morphological decomposition of real nonwords (complex bound forms). Moreover, there is evidence that nonword roots have a particular representation in the Polish mental lexicon.   © 1999 Academic Press

Introduction

In the present study, our primary goal is to investigate the access mode during polymorphemic word recognition, the role of roots or stems and their status (word versus nonword) in the identification of inflected verb forms in Polish, and finally, the implications of these findings for existing models of lexical representation.

There are several conflicting psycholinguistic models of the mental lexicon. These models have not satisfactorily resolved the issue of how polymorphemic words are accessed and represented. The principal models are (1) the decomposition hypothesis, according to which only stems function as primary lexical entries (morphologically complex words must be decomposed before they can be accessed in the mental lexicon (Taft & Forster, 1975; Taft, 1988)), (2) the Full Listing Hypothesis (Butterworth, 1983) and several variations thereof, (including Lukatela, Gligorijevic, & Kostic, 1980; Segui & Zubizarreta, 1985), and (3) the dual-access models, which include a combination of the decomposition and full listing hypotheses and provide a framework for the different consequences of various types of morphological processing (Caramazza, Miceli, Silveri, & Laudanna, 1985; Caramazza, Laudanna, & Romani, 1988; Kehayia & Jarema, 1994).

Method

Subjects. We tested 25 native speakers of Polish, (13 women and 12 men, all right-handed), between 32 and 45 years old. All subjects were born and educated in Poland.

Procedure. In our study, we used a simple visual lexical decision task. Subjects were asked to recognize the target as a word or nonword by pressing either the ''yes'' or the ''no'' key on a computer keyboard. There were no time constraints, but subjects were instructed to respond as fast and as accurately as possible. Testing was done using the PsychLab 0.85 program (Bub & Gum, 1988). A repeated measures ANOVA was used to analyze the results.

Stimuli. There were 189 critical stimuli. Nonwords were created by changing the first phoneme of verb and filler forms (fillers were nouns and adjectives). The total pool of 756 stimuli was divided into 7 blocks of about 10 min each and was preceded by a training block of 36 stimuli. The blocks were run in two testing sessions. Stimuli were randomly reordered for each subject.

For the purposes of this study, the verbs tested were grouped into four

TABLE 23
Averaged RTs for Verb Forms Tested in All Groups (G)

	Root	Stem	Infinitive	1st p. present	3rd p. present	Imperative
G 1	683	634	630	658	634	683
G 2	725	645	609	645	645	636
G 3	740	814	643	638	653	661
G 4	—	699	644	641	648	652

categories (three groups of regular verbs and a fourth group of highly irregular and suppletive verbs that have several stems):

(1) WR–WS   (root is a word; stem is a word): *patrze*⟩ ''to look''
                       root = *patrz;* stem = *patrzy*

(2) NWR–WS   (root is a nonword; stem is a word): *pyta*⟩ ''to ask''
                       root = *pyt-;* stem = *pyta*

(3) NWR–NWS   (root is a nonword; stem is a nonword): *chorowa*⟩ ''to be sick''
                       root = *chor-*; stem = *chorowa-*

(4) NWS   (stems are nonwords): wziÅ⟩ ''to take''
                       stem = *wezm-;* stem = *wzi‰-*.

Verbs were tested in the infinitive, the first and third person singular of the present tense, and the second person singular of the imperative. When the root is a word, it is the second person singular of the imperative. When the stem is a word, it is the third person singular of the present tense. Verbs were matched for frequency, syllable length and transparency. We did not employ the past tense because it is marked for gender nor the future tense because it is a periphrastic form. (See Table 23.)

Results

Our experiment revealed: (1) statistically significant differences in reaction times (RTs) between WRs and NWRs ($F(2, 22) = 8.7$, $p < .001$), and similarly between WSs and NWSs ($F(2, 22) = 52.5$, $p < .001$). These differences were significant in a planned comparison for both roots and stems ($F = 14.7$, $p < .001$ and $F = 104.7$, $p < .001$, respectively); (2) actual nonwords were rejected significantly faster than NWRs and NWSs ($F(1, 22) = 102.3$, $p < .0001$ and ($F(1, 22) = 42.1$, $p < .0001$, respectively); (3) no significant differences between the various inflected forms ($F(3, 22) = 1.5$, $p = .22$); and, (4) an asymmetry between the two kinds of NWSs (in groups 3 and 4): NWSs in the third group were composed of a NWR and two legal suffixes, and recognition of these forms was significantly slower

than that of the NWSs in the fourth group which were nondecomposable ($F(1, 22) = 13.8$, $p < .005$).

Discussion and Conclusion

The results obtained reveal the existence of whole-word access for inflected verb forms, a process of decomposition for morphologically legal, real nonwords (bound stems), and autonomous lexical entries for all forms of irregular verbs (inflected or NWSs). These results constitute strong evidence in favor of a model of the lexicon which explicitly includes morphological structure in the representation of lexical items. According to the AAM (Augmented Addressed Morphology) Model (Caramazza, Miceli, Silveri, & Laudanna, 1985), access to lexical representations for known words may take place through either a whole-word access procedure or decomposition, and through decomposition alone for novel words and legal nonwords. In keeping with this model, the Polish data point toward distinct accessing procedures in that the effects of morphological structure are apparent for nonword stems of regular verbs, but not for regularly inflected verbs or for word and nonword forms of irregular verbs. Furthermore, the present results suggest that nonwords that serve as roots in Polish are represented in the mental lexicon.

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A Test of the HERA Model II: Objects as Stimuli

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The Hierarchical Encoding/Retrieval Asymmetry (HERA) model (Nyberg, Cabeza, & Tulving, 1996; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994) suggests that episodic memory involves interhemispheric interaction, while semantic memory is a unilateral phenomenon. However, most studies supporting the model have used stimuli processed preferentially by the left-hemisphere. It was hypothesized that hemispheric processing superiority might influence hemispheric interaction in tests of HERA. Using stimuli, both hemispheres are equally capable of processing pictures. Subjects performed a semantic or an episodic task. Results did not replicate those found using letter strings in an identical paradigm, suggesting that HERA might only be applicable for strongly lateralized information.   © 1999 Academic Press

Endel Tulving and colleagues (Nyberg, Cabeza, & Tulving, 1996; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994) have proposed a model, called Hierarchical Encoding/Retrieval Asymmetry (HERA), wherein episodic memory involves bihemispheric processing, while semantic memory is a more unilateral phenomenon. HERA, initially based on PET data, has been supported by research employing different methodologies, such as lateralized presentations in normal (Propper & Christman, 1997) and split-brain (Cronin-Golomb, Gabrieli, & Keane, 1996) populations.

