

## Lateral Biases for Holding Infants: Early Opinions, Observations, and Explanations, with Some Possible Lessons for Theory and Research Today

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In 1962, the psychologist Lee Salk reported finding that 80% of mothers held their infants on the left side of their body, so that the infant's head was to their left. Salk's finding has been amply confirmed, with new studies of mothers as well as other adults reporting figures for left-side holding ranging from 60 to 85% (e.g., de Chateau, 1983; Harris & Fitzgerald, 1985; Harris, Almerigi, & Kirsch, 2000). New studies also suggest that the bias is only for holding infants (or infant dolls), not for books, packages, or other objects (e.g., Almerigi, Carbary, & Harris, 2001; Rheingold & Keene, 1965). The possibility that it is unique to infants (or their likenesses) is what gives it special interest for investigators who study laterality of function. The discovery of the bias is often credited to Salk, but it would be more accurate to say that he *rediscovered* it because it was first noted at least two hundred years earlier, then, evidently, forgotten, only to be rediscovered and again forgotten several times through the early decades of the twentieth century. Over this period, however, not all agreed that the preferred side was the left: a nearly equal number said it was the right. Each group also proposed explanations for why one or the other side was preferred. They also foresaw different consequences for the infant being held. In the 1980s, I briefly described some of the early reports in essays on the history of theories and research on laterality of function (Harris, 1980, 1983). A manuscript now in preparation provides a more comprehensive description and evaluation of these reports and suggests certain lessons they may hold for current theory and research. The poster proposed for TENNET XII will summarize the main points of this new review and analysis. The poster will be organized into 6 sections, with bulleted text accompanied by drawings, photographs, and other illustrations. The plan is to make the story as *visual* as possible. © 2002 Elsevier Science (USA)

### PART 1

#### *Introduction*

Part 1, the Introduction, like the opening part of the abstract, will set up the plan for the poster: it will summarize Salk's work along with more recent studies, note the existence of an early literature on the same subject, and describe that literature in broad terms.

### PART 2

#### *Main Interest behind the Early Reports*

Part 2 will describe the main interest behind the early reports. It will note that, in contrast to studies today, they were largely inspired by the debate on the origins of human handedness, a debate that, in far starker terms than those used today, pitted nature vs nurture. Naturists, or nativists, saw handedness as a natural product of structural asymmetries of the body and brain. Nurturists saw it as the product of the environment. Interest in side-of-holding lay in the possibility that it was one of the environmental influences, even the primary one. The idea was that if the infant were held predominantly on one side, one of its hands would be pinned against the holder's body, leaving the other hand free to move and exercise, so that from the resulting combination of enforced early use and disuse, the free hand would become dominant.

## PART 3

*Right-Side Hypothesis: Evidence and Explanations*

Right-handedness being the universal norm in these early periods as it is today, it meant that if side-of-holding were an important contributor to handedness, the preferred holding side would have to be the *right*. That would constrain the infant's left side, leave its right side free, and facilitate the early movement and exercise of the right hand, culminating in right-handedness. It also meant that those presumably many fewer instances of left-side holding would lead to left-handedness. Part 3 will present accounts by advocates of this "right-side-hypothesis," including the observations of infant-holding offered in its support, statements of the presumed effect on infant handedness (in a few cases, supported by anecdotal observations), and, finally, descriptions of how the advocates explained the bias for right-side holding the first place.

## PART 4

*Left-Side Hypothesis: Evidence and Explanations*

The contrary "left-side-hypothesis" supposed that the holding-side preference, rather than being on the right, was, in fact, on the left, meaning that the infant's *right* hand was constrained. Right-handedness being the norm, it followed that side-of-holding therefore could not be a significant contributor to handedness and, for that reason, advocates of the left-side hypothesis either favored nativist explanations or other environmental explanations. Part 4 will present early accounts of this hypothesis, including the observational evidence offered in its support and the proposed explanations for the left-side bias itself.

## PART 5

*Evaluation of Early Reports and Discussion of Possible Lessons for Current Theory and Research*

Part 5 will evaluate the contrasting evidence presented by the advocates of the "right-side" and "left-side" hypotheses, assess the advocates' explanations of the bias (some of those coming from the latter group foreshadow current-day hypotheses), and attempt to reconcile their competing accounts of the direction of the true bias. Based on this analysis, it then will discuss some of the possible lessons the early work might hold for current theory and research.

## PART 6

*Historical Reasons for the Shifts of Interest in Holding-Side Biases*

Parts 1–5 of the poster will have shown that opinions, observations, and explanations of lateral biases for holding infants have a long and also checkered history, one that, evidently, ended in the 1930s until its revival by Salk three decades later. Part 6 will address the historical reasons for these developments by suggesting why scientific interest in the phenomenon began, why it ended as it did, and why it has been so significantly revived by Salk's work.

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## The Timing Deficit Hypothesis of Dyslexia and Its Implications for Hebrew Reading

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Vast amounts of neuropsychological evidence have been collected in recent years in support of the hypothesis that developmental dyslexia is caused not only by phonological deficits, but also by timing deficits that affect all senses (e.g., Tallal, Miller, & Fitch, 1995; Stein & Walsh, 1997). In parallel, recent developments in the study of Hebrew reading place heavy emphasis on root awareness in the mental lexicon and early root extraction in the process of word identification (e.g., Frost, Forster, & Deutch, 1997). The present study creates a link between the timing hypothesis and the special demands of Hebrew reading. The performance of dyslexics and normally reading children is compared on tasks requiring visual extraction of trigrams that approximates extracting roots out of Hebrew words. Partial findings show that dyslexics take longer and make more errors while performing trigram extractions on all levels examined, and that sequentiality in the task affects dyslexics and skilled readers in different ways. © 2002 Elsevier Science (USA)

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## INTRODUCTION

In Hebrew, all verbs and most nouns are comprised of consonantal roots which are embedded in pre-existing morphological word patterns (constructed of affixes and vowels) to form the words of the lexicon. The root carries the core meaning of the words that are formed from it, while the form pattern indicates word class, tense, gender, and quantity. It has been hypothesized that reading Hebrew requires morphological awareness, and that roots are lexical entities that enable lexical access to words (Frost & Bentin, 1992). Lexical access requires parallel detection of the three root letters (which have no significant features) and sequential processing to keep the unique letter order, which is crucial for the definitive identification of the root (Eviatar, 1999). Both processes happen rapidly and prior to lexical access. Given that

timing deficits in dyslexics are posited to result from weakness in the magnocellular component of the visual and auditory system, deficient root extraction may be the core deficit in Hebrew dyslexia. It has been shown that dyslexic readers have less morphological awareness than skilled readers (Ben-Dror, Bentin, & Frost, 1995), but root awareness has never been examined in Hebrew-reading dyslexics.

The experiments described here explored the root extraction abilities by requiring dyslexics and skilled readers to extract trigrams out of arrays of 6 items, while manipulating the type and nature of these arrays. The experiments are subdivided into three array-structures: The Basic level used nonlinguistic stimuli, where sequential order of single items was not necessary for the task. In the Nonlinguistic-Sequential level, sequential order of nonlinguistic stimuli items was crucial for the task, approximating the extraction of three root letters in Hebrew words. In the Linguistic level, the stimuli were composed of letters. Half of the trigrams were not real roots, and they were embedded in pseudowords. In half, the roots were real, and were embedded in real words.

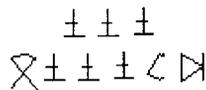
## METHOD

### *Design*

All the experiments involved a trigram identification paradigm. The trigrams were composed of either letter-like forms (Gibson, Gibson, Pick, & Osser, 1962) or Hebrew letters. They were presented above a longer series of forms, in which the target trigram was embedded.