However, investigations supporting the HERA hypothesis have tended to use language material as stimuli. The left hemisphere is primarily responsible for language processing in right-handed individuals, and it is possible that in previous work left-hemisphere processing superiority influenced the manner in which the hemispheres interacted.

The present experiment was designed to determine if the HERA model is descriptive of memory mechanisms when both cerebral hemispheres are equally capable of processing the information.

Method

Participants. Subjects were 116 right-handed undergraduate psychology students randomly assigned to one of two test conditions, such that 60 performed a semantic task and 56 performed an episodic task.

Materials and procedure. Experimental design and procedure replicated that used by Propper and Christman (1997), although pictures rather than letter strings were used as stimuli. Unlike letter-strings, pictures have been shown to be processed equally well by both cerebral hemispheres (Biederman & Cooper, 1991). Stimuli were 58 animate and 58 inanimate line draw-

ings of highly familiar objects taken from the norms of Snodgrass and Van-derwart (1980) and scanned into a MacIntosh computer.

There were four blocks of trials, each containing a total of 28 different pictures. Each picture was presented twice for a total of 56 trials per block. The first presentation of each picture occurred in the left or the right visual field, and the second presentation was either to the same or to the opposite visual field. The second presentation always occurred three to five trials after the first presentation. Inner edges of stimuli were displayed 2° to the right or left of a central fixation marker for 180 ms.

In the semantic task, subjects determined if pictures were of living or nonliving objects. In the episodic task, subjects determined if pictures were new or if they had been seen previously within a block of trials (a given item only appeared in one block of trials). Because the initial trials in a block were by necessity ''new'' items within the context of the recognition task, the first eight trials of each block were excluded from analyses.

If the manner in which the cerebral hemispheres interact during memory tasks is unaffected by the capability of each hemisphere to process the information, then results should replicate those found by Propper and Christman using letter strings; subjects performing a semantic task should demonstrate greater same- than opposite-hemisphere repetition priming, while subjects performing an episodic task should demonstrate greater opposite-than same-hemisphere repetition priming.

Results

Dependent variables were (i) RT for first stimuli presentation minus RT for second presentation, constituting a measure of priming (only those items that were responded to correctly for both presentations were analyzed), and (ii) error rates, computed as percent error scores in order to control for potential biasing of results due to equivalent weighting of errors despite differences in overall number of correct trials.

Dependent variables were analyzed with a five-way, mixed factorial ANOVA, with task (semantic or episodic) and familial sinistrality (present or absent) as between-subject factors, and stimulus type (animate or inanimate object), presentation condition (same visual field or opposite visual field), and visual field of first presentation (left or right) as within-subject factors.

Priming scores. A main effect of Task, $F(2, 116) = 32.0$, MSE $= 20998.22$, $p < .001$, reflected greater priming in the semantic ($x = 43.7$ ms), compared to the episodic ($x = -10.3$ ms) task. A task $\times$ stimulus type interaction, $F(2, 116) = 36.96$, MSE $= 4559.46$, $p < .001$, revealed that subjects performing the semantic task demonstrated more priming in response to inanimate ($x = 55.89$ ms), compared to animate ($x = 31.54$ ms) objects, while subjects performing the episodic task demonstrated more priming in response to animate ($x = 4.96$ ms), compared to inanimate ($x =$

−25.04 ms) objects. The interaction between task and presentation condition was not significant.

Percent error scores. A main effect of task, $F(2, 116) = 67.51$, MSE = 59.37, $p < .01$, reflected more errors in the episodic (5.91%), compared to the semantic (1.74%), task. Although the presentation condition $\times$ task interaction was significant, $F(1, 116) = 11.81$, MSE = 26.06, $p < .01$, simple effects were not ($p > .05$) and were trending in the direction opposite that of the hypothesis (Episodic task; Same visual field 5.05%, Opposite visual field 6.77%: Semantic task; Same visual field 2.04%, Opposite visual field 1.45%).

Simple effects of a visual field of first presentation $\times$ task interaction, $F(1, 116) = 7.47$, MSE = 34.52, $p < .01$ and of a stimulus type $\times$ familial sinistrality interaction, $F(1, 116) = 4.42$, MSE = 39.356, $p < .05$, were not significant.

Discussion

The hypothesis that episodic memory involves bihemispheric processing while semantic memory is a more unilateral phenomenon, has tended to be supported when the left hemisphere is more capable of processing the information. The present research, using material processed equally well by the hemispheres, did not replicate previous work. Although the results suggest that HERA is applicable only to strongly lateralized information, null results should always be interpreted with caution. Future research could test HERA using stimuli processed preferentially by the right hemisphere.

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Mechanisms of Developmental Coordination Disorders: Individual Analyses and Disparate Findings[10]

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Visuomotor control was examined in two children (ages 7 and 9 years) who demonstrated motor difficulties characteristic of developmental coordination disorder (DCD) and was compared to the performance of their same-age peers. Aiming movements were made on a digitizing tablet with and without visual feedback of the moving hand. Results revealed that the nature of the children's performance patterns were not only different from those of their peers, but also from those of each other. The implications of these disparate findings for future research on and intervention in DCD are discussed.   © 1999 Academic Press

Experimental research attempting to identify the mechanism(s) underlying developmental coordination disorder (DCD) has been contradictory and inconclusive. While both sensory feedback (e.g., vision and proprioception) and motor programming abilities have been implicated as causal mechanisms, the only consistent finding is that these children move more slowly and less accurately than their peers, particularly in the absence of vision. The indeterminate findings have prompted the need to develop new approaches for investigating this population and the mechanism(s) underlying their disordered movement. The purpose of the present study was to examine visuomotor control in two children with DCD-like characteristics and to determine if the present paradigm was useful for characterizing developmental movement deficits such as DCD.