### *The Basic Level*

The trigrams were composed of identical elements embedded in an array of other elements. The subjects had to determine the presence of the trigram in the longer series. In half the trials, a distractor replaced one of the target elements, requiring a “no” response. There were 72 trials divided into two blocks of 36 trials. Example:



### *The Nonlinguistic-Sequential Level*

Here order judgement was added to the tasks. The trigrams were composed of three different letter-like forms. There were two types of trials requiring a “no” response: Where an element was replaced by a distractor, and where all three elements of the trigram appeared, but in the wrong order. There were 144 trials, divided into 4 blocks of 36 trials. Example:



### *The Linguistic Level*

This task had the same design as the other tasks, except that the stimuli were trigrams of Hebrew letters. In the first block of 64 trials, the trigram letters did not

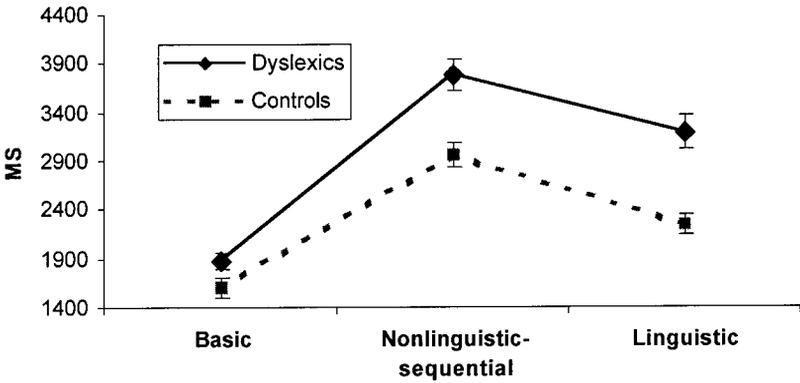


FIG. 1. Median RT of dyslexics and controls.

constitute a real Hebrew root, thus the series created a pseudoword. In the second block of 64 trials the stimuli were real roots creating real Hebrew words. Example:

$\aleph$ $\beth$ $\omega$	/S V R/
$\aleph$ $\beth$ $\aleph$ $\beth$ $\omega$	<u>sh</u> <u>a</u> <u>y</u> <u>a</u> <u>r</u> <u>n</u> <u>u</u>

### Participants

Twenty-eight dyslexic children from learning-disabilities centers in Israel and 22 controls with skilled reading abilities, all from the fifth and sixth grades, were tested. They were pretested to establish their reading level and profile of deficits. All performed the experiments via a laptop computer. Median reaction time (RT) and percentage errors (PE) served as the dependant variables.

## RESULTS

The data were analyzed in two separate 2-way mixed ANOVAS with “Group” (dyslexic vs controls) as a between-groups factor, and “Level” (basic vs nonlinguistic-sequential vs linguistic) as a within-subject factor. Both dependent variables, RT and PE, revealed a significant interaction between Group and Level (RT:  $F(2, 96) = 9.39$ ;  $p < .002$ ; PE:  $F(2, 96) = 5.55$ ;  $p < .0053$ ). Both factors, Group and Level, showed significant main effects in both measures: Group: RT:  $F(1, 48) = 16.73$ ;  $p < .0002$ ; PE:  $F(1, 48) = 3.97$ ;  $p = .052$ . Level: RT:  $F(2, 48) = 210.34$ ;  $p < .0001$ ; PE:  $F(2, 48) = 10.03$ ;  $p < .0001$ . These effects are presented in Figs. 1 and 2.

As can be seen in the figures, tests of the simple interactions revealed that in both time and errors, the simple interaction between Group and Level (Basic vs Nonlinguistic-Sequential) was significant, (RT:  $F(1, 48) = 11.83$ ,  $p < .005$ ; PE:  $F(1, 48) = 4.10$ ,  $p < .05$ ), whereas the simple interaction between Group and Level (Nonlinguistic-Sequential vs Linguistic) was not significant (RT:  $p > .4$ ; PE:  $p > .11$ ).

## DISCUSSION

The results suggest that dyslexics have difficulties in efficiently extracting a visual trigram, that is, establishing its presence in the “word,” and in keeping the original order of the components. The dyslexics were able to cope relatively well with the

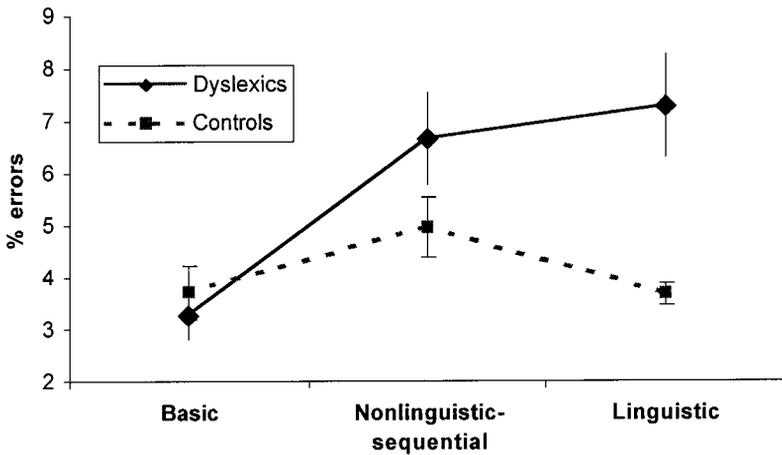


FIG. 2. Percentage errors of dyslexics and controls.

demand for extracting a trigram comprised of an identical repeated element at the Basic level. However, as soon as we introduced the demand for sequential order, the gap between dyslexics and controls widened. This finding agrees with the timing deficit theory hypothesis in more than one way: In addition to their difficulties with sequential order, in both nonlinguistic and linguistic tasks, the dyslexics were also significantly slower than the skilled readers at all of the levels, indicating a timing deficit.

Both the dyslexic and the control groups were faster in the Linguistic level than in the Nonlinguistic-Sequential level. We believe that both groups used morphological knowledge in the Linguistic level that was not available at the Nonlinguistic-Sequential level. That is, it seems that the dyslexic's root awareness has developed to a certain degree, due to 5–6 years of reading efforts. However, this morphological awareness is not as well developed as that of skilled Hebrew readers. The skilled readers are both faster and more accurate in the Linguistic level than in the Nonlinguistic-Sequential level. The dyslexics are faster in the Linguistic level than in the Nonlinguistic-Sequential level, but make the same amount of errors in the two levels. This suggests that in addition to the sequential deficit, there may be a specific linguistic-morphological deficit that affects Hebrew reading dyslexics.

## ACKNOWLEDGMENTS

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## About the Relationship between Basic Numerical Processing and Arithmetics in Early Alzheimer's Disease—A Follow-Up Study

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We studied the relationship between basic numerical knowledge and arithmetics (facts and procedures) in early Alzheimer's Disease (AD). In most patients, basic numerical knowledge was found to be preserved, as reflected by low error rates, distance effect in number comparison, and subitizing in naming numerosities. However, within arithmetics, AD patients exhibited decreased fact and procedural knowledge. Interestingly, double dissociations were found not only between facts and procedures but also between basic numerical knowledge and arithmetics. Thus, our results suggest that basic numerical knowledge need not be a prerequisite for the maintenance of arithmetics, but rather corroborate calculation models that postulate the functional independence of its components. Further, we found patient specific error types which might serve to identify early AD. The follow-up about one year later indicated significant qualitative, but only marginal quantitative performance changes. © 2002 Elsevier Science (USA)

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## INTRODUCTION

The first systematic case description of a calculation deficit in dementia has been provided by Grafman et al. (1989). Their case shows that dementia can lead to highly selective impairments of single components of the calculation system (as fact knowledge or calculation procedures).<sup>1</sup> In fact, later single case studies (Pesenti, Seron, & VanDerLinden, 1994; Cipolotti, DeLacy, & Costello, 1995; Girelli et al., 1999) confirmed the functional independence of facts and procedures and proposed that numerical abilities might be differentially vulnerable in dementia. Further corroborating the modular organization of calculation skills, Remond-Besuchet et al. (1999) observed the selective preservation of specific numerical skills in a 86-year-old patient who otherwise exhibited marked cognitive impairments.

Group studies of numerical abilities in AD stressed that arithmetical impairments are a common finding in early AD and hence could facilitate the clinical diagnosis (Parlato et al., 1992; Carlomagno et al., 1999). Deloche et al. (1995) found that calcu-

<sup>1</sup>*Arithmetic facts* are simple calculations with operands between 1 and 9 (like  $4 + 2$ ,  $4:2$ ). *Rule problems* include 0 or 1 as an operand (like  $5 - 0$ ,  $5 \times 1$ ). Written calculation requires complex, multistep procedural knowledge.

lation performance in mild AD correlated with MMSE and language, but not with memory. Conversely, Carlomagno et al. (1999) reported arithmetics to correlate with executive-attentional abilities only. Mantovan et al. (1999) speculate that AD patients' procedural errors in solving written calculations reflect difficulties to execute/monitor complex algorithms, while transcoding errors were interpreted as reflecting deficient inhibition mechanisms (Tegner & Nybäck, 1990; Thioux et al., 1999) and deficient attentional resources (Kessler & Kalbe, 1996).

So far, little attention has been paid to numerical abilities as counting (Seron et al., 1991), subitizing and number comparison in AD. However, as basic numerical knowledge is innate or at least acquired early in child development (Antell & Keating, 1983; Starkey & Cooper, 1980; Wynn, 1990) and may be more resistant to deterioration processes, it's investigation in Alzheimer patients may be particularly interesting. The quick recognition of small quantities—numerosities of 3 or 4—relies on a preverbal, maybe perceptual mechanism ("subitizing," Resnick, 1983). According to Dehaene and Cohen (1994) subitizing is based upon parallel information processing and thus dissociates from the slower, serial verbal counting. In normals reaction times (RTs) increase proportionally to the quantity of represented items (Mandler & Shebo, 1982), once the quantity of 4 is exceeded. Seron et al. (1991) found demented subjects performing worse than other patient groups on counting tasks, however, the basic counting principles (Gelman & Gallistel, 1978) were still preserved. Number comparison, another basic numerical skill, requires a cardinality judgement of two numbers (5 is bigger than 3). The so-called "distance-effect" reflects a negative correlation between RT and numerical distance of the two numbers to be compared (Moyer & Landauer, 1967). These RT effects are very robust (Gallistel & Gelman, 1993; Pesenti, 1995). Timed comparison tasks have never been used before in AD.

The relation between basic numerical knowledge (such as subitizing or number comparison) and arithmetics (facts and procedures) is of particular interest and has been rarely discussed in adult performance. The calculation model proposed by McCloskey et al. (1985, 1991) allows no respective predictions. According to the triple code model (Dehaene & Cohen, 1995) difficulties in processing magnitudes—thus quantity manipulation like subitizing and number comparison—should not affect stored arithmetical knowledge. Double dissociations between basic numerical knowledge and memorised arithmetical knowledge (particularly facts) would be thus compatible with the triple code model. Alternatively, Gallistel and Gelman (1991) propose that deficits in basic numerical processing should critically affect fact retrieval as the latter is mediated by the mapping to preverbal magnitudes.

The aim of this study was to see whether basic numerical knowledge is still preserved in early AD and whether it is a prerequisite for the maintenance of arithmetics. Further, qualitative analysis might reveal specific error types or distributions. Finally, as AD is a progressive deteriorating disease the follow-up should reveal performance decreases.

## METHODS AND SUBJECTS

All subjects underwent *neuropsychological background tests* (MMSE, verbal/non-verbal semantic memory, episodic memory, visuo-motor and visuo-constructional skills, specific frontal-lobe tasks).

To ensure performance on calculation tasks, we assessed *transcoding abilities* (repeating number words,  $n = 10$ ; reading written arabic numerals,  $n = 30$ ; writing arabic numerals upon dictation,  $n = 30$ ), *comprehension/production of operational signs* ( $n = 8$ ), and *number sequences* (counting from 1 to 20).

Basic numerical knowledge was tested by computerised dot counting and number comparison tasks (MEL2, Schneider, 1995). Stimuli in *dot counting* were regular dot patterns (quantities between 1 and 9; adapted from Mandler & Shebo, 1982), oral answer; 5 training, 45 test trials. In *number comparison*, subjects had to classify single arabic digits as smaller or larger than the internal standard of 5, manual response. Presented were digits between 1 and 9 (except 5), thus receiving numerical distances of 1, 2, 3, 4; 10 training, 60 test trials. Stimuli duration response-bound, fixation point 500 ms, ISI 1000 ms.

Arithmetical tests assessed *arithmetical fact knowledge* (including rules) and procedural knowledge (*written calculation*). Within each mathematical operation subjects had to solve 16 fact/4 rule problems orally (64 facts/16 rules) as well as 4 multi-digit written calculations (16 problems). Subjects were asked to rewrite the problem and to note intermediate results, no time-limit.

Nineteen right-handed, Spanish speaking patients participated in the study (mean age 74,95/*SD* 8,07; educational level 1,63/*SD* 0,76).<sup>2</sup> Selection criteria: diagnosis of probable DAT according to DSM-IV (APA, 1994) and NINCDS-ADRDA (McKhann et al., 1984). Exclusion criteria: vascular/subcortical dementia, focal neurological diseases, depression or debilitating sensory-motor deficits, impairment in transcoding 2-digit numbers. The control group ( $n = 19$ ) consisted of healthy, matched individuals (mean age 67,53/*SD* 7,60; educational level 2/*SD* 0,67).

## RESULTS

We found significant group differences regarding MMSE ( $p = .00$ ), confrontation naming ( $p = .03$ ), semantic fluency ( $p = .00$ ), verbal memory (learning curve, short-term/long-term memory, each  $p = .00$ ), verbal recognition memory ( $p = .01$ ), visual memory ( $p = .00$ ), visual recognition memory ( $p = .05$ ), verbal memory false-positives ( $p = .02$ ), episodic memory (short/long delay events, each  $p = .00$ ), Rey copy ( $p = .03$ ), trail making test-A ( $p = .00$ ), digit-symbol test ( $p = .00$ ), Wisconsin card sorting-categories ( $p = .00$ ) but not in visual memory false-positives, Block Design, ideomotoric praxia and phonological fluency.

AD patients accuracy rates in reading arabic digits were 96.83% (CO 98.76%), in writing arabic digits 95.93% (CO 98.23%) and in reading/writing operational signs 76.38% (CO 88.13%). Both groups were 100% correct in counting from 1 to 20. Performance differences were not significant (except to writing arabic digits to dictation,  $p = .05$ ).

Regarding basic numerical knowledge: (a) In *dot counting* we excluded dot patterns of 1 and 7 because of extremely long RTs in both groups. Though overall accuracy was high for both patient (98.28%/SD 3.02%) and control group (99.70%/SD 0.90%) the group difference was found to be significant (Mann-Whitney  $p = .04$ ) and highly significant regarding overall RTs (Mann-Whitney  $p = .001$ ). Significant differences between groups were also found in mean RTs for small (2, 3, 4 dots;  $p = .001$ ) and large numerosities (5, 6, 8, 9 dots;  $p = .001$ ). Regression results corroborated our previous assumption that both groups subitize patterns up to 4 dot arrays, while changing to a counting strategy thereafter (goodness-of-fit measure of different linear models:  $R^2 = 0.172$  and  $R^2 = 0.155$  for a straight line through 4 and 5 dot arrays, respectively). (b) In *number comparison* we excluded distance 4 (to

<sup>2</sup> Education was coded into the following classes: coding value 1 was designated to education of up to 5 years, coding value 2 was assigned to a range from 5 to 8 years of education and 3 to a range of 8 years and more.

avoid possible anchor effects [Pesenti, 1995]), thus analysing distances 1, 2, 3 only. Regarding accuracy, performance of the two groups (patients 92.74%/SD 9.63% and controls 98.08%/SD 5.23%) reached the significance level (Mann–Whitney  $p = .001$ ), which was due to distances 2, 3 only ( $p = .04$  and  $p = .05$ , respectively). Regarding RT, the distance effect was found to be significant in both groups (Kendall–W-Test; patients:  $p = .000$ ; controls:  $p = .001$ ). Altogether, despite patients' prolonged RTs, basic RT effects—subitizing in dot counting and distance effect in number comparison—were found to be preserved (Fig. 1).

In arithmetical fact retrieval, AD patients committed more errors than controls (facts: 18.2 versus 8.8%; rules: 27.3 versus 18.4%), but differences were significant only regarding subtraction facts and division rules (Mann–Whitney  $p = .02$  and  $p = .05$ , respectively). Most interestingly, in both groups, the absolute error rate of rules is far higher than the one of facts (controls: 18.4 versus 8.8%; patients: 27.3 versus 18.2%). Similarly, in written calculation patients committed more errors than controls (39.5 versus 16.8%, respectively;  $p = .04$ ). Error distribution over operations was comparable between the two groups regarding facts (not rules) and written calculation. Interestingly, we found patient specific error types in both fact retrieval (e.g.,  $4 + 3 = 43$  which we called *full naming errors*) and written calculation (e.g.,  $58 - 24 = 4$  classified as *incomplete operations*).

Correlating general cognitive abilities to numerical knowledge (Spearman  $r_s$  tests) we found that patients' MMSE correlated only with written calculation ( $p = .03$ ). Further, verbal semantic memory was significantly correlated to fact retrieval ( $p = .03$ ) while executive functioning (WCST, Categories) was correlated to rule retrieval ( $p = .05$ ).