Method

Case reports. Two right-handed, male children, B.T. and G.F. (7 and 9 years, respectively) who presented motor difficulties characteristic of DCD participated in this study. Both children were of normal intelligence but demonstrated significant difficulty with fine and gross motor activities as well as with balance control relative to their peers. Sixteen right-handed children (eight 7-year-olds and eight 9-year-olds) without cognitive or motor difficulties also participated in the study.

Movement task and procedures. Aiming movements were made with a mouse on a digitizing tablet to various targets (2 sizes, 3 amplitudes) presented on a computer monitor. The presentation of targets was randomized and the task was performed with and without vision of the moving hand.

Visual feedback was manipulated by providing or removing vision of the cursor.

Data analysis. Kinematic measures, spatial accuracy, and the frequency of various movement patterns were examined. Analyses were performed separately for both children, as each child's performance was compared to the overall mean performance of his respective age group. Trials and interactions with trials were pooled as used as the error terms to test the effects of group (DCD vs peers), feedback, size, and amplitude for both analyses.

Results: B.T.

Movement patterns. Consistent with previous research (Hay, 1979; Pryde, 1997), analysis of the velocity profiles in the no visual feedback condition revealed that the children used three types of movement control: (1) immature ''step'' patterns involving several velocity peaks indicative of a greater reliance on feedback control, (2) ''double peak'' patterns including two velocity peaks, which are a progression of the immature step movements yet are lacking in feedforward capabilities, and (3) ''mature'' patterns characterized by a bell-shaped profile and typical of adult movement patterns. Chi-square analyses revealed that the frequency of movement patterns exhibited by B.T. was typical of and consistent with that of his peers, $\chi^2(df = 1) = 2.61$, $p > .1$.

Kinematic variables. RT analyses revealed that B.T. initiated his movements significantly faster than his age-mates (B.T. = 488 ms; 7 years = 592 ms). All other variables including MT and velocity measures were not affected by group, indicating that B.T.'s movement problems did not dramatically affect his ability to perform the aiming task.

Accuracy. A group $\times$ feedback interaction revealed that in the absence of visual feedback, the accuracy of both the preprogrammed submovement (B.T. = -46 mm; 7 years = -16 mm) and the total movement (B.T. = -27 mm; 7 years = -10 mm) was significantly less for B.T. than for his peers.

Results: G.F.

Movement patterns. Chi-square analyses revealed that G.F. made significantly more step movements and significantly fewer mature movements than his peers, $\chi^2(df = 1) = 17.55$, $p < .001$ (see Fig. 43). This pattern of performance indicates that G.F.'s movements are characterized by an immature movement strategy and are dependent on feedback control.

Kinematic variables. Analyses revealed a significant effect of group for all kinematic measures, where RT (G.F. = 686 ms; 9 years = 480 ms), MT (G.F. = 1636 ms; 9 years = 1137 ms), time to PV (G.F. = 574 ms; 9 years = 409 ms) and time after PV (G.F. = 1061 ms; 9 years = 728 ms) were longer and PV (G.F. = 109 mm/s; 9 years = 166 mm/s) was lower for
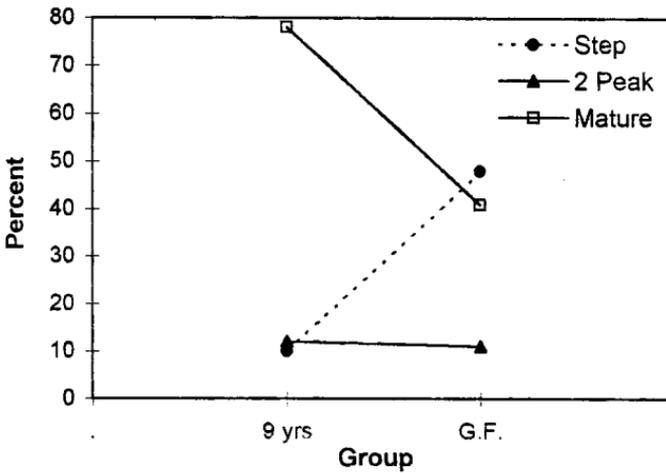
FIG. 43. Percentage of step, double peak, and mature movement patterns for G.F. and his peers.

movements made by G.F.. A group × amplitude interaction occurred, where G.F. was much more affected by amplitude than his peers. For the 100-mm amplitude,[11] G.F. demonstrated a longer MT (G.F. = 1932 ms; 9 years = 1255 ms), a longer time after peak velocity (G.F. = 1305 ms; 9 years = 818 ms), and a lower PV (G.F. = 123 mm/s; 9 years = 201 mm/s). In addition, a group × feedback × amplitude interaction revealed that G.F. had difficulty scaling the velocity of his movements to the amplitude of the target when visual feedback was not available (see Fig. 44). These interactions suggest that G.F.'s movement problems are likely related to difficulties in regulating the amount of force necessary for efficient movement production. Because his movements are poorly planned with respect to amplitude, G.F. spend more time in the deceleration phase of the movement in order to control his hand toward the target.

Accuracy. A group × feedback × amplitude interaction also occurred for initial accuracy indicating that in the absence of vision, G.F.'s preprogrammed movements were significantly less accurate to the further amplitude target (see Fig. 44). The marked undershooting of his initial movement provides additional support for the idea that G.F.'s difficulty is in programming the force parameters of movement.