Comparing basic numerical knowledge to arithmetics, a *subject-to-subject analysis* disclosed that basic RT effects are preserved in all but four patients (AD1,2,3,4; Table 1). Interestingly, all of these four patients were impaired in written calculation as well and three of them additionally in fact and rule retrieval (AD2,3,4). Dissociations between basic numerical knowledge and arithmetics were repeatedly observed, mostly showing intact basic RT effects and impaired arithmetics (AD6,10,11,15,16,17). However, also the reverse was found (AD1). Within calculation tasks, various patterns of dissociations were found between fact, rule and procedural knowledge (Table 1).

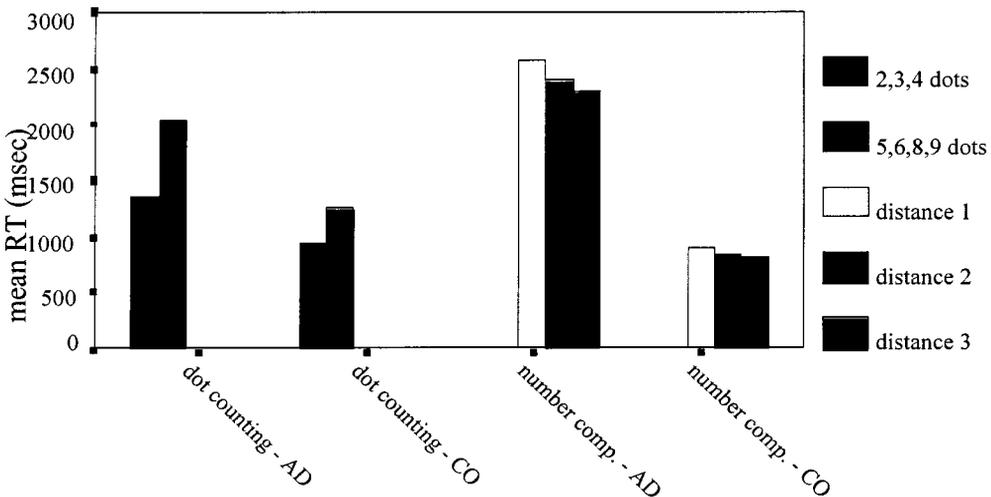


FIG. 1. Basic RT effects.

TABLE 1  
 Relating Basic Numerical Skills (Number Comparison and Dot Counting) to Arithmetics  
 (Facts, Rules, Procedures)—AD Patients

ID#	Dot counting <sup>c</sup>	Number comparison <sup>b</sup>	Facts <sup>c</sup>	Rules <sup>c</sup>	Written calculation <sup>c</sup>
	Subitizing RT (mean $\pm$ 2 SD)	RT diff s1-s3	Criteria	Criteria	Criteria
	T1	T1	T1	T1	T1
AD1	—	+	+	+	—
AD2	—	—	—	—	—
AD3	+	—	—	—	—
AD4	—	+	—	—	—
AD5	+	+	+	+	+
AD6	+	+	—	+	+
AD7	+	+	+	+	+
AD8	+	+	+	+	+
AD9	+	+	+	+	+
AD10	+	+	+	—	+
AD11	+	+	+	—	+
AD12	+	+	+	+	+
AD13	+	+	+	+	+
AD14	+	+	+	+	+
AD15	+	+	—	+	—
AD16	+	+	—	—	—
AD17	+	+	—	+	+
AD18	+	+	+	+	+
AD19	+	+	+	+	+

Note. AD1–AD4: absent basic RT effects (absent subitizing and/or distance effect).

<sup>a</sup> Subitizing RT: mean  $\pm$  2 SD of controls mean (small dot arrays from 2 to 4 dots).

<sup>b</sup> diff s1-s3: RT difference between distances 1 and 3 (+ if difference is a positive value).

<sup>c</sup> Criteria: mean total scores  $\pm$  2 SD of controls mean.

## FOLLOW-UP RESULTS

One year after the initial assessment 14 patients repeated the calculation battery. Performance changes over time were not significant. Regarding both computerised tasks, this holds true for accuracy and RT (dot counting: accuracy  $p = .13$ ; RT  $p = .18$ ; number comparison: accuracy  $p = .16$ ; RT  $p = .88$ ). Regarding *arithmetical fact knowledge* we observed a significant performance decrease in division facts only ( $p = .01$ ) which is attributable to the high incidence of omission errors (initially 18 versus follow-up 42). Interestingly, the absolute error rate increased considerably though not significantly on rule knowledge (from 24.6 to 33.5%;  $p = .08$ ), while only slightly regarding fact knowledge (17.2 versus 19.2%). However, qualitative performance changes were observed (e.g., addition facts: “perseverations” increased from 0 to 25%; written subtractions: “failure of factor selection” increased from 42.9 to 81.3%).

With respect to single-subject analysis we found basic RT effects still mainly preserved (McNemar tests were not significant for all patients and variables). Again, results indicated double dissociations between basic numerical knowledge and arithmetics (AD6,8,9,11,14) as well as between fact/rule and procedural knowledge (AD1,6,9,11).

## DISCUSSION

Results show that basic numerical knowledge is generally well preserved in early AD which might reflect intact representation and manipulation of number magnitudes. Although RTs are prolonged relative to controls, most patients showed intact subitizing in dot counting as well as distance effects in number comparison. Regarding dot counting we assume that both groups (with few exceptions) used different approaches for small and large dot arrays, subitizing for the former and counting for the latter. As compared to previously reported results (Seron et al., 1991) patients accuracy in dot counting was found to be rather high which may be partially explained by differences in stimulus material and patient selection. Number comparison is of particular interest since an absent distance effect reflects faulty access to magnitudes immediately evoked by the numerals (Moyer & Landauer, 1967; Dehaene, Dupoux, & Mehler, 1990). The consistent distance effect displayed by our patients thus suggests that Alzheimer's patients mostly have no difficulties in processing magnitudes.

In line with other studies (Girelli et al., 1999; Diesfeldt, 1993; Grafman et al., 1989) our data show that the double dissociation between fact and procedural knowledge is not only a feature of developmental (Temple, 1991) and acquired brain lesion studies (McCloskey et al., 1985; Warrington, 1982), but holds true for Alzheimer's patients as well. Within simple arithmetics, patients showed particular (and over time increasing) problems with rules. Selective impairment of rule versus fact knowledge is in line with the assumption of separate mental representations for rules and facts (McCloskey et al., 1985; Pesenti et al., 2000). While the former are assumed to be answered by a stored rule (e.g., everything times 0 gives 0), the latter are thought to be part of stored knowledge. In line with this hypothesis we found a significant correlation between verbal semantic memory and fact (but not rule) retrieval. In written calculation various types of errors were found which may be attributed to both, faulty knowledge of procedures (Girelli & Delazer, 1996) as well as deficient control mechanisms (Semenza et al., 1997; Mantovan et al., 1999). Relating basic numerical knowledge to arithmetics we found very heterogeneous performance patterns and most interestingly, double dissociations as well. Thus, our results suggest that basic numerical knowledge need not be a prerequisite for the maintenance of arithmetics, but rather corroborate models that postulate specific, functionally independent components within the calculation system (Dehaene & Cohen, 1995). However, our data also suggest that basic numerical knowledge is more resistant to deteriorating dementing processes than arithmetics, as in most patients basic RT effects were still preserved despite deficient performance in arithmetics. At the follow-up we found only partial quantitative performance changes. It might be that the time span between the two assessments was too short to tap the deterioration process. Interestingly, the qualitative error analysis revealed a remarkable increase of such error types which reflect inhibition problems in fact retrieval and deficient control mechanisms in written calculation.

Taken together, our results show that numerical abilities are differentially affected already in mild AD. Error patterns are heterogeneous across subjects and suggest various, selectively vulnerable, cognitive components employed in numerical processing. Our findings further suggest that basic numerical processing is not necessarily a prerequisite for the maintenance of arithmetic fact knowledge (as postulated by Gallistel & Gelman, 1991). Rather, our results are compatible with Dehaene's triple code model (1992; Dehaene & Cohen, 1995), which assumes that the processing of magnitudes should not affect stored overlearned arithmetical knowledge. It should

also be stressed, however, that basic numerical processing seems more resistant to deterioration processes than later acquired, formally taught, arithmetic skills.

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## Prospective Memory and Executive Function in Schizophrenia

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Experimental studies of normal subjects have shown that the intention to perform an action speeds word recognition for items related to that intention (Goschke & Kuhl, 1993). This phenomenon—the *intention superiority effect* (ISE)—is thought to be mediated by frontal executive functions. Since schizophrenia is characteristically associated with forms of frontal-executive dysfunction, an impaired ISE might be expected in this patient group. A script-learning paradigm was used to investigate the ISE in 10 schizophrenics who do show evidence of executive dysfunction and in 10 who do not. As predicted, only the former showed an ISE; however, all schizophrenics showed an ISE to words semantically related to the intention. It seems that the ability to form specific intentions is impaired only in schizophrenics with executive dysfunction; however, they retain the ability to form more generalized intentions. © 2002 Elsevier Science (USA)

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## INTRODUCTION

Studies of memory in schizophrenia have generally focused on retrospective memory, i.e., the ability to remember past events (for a review, see McKenna, McKay, &

Laws 2000). A previously unexamined aspect of memory in schizophrenic subjects concerns their ability to remember to do something (e.g., to take medication). This “remembering to remember,” or memory for intentions is sometimes called prospective memory (PM) and is formally defined as memory for the intention underlying the punctual execution of a delayed action (Kvavilashvili, 1987).

In a series of elegant experiments, Goschke and Kuhl (1993) examined how normal subjects form intentions and what is it about this formulation that culminates in the successful completion of a delayed intention. By using short descriptions of everyday actions—“scripts”—they found that the “to-be-performed” (i.e., intended or PM) scripts yield faster reaction time latencies than to-be-observed (i.e., performed by someone else or non-PM) scripts—a finding that they call the *intention superiority effect* (see also Goschke & Kuhl 1996; Marsh, Hicks, & Bink, 1998). Goschke and Kuhl speculate that in the “perform” condition, script items are raised to a heightened state of activation through the modulatory influence of frontal lobe executive systems on brain areas subserving declarative memory.

Indeed, PM does seem to be strongly related to aspects of frontal executive function (e.g., McDaniel, Glisky, Rubin, Guynn, & Routieux, 1999; Glisky, 1996). Furthermore, most PM tasks seem to require exactly the same functions that are associated with the frontal lobes, i.e., planning, interruption of ongoing behaviors, monitoring of environment or context, and ensuring the execution of multiple procedures in an organized and timely fashion. Given that schizophrenic patients are frequently reported to be impaired on tests of executive function and show hypofrontality during functional imaging (for a review see Laws, 1999), we might also expect PM to be impaired in schizophrenic patients. In the current study, we used the Goschke and Kuhl paradigm to compare ISE in a group of schizophrenics showing evidence of executive dysfunction with another group of schizophrenics showing no evidence of executive dysfunction.

## SUBJECTS

Twenty schizophrenic patients (14 male and 6 female) were drawn from a large population of chronically schizophrenic patients. None had any history of organic brain disease, head injury, or alcohol or drug abuse. Although all patients had long histories of illness, they showed little clinical deterioration and 14 were living in the community. All had full scale WAIS IQs within the average or above average range (mean 98[ $SD = 7.5$ ]).

Subjects were assigned to an “intact” executive function group if they performed above the 25th percentile (when compared with test norms) on two tests of executive function: the Cognitive Estimates test and Category Fluency (animals); and classified as “impaired” if they performed between the 5th and 10th percentiles on one or both of the tests. Norms for the cognitive estimates test were derived from O’Carroll, Egan, and MacKenzie (1994); for the category fluency test, norms were derived from 85 normal subjects (McKenna, unpublished data). The groups differed significantly in their performance on Cognitive Estimates ( $t = -2.52, p = .02$ ) and category fluency ( $t = -2.66, p = .01$ ).

## MATERIALS

Four short texts describing everyday actions were constructed under titles such as “Setting a dinner table” and “Clearing a messy desk.” Each description consisted

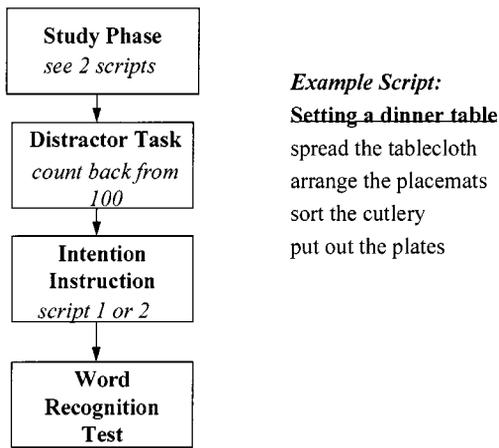


FIG. 1. Experimental paradigm.

of a header title and four lines describing the component actions in a logical and temporal sequence (see Fig. 1). It should be noted that subjects were not required to plan any of the actions themselves.

There were two blocks of two scripts. Only *after* viewing both scripts in a block (for 1 min each) were patients told that they would later have to perform one of the scripts (i.e., this became the prospective [PM] script); no instruction was given for the other script(s) (i.e., this became the neutral or “nonprospective” script [NPM]). After each of the two blocks, patients had their recognition memory tested for the material presented in the scripts.

The subsequent recognition test comprised 26 items (per script) presented on a computer screen for a yes/no response and RT was recorded (the stimuli comprised: 8 targets [4 nouns and 4 verbs] from the scripts; 6 semantically related items [3 nouns and 3 verbs]; and 12 unrelated [neutral] words). With 4 scripts tested in 2 separate blocks, this provided two recognition tests each with 52 items. The mean written word frequency for targets, semantically related items, and unrelated items were matched across scripts (Celex, 1995).

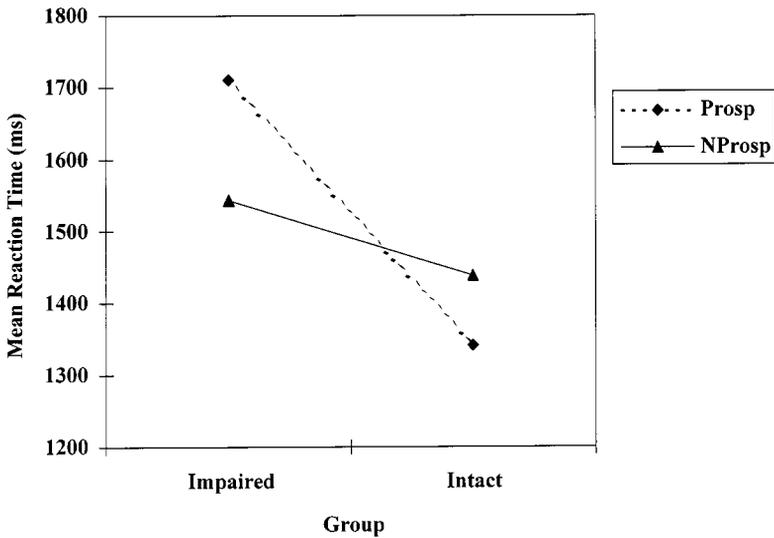
## RESULTS

Five participants (3 from the intact group and 2 from the impaired group) were excluded because of outlying RTs or error rates. The final analyses involved 15 subjects (8 impaired and 7 intact patients).<sup>1</sup> All errors were excluded from the analyses, as were any RT scores three standard deviations above a subject’s mean RT (1.75% of responses were excluded).

**Targets.** RTs for targets (see Fig. 2) revealed a significant group-by-script interaction ( $F(1, 13) = 4.75, p = .04$ ); no other effects reached significance.

**Post-hoc** analyses showed that the executive intact patients were significantly faster than the executive impaired group for the PM scripts  $t(13) = 1.7, p = .05$ ; the difference between groups for the NPM scripts was nonsignificant,  $t(13) = .41, p = .34$ . Within-group comparisons revealed that the intact patients showed a trend toward an intention superiority effect (i.e., faster latencies for PM than NPM scripts),

<sup>1</sup> Their performance on Cognitive Estimates and Category Fluency still remained significantly different ( $t(13) = 2.83, p = .014$ ;  $t(13) = -2.18, p = .045$ ), and showed no significant differences in WAIS IQ or age ( $t(13) = -0.79, p = .44$ ;  $t(13) = 1.76, p = .10$ ).



**FIG. 2.** Mean RTs for Target item recognition. A comparison of schizophrenics (with and without impaired executive function) on prospective and nonprospective scripts: Prosp = to be performed task (i.e., prospective task); Nprosp = neutral task (i.e., Nonprospective task). This figure shows that executive intact schizophrenics show a normal ISE, while executive impaired schizophrenics do not (indeed, they show the reverse pattern).

$t(7) = .98, p = .09$ ; in contrast, the executive impaired patients showed an inverse effect (i.e., latencies were significantly faster to the NPM than the PM scripts),  $t(6) = -2.28, p = .028$ .