General Discussion

Our findings revealed that the present paradigm is useful for characterizing the movement problems of children with DCD-like characteristics and that

[11] Preliminary analyses revealed that G.F. did not exhibit any mature movements to the 150-mm amplitude target. Thus, analyses were performed on the 50- and 100-mm amplitude targets only.
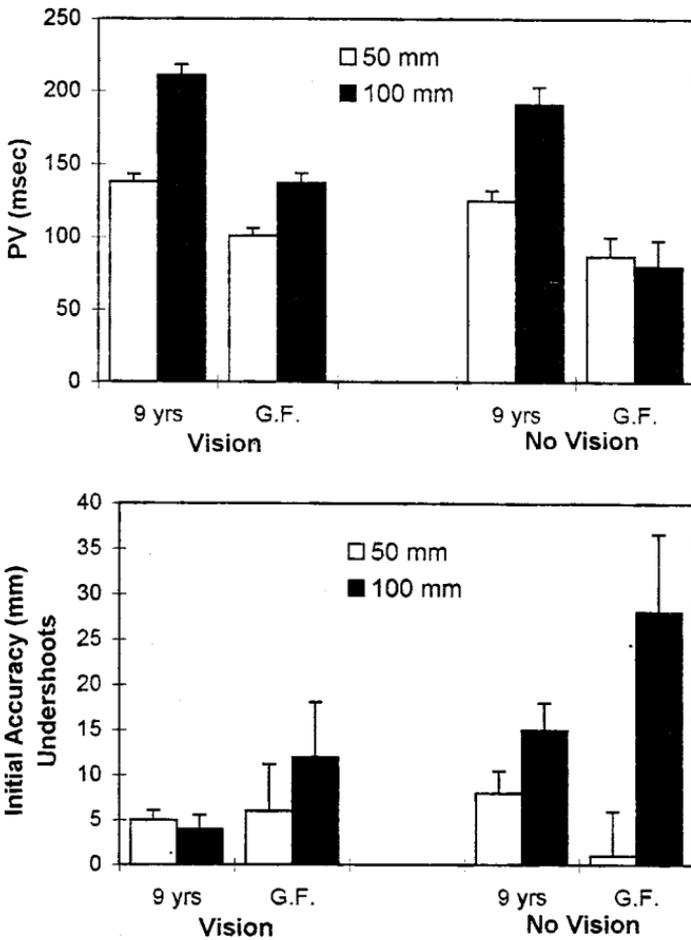
FIG. 44. Interaction between group, feedback, and amplitude for peak velocity and initial accuracy.

the patterns of performance within this population are drastically different. The findings reported for B.T. revealed that his movement problems did not dramatically affect his ability to produce aiming movements. The only difficulty exhibited by B.T. was with respect to initial and final accuracy in the absence of vision, suggesting that his problems lie at the perceptual stage of processing affecting his spatial localization abilities. In contrast, the findings for G.F. indicated that his motor problems did dramatically affect his ability to produce aiming movements. The nature of G.F.'s difficulties suggested that his problems lie at the response programming and/or execution stages of processing affecting his ability to adjust the force parameters of movement.

These findings have important implications for future research on and in-

tervention in DCD. Consistent with previous research revealing that children with motor deficits do not comprise a homogenous group (Dewey & Kaplan, 1992), our findings suggest that different mechanisms underlie DCD-like motor difficulties that can only be identified through individual analyses. Investigations such as the present one are essential for guiding assessment and intervention, as well as research that will foster the development of more theory-based descriptions of DCD.

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Frontal Lesions and Fluctuations in Response Preparation[12]

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The present study tested the hypothesis that frontal lobe lesions affect the temporal control of response preparation. We examined the effect of the temporal predictability of the response signal on reaction time in a delayed response task. Eight frontal patients were compared to eight temporal patients and eight controls in four reaction time tasks in which choice responses were either (1) not delayed, (2) delayed by a short unpredictable interval (1.0–1.5 s), (3) delayed by a long unpredictable interval (4.75–5.25 s), or (4) delayed by an interval of 4.75–5.25 s filled with a countdown cueing the onset of the response signal. Frontal patients showed normal error rates and only slightly increased response times. However, the variability of their response time was increased when the response signal was unpredictable, but not when the response signal was cued. These results suggest an effect of frontal lesions on the temporal aspect of response preparation.   © 1999 Academic Press

Errors in delayed response tasks have been associated with frontal lesions in nonhuman primates (Jacobsen, 1936), but not in humans (Ghent, Mishkin, & Teuber, 1962; Richer et al., 1996). However, frontal lesions produce difficulties in planning and preparing responses (Alivisatos & Milner, 1989;

Lepage and Richer, submitted), and in the temporal control of sequential responses (Halsband et al., 1993). We hypothesized that frontal lesions could affect the temporal control of response preparation in delayed response tasks.

To perform optimally in forewarned reaction time (RT) tasks, subjects must prepare themselves to respond at the moment when signals fall due. Since maximum preparation cannot be maintained indefinitely, RTs will be fastest if subjects can arrange to attain their point of maximum preparation to coincide with the expected signal (Rabbitt, 1989). The temporal control problems of frontal patients could be reflected in a slowing of RTs or in an increase in their variability. More importantly, a temporal control problem should disappear when the timing of response preparation is cued by pacing stimuli such as a countdown. The present study directly investigated the effect of the temporal predictability of the response signal on RT in frontal patients.

Method

Subjects. Eight patients with a unilateral frontal excision for the relief of epilepsy (5 right) were compared to eight temporal patients (4 right) and eight controls. Groups were matched in age (mean: 38 years) and education level (mean: 12 years). Frontal excisions were variable in extent but always included dorsal premotor cortex (medial and lateral), anterior cingulate cortex, and a variable amount of prefrontal cortex.

Tasks and procedure. Subjects were tested in four tasks involving rapid keypress responses to visual stimuli presented centrally on a monitor. All trials consisted of a fixation cross (750 ms) followed, after one second, by a choice stimulus (yellow or blue square, 750 ms) followed, in most conditions, by a response signal (an asterisk) present until the subject responded. In the *immediate response task,* subjects were asked to respond to the choice stimulus, and no response signal was presented. In the *short-preparation task,* the delay between the square and the asterisk varied pseudorandomly between 1.0 and 1.5 s. In the *long-preparation task,* the same delay varied between 4.75 and 5.25 s. In the *countdown task,* the delay was identical to that in the previous task except that the digits 4, 3, 2, and 1 (950 ms per digit) appeared in the center of the screen during the delay indicating the time remaining before the presentation of the asterisk. Each task was composed of 10 practice trials and 70 experimental trials and the order of the tasks was counterbalanced. A short pause separated adjacent conditions.