*Semantic distractors.* A significant main effect for script,  $F(1, 13) = 6.21, p = .027$ ; no other interactions reached significance.

*Unrelated distractors.* No significant main effects or interactions were observed.

*Errors (Discriminability Index:  $A'$ ).* Errors were examined using a discriminability index ( $A'$ ), the nonparametric equivalent of  $d'$ . There were no significant effects for discriminating between target and unrelated items. For target and semantic items, the intact patients were significantly better at discriminating target and semantic items than impaired patients ( $A'.768$  vs  $.667$ ):  $F(1, 13) = 4.81, p = .047$ .

## DISCUSSION

One striking result was that the executive-intact schizophrenics showed the ISE repeatedly documented in studies of normal subjects (cf. Goschke & Kuhl, 1993; Goschke & Kuhl, 1996; Marsh, Hicks, & Bink, 1998). In contrast, the executive impaired schizophrenic patients failed to show an intention superiority effect and indeed, were significantly slower to the prospective than non-prospective script.

Equally surprising, however, was the finding that the entire group showed an intention superiority effect to semantically related distractors. This differs qualitatively from the pattern in normal subjects, who respond in the same manner to semantically and unrelated items (Goschke & Kuhl, 1993; Goschke & Kuhl, 1996). A possible rationale for these findings concerns the automatic spread of activation within semantics from target words to semantically associated words. So, while the "perform" or intention instruction is thought to raise the activation of these items to a higher state (Goschke & Kuhl, 1993), semantically associated items may also become "charged"

(albeit to a subtarget activated level). While the spreading of activation in schizophrenic subjects may itself be abnormal (Spitzer et al., 1993), the activation associated with encoding appears to be similar across both the executive intact and the impaired patient groups (since both show ISE for the semantically related items).

It seems likely that executive function plays a role in at least three stages of the experimental paradigm: first, to *encode* items; second, to heighten activation in response to the intention instruction; and finally, to permit discrimination between targets and (primarily semantic) distractors during recognition. To show the intention-superiority effect, intact executive function is required to control the decision-making process for selecting target items activated in memory with those on the screen. That executive impaired patients showed an ISE to semantic distractors but not targets suggests that (a) the former occurs *automatically* and *incidentally* and (b) that executive impairment affects the ability to discriminate activated targets from incidentally activated semantic items. Since the semantic items become activated automatically, a different decision-making process occurs in this condition. Subjects are simply required to match the on-screen item with the same item activated in memory. In the target condition, subjects must match an item presented on the screen with one that they have previously seen. It seems reasonable to assume that the latter may depend more heavily on executive control than the former. The discriminability analyses support the notion that target items are hard to discriminate from semantic items. It is not coincidental that only the intact group showed a trend toward intention-superiority and was better at discriminating target from semantic items. Within this framework, patients in the executive impaired group would encode the intended (target) and semantically related items in a higher state of activation; however, executive dysfunction impairs the ability to discriminate between these competing items and so, it seems that they fail at stage three (i.e., between target and semantic items and non-presented semantic from presented-semantic items).

To conclude, the current study of schizophrenic patients with and without executive dysfunction shows that although executive function may influence several processes (from encoding through to eventual retrieval), it is at this latter stage that the impairment has the greatest effect. The findings show that schizophrenic patients *per se* are able to formulate and recall *general* intentions—but executive impairment may hinder the ability to remember the *specific* content for intended actions.

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## Inflectional Morphology in German Williams Syndrome

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In a recent paper, Clahsen and Almazan (1998) reported a dissociation between unimpaired regular and impaired irregular past tense morphology in English Williams syndrome (WS). Our aim is to investigate whether these findings carry over to another language with different morphological systems. We present data on regular and irregular participles and noun plurals from 2 German WS subjects and 10 controls matching in mental age. For noun plurals, regular morphology is intact in WS, whereas irregular forms are impaired. A similar dissociation is observed for participles: while regular inflection is unimpaired, WS subjects, unlike controls, apply the regular suffix incorrectly to frequent irregular verbs. We discuss our findings against the current debate between connectionist and dualistic approaches to the language faculty.

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## INTRODUCTION

Williams syndrome (WS) is a rare neuro-developmental disorder of genetic origin that is associated with physical (e.g., renal and cardiovascular) anomalies and cognitive deficits, especially in nonlinguistic domains such as visuospatial constructive cognition. Grammatical knowledge, in contrast, is relatively intact (Bellugi et al., 1994). Recently, Clahsen and Almazan (1998) reported a marked dissociation between regular and irregular inflectional morphology in English WS children. While regular past tense inflection was intact, performance with irregular verbs was significantly worse compared to unimpaired children. The aim of this paper is to investigate whether these findings carry over to another language with different morphological systems.

Comparable to the English past tense, German distinguishes between regular and irregular inflected forms in participle and plural formation. There are, however, much less regularly inflected forms in German than in English, and in con-

trast to English both regular and irregular forms have separable endings (Clahsen 1999). Regular participles are inflected with *-t* (*gelacht* 'laughed'), whereas irregular participles take the ending *-n* (*gelaufen* 'run'). For German plural formation the situation is more complex. Yet, most researchers agree that noun plurals on *-s* are regular (*Autos* 'cars'), whereas plurals on *-er* (*Kinder* 'children') and *-n*-plurals on masculine/neuter nouns not ending in 'e' in the singular (henceforth *-n<sup>masc.</sup>*) are irregular (*Muskeln* 'muscles') (e.g., Clahsen, 1999, and subsequent discussions).

## METHOD

We elicited regular and irregular noun plurals and participles from 2 German subjects who were diagnosed with WS (C. age 15, and M. age 18). Medical and (neuro)-psychological testing was performed by a team of pediatricians and psychologists in a specialized children's hospital and revealed typical physical and cognitive characteristics of WS for both subjects (see Gosch & Pankau, 1996). Intelligence testing (HAWIK-R) gave IQ values of less than 44 for C. and 53 for M. To take the dissociation between impaired nonlinguistic skills and spared linguistic skills into account, we determined mental age on the basis of the verbal IQ values. This resulted in a mental age of 6;5 years for C. and 8;3 years for M. A group of 10 unimpaired children matching in mental age (5 children: age 6;1–6;11, Ø 6;5, 5 children: age 7;9–8;3, Ø 8;1) served as controls.

Subjects had to transform (i) a given 1.pers./sg./present form into a participle, or (ii) a singular noun into its plural form. We elicited 23 regular and 26 irregular participles as well as 20 plural forms each for the regular *-s*-plural, and the irregular plurals on *-er* and *-n<sup>masc.</sup>*. As both WS children showed the same pattern of results (see Appendix), we present collapsed data for WS children and for controls.

## RESULTS

Like Clahsen and Almazan, we find that regular participle formation is intact and correctness scores are the same as those for controls (98% WS, 97% controls,  $\chi^2$  ns). In contrast to the English data, however, both WS and control children achieve relatively low correctness scores for irregular participles (62% WS, 68% controls,  $\chi^2$  ns). A clear difference between WS and control children, however, emerges when we consider frequent and infrequent irregular participles separately. Unimpaired children are known to overregularize infrequent irregular forms; i.e., they produce the regularized form *gelauft* instead of the correct *gelaufen* (Clahsen, 1999). In fact, 84% of the controls' errors with irregular participles are overregularizations of infrequent verbs. In contrast, in WS children, 40% of errors with irregular participles result in overregularizations of frequent verbs. This difference in the frequency distribution of errors between WS and control children is significant ( $\chi^2 p < .05$ ). Thus, while the control children's overall low correctness score for irregular participles might be due to the relatively high number of infrequent participles included in our study, the results for frequent irregular participles clearly reveal a deficit with irregular inflection for WS.

The results on participles are confirmed by the data on plural formation. For the regular *-s*-plural, there is no significant difference in the correctness scores for WS subjects and controls (83% WS, 74% controls). In contrast, correctness scores for

the irregular *-er* and *-n<sup>masc.</sup>*-plurals are significantly lower for WS children compared to controls (67% WS, 80% controls,  $\chi^2 p < .05$ ). Moreover, WS children rarely apply the irregular pattern to produce plural forms: only 3% of their errors are overirregularizations of *-er* and *-n*, compared to 17% for the controls ( $\chi^2 p < .05$ ). The relatively high error rate for irregular plural forms and the low rate of overirregularizations, provide converging evidence for an impairment of irregular inflection.