Results

Table 24 presents performance measures of the three groups in the four tasks. Errors were rare and were similar among groups and across tasks. Anticipatory responses were not produced during the immediate response task and the countdown task. They were more frequent at the short delay

TABLE 24
Performance Measures for the Three Groups in the Four Rapid Choice Tasks

	Frontal	Temporal	Control
Immediate-response task			
Errors	3.9% (2.7)	1.4% (1.3)	2.5% (2.1)
Mean RTs	520.36 (79.17)	450.84 (48.73)	396.48 (37.35)
Standard deviations of RTs	134.58 (34.53)	88.03 (19.39)	82.34 (21.75)
Short-preparation task			
Errors	0.8% (1.5)	0.3% (0.6)	0.5% (1.1)
Anticipatory responses	7.9% (4.5)	2.7% (1.8)	3.8% (4.2)
Mean RTs	447.35 (159.68)	335.14 (61.03)	288.95 (35.75)
Standard deviations of RTs	202.79 (124.94)	93.81 (38.18)	69.64 (30.30)
Long-preparation task			
Errors	1.3% (1.4)	0.2% (0.5)	0.0% (0.0)
Anticipatory responses	4.8% (3.8)	1.8% (1.8)	1.3% (0.5)
Mean RTs	464.41 (122.16)	351.21 (74.49)	311.24 (48.91)
Standard deviations of RTs	161.80 (57.26)	92.24 (43.57)	72.85 (21.79)
Countdown task			
Errors	1.6% (1.9)	0.4% (0.6)	0.3% (0.6)
Mean RTs	324.68 (222.62)	272.49 (92.75)	214.63 (88.01)
Standard deviations of RTs	126.69 (70.66)	105.84 (41.44)	70.64 (24.60)

Note. Standard deviations are in parentheses.

than at the long delay, $F(1, 21) = 8.7$, $p = .008$, and they were more frequent in frontal patients than in other groups, $F(2, 21) = 6.4$, $p = .007$, HSDs > 3.8, $p < .005$.

The longest mean RTs appeared in the immediate response task, whereas the shortest appear in the countdown task. The analyses on mean RT showed a significant slowing in frontals, $F(2, 21) = 4.6$, $p = .02$, HSDs > 80.9, $p < .006$, a significant effect of condition, $F(3, 63) = 40.3$, $p < .001$, and no significant interaction, $F(6, 63) = 0.6$, $p = .73$. For the condition effect, post hoc analyses showed that the short-preparation task was not significantly different from the long-preparation task, HSD = 18.4, $p = .95$. The other comparisons were significant, HSDs > 86.5, $p < .05$ except for that between immediate response and long-preparation tasks, HSD = 80.3, $p = .08$, which was not significant probably due to a lack of statistical power.

Intertrial standard deviations of RT were examined to study the variability of response preparation in the three groups. The ANOVA showed a main effect of group, $F(2, 21) = 8.1$, $p = .003$, again due to frontal patients, HSDs > 61.5, $p < .001$, no significant effect of condition, $F(3, 63) = 1.9$, $p = .15$, and a significant interaction between group and condition, $F(6, 63) = 3.2$, $p = .008$. Post hoc analyses revealed no significant differences between temporal patients and controls, in the four tasks, HSDs < 35.2, $p > .35$. There were no significant differences between the three groups in the countdown task, HSDs < 56.1, $p > .08$, but in all the other tasks, frontal patients significantly differed from the other groups, HSDs > 46.6, $p < .03$.

Discussion

There were no differences in error rates between the three groups in any of the delayed response tasks. This is consistent with previous studies (Ghent, Mishkin, & Teuber, 1962; Richer et al., 1996) and suggests that errors are not very sensitive to processes involved in delay tasks in man. Since errors were more frequent in the immediate response task, it appears that the three groups can benefit from the delay to prepare their response. One second seems to be long enough for subjects to prepare their response, since the short and long-preparation tasks were not significantly different from each other. Frontal patients were slower in their mean reaction time than the two other groups and made more anticipatory responses, which suggests that they had more difficulty predicting the arrival of the response signal.

Even though mean RT is a measure of central tendency, which describes typical behavior, Wing (1992) proposed that the degree of consistency is a hallmark of the underlying control processes. The intertrial standard deviations were high in frontal patients in both immediate and delayed response tasks. Frontal patients appear to have more difficulty achieving and maintaining maximum response preparation during several trials. However, inserting a countdown which externally controls the timing of response preparation appears to help frontal patients achieve normal RT variability.

These results are consistent with a role of frontal cortex in the timing of preparatory processes. Recent work has suggested that variability in RT can be linked to variability in the rate of increase in neuronal firing rate in premotor cortex (Hanes & Schall, 1996). The present data in humans help support the notion that premotor cortex plays an important role in optimizing activity in networks critical for response initiation.

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Picture–Name Agreement for French–English Bilingual Adults

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Two groups of French/English bilinguals named 100 of the Snodgrass and Vanderwart pictures (50 cognate and 50 noncognate names). The balanced group ($N = 18$) claimed equal proficiency in both languages. The French dominant group ($N = 18$) claimed better expressive abilities in French. For both groups the level of name agreement was high in French. For the French-dominant group, name agreement was lower in English. Cognate status did not influence name agreement. Levels of name agreement were very similar to those for the Snodgrass and Vanderwart study for the selected pictures.   © 1999 Academic Press

Introduction

The set of pictures developed by Snodgrass and Vanderwart (SV) (1980) has been widely used in cognitive psychology and related fields. American university students provided norms for name agreement, familiarity, and visual characteristics for each picture. Cross-linguistic studies of the same pictures show that name agreement in English may be different from that in other languages (Metz-Lutz et al., 1991; Sanfeliu & Fernandez, 1996). These studies used ostensibly monolingual speakers. Yet, much of the world's population is bilingual (Schreuder & Weltens, 1993). To understand bilingual lexical semantics, there is a need for stimuli with known properties such as name agreement for specific subgroups of bilingual speakers. Goggin, Estrada, and Villareal (1994) compared English speaking, Spanish speaking, and English/Spanish bilingual speakers. Using the SV pictures, they found name agreement was higher for monolingual than for bilingual speakers. The more proficient bilinguals had higher rates of name agreement than did the less proficient bilinguals. This last finding is consistent with other studies which have found that the level of bilingualism influences performance on a range of lexical-semantic tasks (e.g., Dufour & Kroll, 1995).

A second factor which influences bilingual lexical performance is the cognate status of the words used. Pairs of words with the same meaning in each language (translation equivalents) can be completely dissimilar in their form (e.g., dog/chien) or highly similar (e.g., carrot/carotte). Translation equiva-

lents that are highly similar orthographically and/or phonologically are called cognates (de Groot, 1993). Cognate status can influence translation, priming, and word associations (for a review, see De Groot, 1993). Roberts and Deslauriers (1996) found a cognate effect in aphasic but not in neurologically intact adults on a confrontation naming task. Cognateness and the level of bilingualism may interact (de Bot, Cox, Ralston, Schaufeli, & Weltens, 1995).

The present study was conducted to measure the effects of cognateness and level of bilingualism on the name agreement for a subset of the SV pictures.

Method

Subjects. Thirty-six university freshmen, 19–39 years old, formed 2 groups. The Balanced group ($N = 18$) claimed equal abilities in French and English in 4 language modalities: auditory and reading comprehension, verbal and written expression. The French-dominant group ($N = 18$) claimed better verbal and written expressive skills in French than in English. All Balanced subjects and 1 French subject began learning English before age 6. Most French-dominant-subjects (14/18) began learning English between 6 and 10 years old.

Procedure. Six bilingual judges rated possible pairs of stimulus words (English picture names and French translations). From these, 50 cognate and 50 noncognate pairs were selected. Each subject completed a test booklet containing a questionnaire on their language acquisition/use and a self-evaluation comparing modality-specific levels of proficiency in the two languages (both from Roberts & Le Dorze, 1997), the 100 pictures to be named in one language and the same pictures in a different order to be named in the other language.

Analysis. Two types of analysis were done. First, the percentage of subjects who agreed on the dominant name for each picture as determined by SV (and the translation of that name) was calculated to compare with the SV results. Second, a $2 \times 2 \times 2$ ANOVA tested for the effects of word form (cognate/noncognate), language (French or English) and level of bilingualism (balanced or French-dominant) on the percentage of name agreement for each language. Following Snodgrass and Vanderwart (1980), minor spelling errors were accepted as correct responses.

Results

The level of name agreement was high for both groups and was similar to SV figures. Agreement was lower for the French-dominant group responding in English, as Table 25 shows. There was a significant effect for Language ($F(196, 1) = 5.21$, $p < .03$) and a Group by Language interaction ($F(196, 1) = 13.44$, $p < .001$) with a lower percentage name agreement for

TABLE 25
Mean Percent Name Agreement for Pictures

		Balanced group		French-dominant group		SV group
		French	English	French	English	English
Cognates	Mean	88.9	88.6	86.4	80.2	88.3
	SD	(19.6)	(17.1)	(24.2)	(22.9)	(12.7)
Noncognates	Mean	86.8	90.2	90.1	82.7	90.4
	SD	(22.0)	(15.4)	(19.3)	(24.0)	(12.9)

the French-dominant group in English only. There were no significant effects or interactions involving Form.

Discussion

The significantly lower name agreement for the French-dominant group in their weaker language is consistent with Goggin et al.'s (1994) results. Unlike Goggin, however, the agreement for both types of bilinguals in their first language (French) and for the Balanced subjects in English was high and was similar to that of the presumably monolingual SV subjects in English. Cultural factors and differences in language acquisition and/or use between our subjects and those of Goggin may be responsible.

Although there was no statistical effect of cognateness on name agreement, we observed a much higher number of spelling errors for cognate words than for noncognates in both subject groups. In future studies of written naming, this should be explored further.

The present results highlight the fact that while bilinguals differ from monolinguals in some areas (Grosjean, 1989), their performance may also resemble that of monolinguals in important ways.

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Sexual Dimorphism in Anterior Speech Region: An MRI Study of Cortical Asymmetry and Callosal Size

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We measured the cortical surface of Broca's area and Planum temporale on brain MRI sections in 20 volunteers, together with the size of the corpus callosum suspected to be sexually dimorphic. We did find sex differences in asymmetry of Broca's area, but in the opposite direction than expected, and a negative correlation between Broca's area asymmetry and anterior corpus callosum size in women. Results suggest that Broca's area may be a specific target of factors determining sex differences and that an inhibitory role of the corpus callosum could account for complex anatomical–functional relationships.   © 1999 Academic Press

Although it is generally held that language is more bilaterally represented in women than in men, the typical leftward asymmetry in temporal speech regions has been found in most individuals of either sex. Indeed, there is so far little evidence of sexual dimorphism in these regions (Witelson & Kigar, 1992). A marked sex difference in morphology, however, is found in the corpus callosum (isthmus), a structure which may play a crucial role in the development of cortical asymmetries. The size of the isthmus is correlated to posterior Sylvian fissure asymmetry in either direction in males but not in females (Aboitiz et al., 1992).

Using high-resolution brain MRI, we assessed the cortical volume of pars opercularis (Brodmann's area 44) and pars triangularis (BA45) in normal male and female righthanders. In addition, Planum temporal surface and

asymmetry and total midsagittal area of the corpus callosum as well as that of its different subregions were also measured.

Methods

Subjects. We examined 10 males and 10 females, strictly right-handed, ages 23 to 31, without known history of developmental, neurological, or psychiatric disease.

Magnetic resonance imaging. HR-MRI was performed on a G.E. Signa 1.5T Magnet providing axial series of 124 contiguous 1.17-mm thick slices across a 256×192 pixel matrix. The digital data were transferred to a Sun SparcStation, where image analysis was performed.