## DISCUSSION

Summarizing, our data show that the findings of Clahsen and Almazan can be transferred to German despite the differences in morphological systems. Our 2 German WS subjects, as well as the English subjects of Clahsen and Almazan, show selective deficits with irregular inflection, while regular inflection is unimpaired.

Adopting a broader perspective, this selective deficit casts some light on the current debate between the associative single-mechanism approach to language adopted in connectionism and the dualistic approach, which assumes a computational component besides a lexicon of stored forms (see Pinker, 1999; Clahsen, 1999). Dualistic models of language propose two qualitatively different cognitive operations underlying regular and irregular inflection: whereas irregular forms are stored fully inflected in an associative memory, regular forms are built by rule-based affixation. Seen against this debate, the selective deficit with irregular inflection found in WS confirms a necessary prediction of dualistic models, i.e., that these two processes should be selectively disturbable by language disorders, and this therefore provides evidence for a qualitatively different representation of regular and irregular inflection as proposed in dualistic models of the language faculty.

## APPENDIX

TABLE 1

	<i>n</i>	∅ word-form frequency	Errors of WS subjects M. and C.
Participles			
infrequent regular	14	10,1	M: geheft
frequent regular	9	250	
infrequent irregular	12	10,2	C: gefecht <sup>t</sup> , geschweigt, geschwört, gestecht, getrügt, gewerbt M: gefecht <sup>t</sup> , geschwört, geschmelzt, getrügt, ewardt, geflecht
frequent irregular	14	342,6	C: gelest, gemesst, genehmt, gestreicht M: gelest, gemesst, geleidet, gestreicht
Noun plurals			
regular <i>-s</i> -plural	20	57,6	C: Zebra, Brikett, Ballon, Krimi M: Ballon, Schal, Opa
irregular plurals ( <i>-er</i> and <i>-n<sup>masc.</sup></i> )	40	56,6	C: Korns, Biest, Kraut, Gemache Nerve, Schmerze, Bauer, Hemde, Ohre, Fürst, Solist, Insekter, Fink, Dorne, Stachel M: Lamms, Kräute, Gemache, Neste, Munde, Hemd, Bauer, Fürste, Vetter, Insekt, Finke

Note. Frequency information based on the CELEX-database.

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## An Examination of the Lateralized Abstractive/Form Specific Model Using MiXeD-CaSe Primes

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CaSe AIteRnAtIoN effects on the two cerebral hemispheres were studied in a lateralized visual lexical decision task with 32 right-handed participants. The study aimed to compare two well-known lateralization theories, the two processing modes and the abstractive/form-specific theories, that differ in the predictions regarding case alternation effects on the hemispheres. The experiment employed the masked priming paradigm, where prime and target words were presented in mixed case. The results of the experiment demonstrated no hemispheric differences in priming size when prime and target were similar in (mixed) case, thus were in line with the two modes theory. However, a new interpretation to the abstractive/form-specific model may also account for the results. © 2002 Elsevier Science (USA)

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## INTRODUCTION

Previous lateralization studies have suggested two qualitatively different word processing modes in the two cerebral hemispheres (Ellis, Young, & Anderson, 1988; Young & Ellis, 1985). In general, it has been suggested that the Left Hemisphere (LH) processing of letters in strings is relatively insensitive to the number of letters in the string, whereas the right hemisphere (RH) is affected by string length. Thus, when Young and Ellis (1985) presented words in normal, horizontal format, recognition rates in the RH declined as the number of letters in the word increased. In contrast, performance in the LH was unaffected by word length. When the stimuli were invented nonwords rather than real words, performance was a function of word length in both visual hemifields, as it was when familiar words were presented in unusual formats (vertical or with ‘‘s<sup>t</sup>e<sup>p</sup>d’’ letters).

Besner (1983) and many others have used CaSe AlTeRnAtIoN to eliminate configurational features of the words. Assuming that MiXeD CaSe constitutes a manipulation that distorts the “normal” format of words (like vertical or stepped words), we would expect that case alternation will disrupt word recognition in the LH more than in the RH. This prediction is compatible with the lateralized two processing modes theory (Ellis et al., 1988) with the LH able to process letters in normally formatted words in parallel while the RH shows length sensitivity for all formats. Indeed when manipulating letter case and length in a lateralized lexical decision task (Lavidor & Ellis, in press) we found that with case alternated presentation, both visual hemifields were affected by word length, while for normal word formats (e.g., upper and lower cases), word length affected left visual field (LVF/RH) but not right visual field (RVF/LH) performance. Although both hemifields were affected by case alternation (the mixed case compared to lower or upper case), the cost was significantly larger for RVF stimuli (i.e., the left hemisphere). To the best of our knowledge, only one additional study manipulated letter case in a lateralized word recognition task (Fiset & Arguin, 1999). They also found a case alternation cost for response times and error rates, but only for LH stimuli.

These results do not support the hypothesis drawn by Marsolek, Kosslyn, and Squire (1992). They argued that LH visual word recognition is abstractive in nature. This means that the forms TABLE and table both converge upon the same abstract representation of ⟨table⟩, which serves to recognize the different forms of that word. In contrast, RH word recognition is more form-specific. The idea here is that TABLE and table are recognized by distinct operations that map between orthographic forms and meanings in the RH. Based on the abstractive (LH) and form-specific (RH) distinction, the disruption of the visual form of written stimuli (by using mixed-case) would be expected to have a greater effect on the right than on the left hemisphere.

Since the abstract/form-specific model has been tested and developed based on priming experiments only, it can be argued that the model does not predict effects of mixed-case on lateralized performance. In fact, mixed case was not used in the Marsolek and colleagues studies. While using different tasks, all studies had always a learning phase and a test phase. The primes were presented centrally, either in upper or lower case. In the test phase, targets were presented briefly to the left or right visual field, in upper or lower case. The general finding unifying these studies was that for compatible prime–target pairs (both in same case), priming was larger for the RH than for the LH, and the abstractive/form-specific theory was based on these findings. It may be argued that manipulating MiXeD case, as we did, cannot be directly predicted from Marsolek’s theory. A better replication would be therefore to use mixed-case in a priming paradigm, and that was done in the experiment reported here.

I used the masked-priming technique developed by Evett and Humphreys (1981). Many studies reported an automatic prelexical coding of orthographic information during visual word recognition when using visual masking procedures and very brief prime presentation duration. The advantage of this procedure for current purposes is that masked priming has been shown to be highly sensitive to overlap at the level of the word-form (Forster & Taft, 1994), but not to word-meaning. This suggests that masked priming may be well suited to our aim of detecting type of case effects at the level of form.

Two types of letter case were used: mixed such that the first letter was always in upper case (MiXeD), and mixed such that the first letter was always in a lower case (mIxEd). Target words could be primed with a relevant prime (identical word) or a nonrelevant prime (unrelated word). While prime stimuli were always centrally presented, target stimuli were lateralized to the right or left of a fixation point.

## METHOD

*Participants*

Thirty-two native English speaking, undergraduates served as participants for a course credit or £2 payment. They were between the ages of 18 and 28 (mean age 19.6, *SD* 1.7). All the subjects were right-handed and scored at least 70 on the Edinburgh test (Oldfield, 1971), mean score = 89. Fourteen were males, 18 were females.

*Stimuli*

One-hundred ninety-two English content words and 192 nonwords were used as target stimuli. All stimuli had 5 letters. The words were divided to 8 sets of 24 words in each set, for the different 8 experimental conditions: 2 priming conditions (prime, unrelated prime)  $\times$  2 visual field  $\times$  2 target–prime case compatibility (similar as in MiXeD–MiXeD or different as MiXeD–mIxEd). The 8 groups of words were matched for written frequency (frequency norms by Kucera & Francis, 1967, mean frequency = 19.1 per million), age of acquisition (Gilhooly & Logie, 1980, mean AoA = 368, from a 100–700 scale), imageability (Coltheart, 1981, mean = 483, from a 100–700 scale) and number of orthographic neighbours (Quinlan, 1993, mean = 4.9 neighbors). The nonwords were generated from another word pool of 5-letter words by changing one letter, such that the nonwords were pronounceable. Ninety-six additional 5-letter words and 96 different 5-letter nonwords served as the unrelated prime.

*Design*

Each subject was assigned to one of the 8 versions of the experiment. The different versions counter-balanced the 8 different experimental conditions and rotated the 8 word lists across the experimental conditions. The within subject factors were type of prime (related–unrelated), computability of prime–target letter-case (compatible or not), visual field (RVF, LVF), and target lexicality (word, nonword), each within subject combination was repeated 24 times, thus there were 384 trials per subject, and 36 additional trials served as practice trials.