Broca's area. Measurements were performed on axial slices with control on sagittal sections. Broca's area was defined as the cortical region limited posteriorly by the precentral sulcus, superiorly by the inferior frontal sulcus, and anteriorly by the horizontal anterior ramus of the Sylvian fissure (Fig. 45). BA44 and 45 were defined as parts of Broca's area situated, respectively, posterior and anterior to the vertical ascending ramus of the Sylvian fissure. Linear measurements obtained on each axial slice, reported to the overall brain volume, were plotted using a computer program calculating the planimetric surface of right and left BA44 and 45, as well as an asymmetry coefficient according to

$$\delta = (R - L)/[0.5(R + L)].$$

Planum temporale area. The extent of cortex limited anteriorly by the transverse temporal sulcus of Heschl and posteriorly by the posteriormost point of the lateral fissure (i.e., Planum temporale, PT) was measured according to a similar method described elsewhere (Habib et al., 1995). Individual right and left surfaces relative to brain volume as well as asymmetry coefficients were calculated.

Measurement of callosal area and subregions. Pictures of medial sagittal slices representing the corpus callosum were magnified to a standard size in order to control for interindividual variations. Measurements were obtained automatically using a computer program described elsewhere (Robichon et al., in press), which segmented the total callosal area into 6 subregions: A1 to A3 and P1 to P3.

Results

There was no gender difference for the Planum temporale area asymmetry nor for total right + left PT volume. In contrast, significant sex differences emerged for Broca's area asymmetry. Globally, females show more leftward asymmetry than males in the 3 regions measured, especially for **d**44 and **d**Broca (Table 26). Group comparisons computed on individual right and
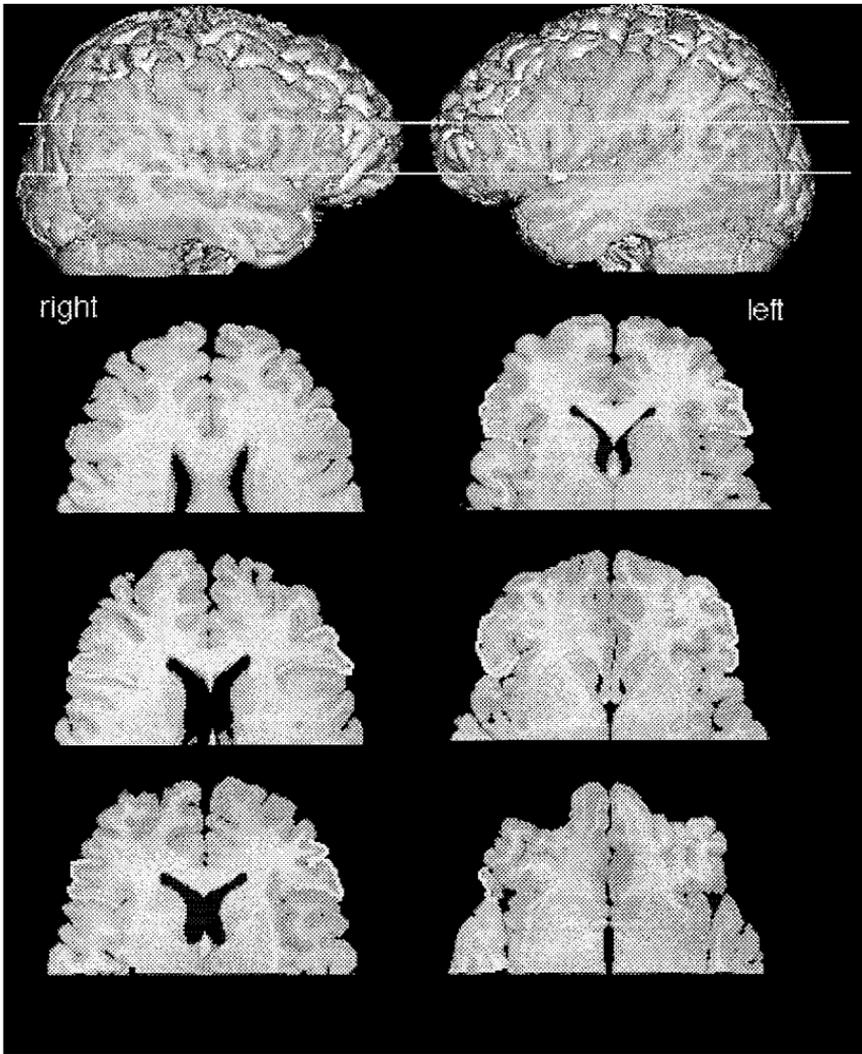
FIG. 45. Measurements of cortical asymmetry of Broca's area. Sagittal sections (top right and left) are used to locate BA44 (solid arrows) and BA45 (open arrows). The bottom figures illustrate 6 representative horizontal sections where linear measurements were performed.

left areas show that this difference in Broca's area asymmetry is attributable to smaller right areas in females than in males.

Of the ANOVAs performed, only those involving **d**45 yielded significant results. As expected, no simple effect of sex on callosal morphology was found, either for overall callosal area or for the subregions measured. Area 45 asymmetry proved to influence callosal morphology, especially in the anterior half and the anterior and posterior fifths. Moreover, there was an interaction between sex and asymmetry for 3 subregions (Fig. 46).

TABLE 26
Mean Comparisons of Right and Left Areas: Measurements and Asymmetrics between
Male and Female Subjects

	Area 45			Area 44		
	Right[a]	Left[a]	δ	Right[a]	Left[a]	δ
Males (N = 10)	78.4	73.2	0.049	78.5	59.3	0.132
Females (N = 10)	57.1	69.4	−0.127	55.9	60.4	−0.056
F(1, 20)	5.935	0.13	3.737	5.374	0.025	8.238
p	.0240	ns	.0675	.0311	ns	.0095
	Broca's area			Planum Temporale		
	Right[a]	Left[a]	δ	Right[a]	Left[a]	δ
Males (N = 10)	156.9	132.5	0.082	95.7	122.8	−0.123
Females (N = 10)	113	129.8	−0.094	86.2	109	−0.095
F(1, 20)	9.096	0.051	8.161	0.684	0.356	0.240
p	.0068	ns	.0098	ns	ns	ns

Note. One-factor ANOVA.
[a] Values are in mm^2 and corrected for overall brain volume.

The nature of this association was assessed after computing correlation coefficients. The asymmetry coefficient for BA45 was found to correlate positively with the total callosal area, the anterior half, A1, and P3. Positive correlations indicate that larger callosal areas are associated with smaller asymmetry (or more rightward asymmetry), while greater leftward asymmetry is related to smaller callosal measurements. These correlations seemed highly dependent on sex, since no correlations emerged when only males were considered, while correlations were stronger for females ($r = 0.901$; $p = .0004$). No such correlations emerged for area 44 or Broca's area asymmetry.

Discussion

Although Broca's area has not been studied to the same extent as other language regions, there is general consensus in the literature that it is represented with a leftward asymmetry in most individuals. Unexpectedly though, more than half of our sample showed either a rightward or an absence of asymmetry. One explanation for this discrepancy may be that our measurements of cortical regions included cortex buried in the depth of sulci, which would provide a better appraisal of cortical area than measuring only surface cortex or making a linear measurement on an arbitrarily chosen slice.
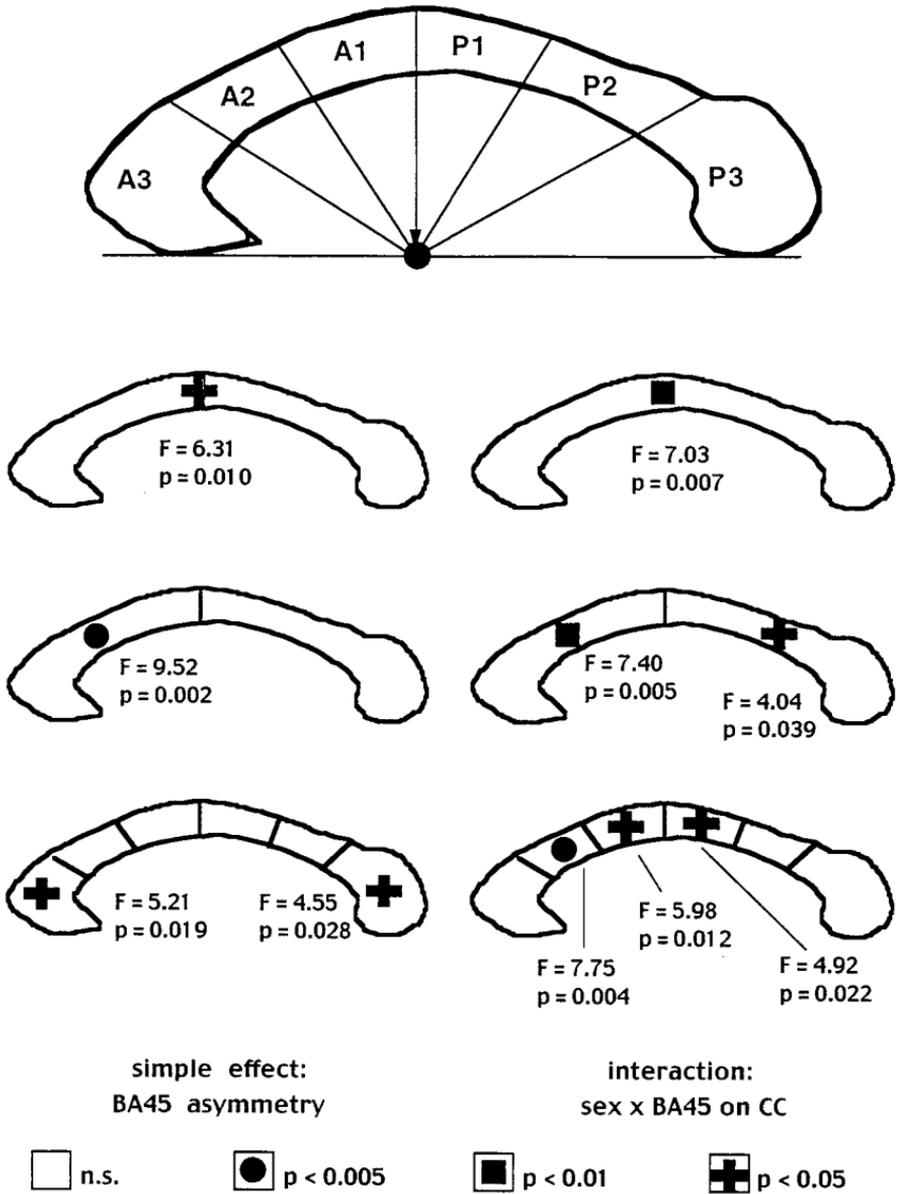
FIG. 46. Schematic representation of the relationships between anterior speech region (area 45) asymmetry and global and segmental callosal size according to sex (two-way ANOVA results). The top part of the figure represents the mode of partitioning of the midsagittal callosal area.

The main result is that leftward asymmetry in Broca's area and its two subregions was significantly more pronounced in females than in males. In the latter, these cortical regions were either symmetric or showed a reversed rightward asymmetry. Our findings are at variance from those of a recent study of postmortem specimens, which had found larger relative right and left Broca's areas in females than in males (Harasty et al., 1997). This discrepancy may result from differences in measurement methods or alternatively from different characteristics of the population studied.

We also found that greater asymmetry was correlated with smaller callosal area, especially in females. This association was strongest with the anterior callosal regions (particularly with subregion A2, which contains fibers connecting right and left lateral premotor cortical regions). It seems then that the female brain is characterized by more of a leftward morphological asymmetry in anterior speech regions, a greater functional dependence on right hemisphere language capacities, and fewer connections between right and left premotor regions. Males, on the other hand, would depend more exclusively on left-hemisphere functional capacities, the anatomical substrates of which would be less asymmetric. The fact that the male brain, though anatomically more symmetric, makes less functional use of linguistic competences in the right hemisphere may be explained by an inhibitory influence exerted by the dominant left hemisphere through callosal connections. It is known that the corpus callosum houses fibers which yield a contralateral inhibition effect rather than an interhemispheric transmission or facilitation one. In females, on the other hand, since the typical leftward asymmetry is associated with less interhemispheric connectivity, linguistic competences in the right hemisphere can be put to use without inhibition from the left hemisphere.

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