*Procedure*

Stimulus presentation was controlled by an IBM Pentium computer with a 586 processor, using a 17" SVGA display. The participants sat at a viewing distance of 50 cm, with the head positioned on a chin rest. Each trial began with a row of 5 # symbols in the center of the screen for 500 ms (forward mask). The ##### then disappeared to allow the presentation of a prime word in center screen for 45 ms and then reappeared for 500 ms (backward mask). After that the target stimuli was presented for 180 ms 2.5° to the left or to the right of a central fixation point (LVF and RVF in accordance). After time limit of 1800 ms the series of forward mask–prime-backward mask and target repeated. Participants responded by pressing one of two available response keys, labeled “word” and “nonword.”

## RESULTS

*Response Times to Words*

A main effect for visual field [ $F(1, 31) = 14.3, p < .01$ ] was found. Performance to RVF words (mean = 573 ms) was significantly faster than to LVF stimuli (612 ms).

A main effect for prime type [ $F(2, 30) = 9.4, p < .01$ ] was found. Reaction times to primed targets with compatible case (550 ms) was significantly faster than to incompatible case (586 ms), and both were faster than to targets primed with unrelated primes (640 ms), as indicated by Scheffe post hoc analysis ( $p < .05$ ).

Target–prime compatibility and visual field did not interact significantly. For compatible prime–target case, prime was similar in size in both visual field (see Fig. 1).

### Accuracy

A main effect for prime type [ $F(2, 30) = 12.6, p < .01$ ] was found. Accuracy to primed targets with compatible case (89%) or incompatible case (87%) was significantly higher than to targets primed with unrelated primes (80%), as indicated by Scheffe post hoc analysis,  $p < .05$ .

*Response times to Nonwords.* No effects were found.

*Accuracy for Nonwords.* No effects were found.

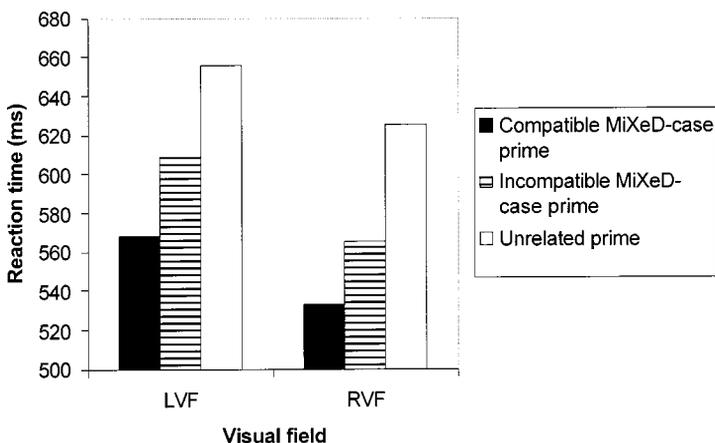
## DISCUSSION

The results of the experiment demonstrated clearly no hemispheric differences in priming size when prime and target are similar in (mixed) case, as was shown by Koivisto (1995). Koivisto (1995) repeated Marsolek et al. (1992) methods, but did not find hemispheric differences in prime size.

The lack of priming for nonwords targets are in accordance with previous experiments that reported repetition priming for words but not for nonwords (Rueckl, 1995). Although Masson and Isaak (1999) reported nonwords repetition priming, it was larger for words than for nonwords.

The consistent larger priming effect when target and prime were presented in the same letter case was found in both visual fields. If type face is decoded mainly in the right hemisphere (according to the abstractive/form specific model), than we should see larger prime effects in the LVF for compatible prime–target words. But we did not find such a pattern. Taken with previous results (Fiset & Arguin, 1999; Lavidor & Ellis, in press), there is no base to assume a form-specific decoding for words presented to the right hemisphere.

Recently Chiarello (in press) have suggested a new interpretation to the



**FIG. 1.** Mean reaction time to correct 5-letter words as a function of letter-case compatibility to prime and visual field.

abstractive/form-specific model (Marsolek et al., 1992). She suggested that words received by the LH very rapidly achieve deeper or more abstract encoding, while words received by the RH maintain and perhaps even amplify early encoding even when deeper level codes become available. Using her interpretation, it may be that words presented to the LH achieve a deeper encoding sooner than RH stimuli, but only if their format is standard. Distorted words (misoriented or made of mixed-case letters) are staying longer in the early encoding stages. This delayed stage is the routine process in the RH for all written stimuli. Thus for such words the prelexical processing stages are similar in both hemispheres. Hence we got the same compatibility priming effect for mixed case words in both visual fields. Further experiments are required to test this potentially interesting theory that may link the relatively old theory of the two processing modes (Ellis et al., 1988) with the more recent theories.

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## Category-Specific Naming and Modality-Specific Imagery

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Some attempts to explain category-specific disorders have stressed how different modality knowledge bases (i.e., visual knowledge vs motoric/functional knowledge) may underlie the distinction between living and nonliving things. This study examined 60 normal subjects for the relationship between picture naming in four subcategories (animals, fruit/vegetables, praxic and nonpraxic objects) and imagery vividness in seven modalities. Participants made more nonliving than living errors; and females made more nonliving errors than males. There was a significant correlation between naming of animals and fruits/vegetables and visual imagery vividness; however, this association was also significant for praxic and nonpraxic object naming. There was no evidence of associations between kinesthetic imagery and praxic object naming or gustatory/olfactory imagery and fruit/vegetable naming. These findings accord with the notion of a general association between visual imagery and picture naming, but provide no support for more specific links between modality-specific imagery vividness and naming in different categories. © 2002 Elsevier Science (USA)

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### INTRODUCTION

One group of explanations for category-specific disorders (see Warrington & McCarthy, 1987) suggests that different modality knowledge bases—important during concept acquisition and presumably maintenance—underlie the conceptual distinction between living and nonliving things (e.g., visual vs motoric/functional knowledge). Investigations of this model typically center upon testing whether patients show a disproportionate loss of visual knowledge in living thing cases or a disproportionate loss of functional knowledge in nonliving thing cases. The notion that various sense modalities play differential roles for different categories of item (e.g., taste for food, touch for tools, vision for animals) has strong intuitive appeal. Indeed, Tranel et al. (1997) obtained ratings from normal subjects for the extent to which different sensory modalities (vision, touch, and hearing) play a part in the experience of items from different categories. The results largely accord with the expected outcomes: tools and fruit/vegetables were significantly higher for touch than vehicles, musical instruments and animals; animals, tools, and fruits/vegetables were significantly higher on vision than musical instruments; musical instruments were high on hearing. For manipulability, musical instruments were higher than tools, which were higher than fruit/vegetables and animals. For characteristic motion, tools, music, and vehicles were higher than for animals, fruit/vegetables.

The current study examined the relationship between self-reported vividness of imagery in seven different modalities and picture naming for living and nonliving things. Given the explanations of category specific disorders outlined above, several predictions might be made, including associations between (a) visual imagery vividness and living thing naming; (b) kinesthetic imagery and naming of nonliving things (especially praxic items); and (c) gustatory and olfactory imagery with fruit and vegetable naming

### SUBJECTS

Sixty normal subjects (30 males and 30 females: age range 18–40 years) participated in the study. All had normal or corrected-to-normal vision and none had previously seen the pictures.

## STIMULI AND PROCEDURE

Participants were presented with 120 color photographs/drawings from the Category Specific Names Test (McKenna & Parry, 1994): comprising 30 fruits and vegetables; 30 animals; 30 praxic (objects with a specific associated action, e.g., darts); and 30 nonpraxic objects (objects with no specific associated action, e.g., calendar). The pictures in each category are presented in terms of normative naming difficulty and are matched across category for conceptual familiarity.

Participants also completed Sheehan's (1967) shortened (35-item) version of Bett's Questionnaire upon Mental Imagery (QMI). Subjects are asked to rate the vividness of images brought to mind by descriptions. Ratings on a seven-point likert type scale (1 = perfectly clear and as vivid as the actual experience, through to 7 = no image present at all, you only know that you are thinking of the object) are obtained for five descriptions in each of seven modalities:

- *Visual* [e.g., the sun is sinking below the horizon]
- *Auditory* [e.g., the clapping of hands in applause]
- *Cutaneous* [e.g., the feeling of fur]
- *Kinesthetic* [e.g., running upstairs]
- *Gustatory* [e.g., taste of salt]
- *Olfactory* [e.g., smell of fresh paint]
- *Organic* [e.g., bodily sensations such as a feeling of drowsiness, hunger]

## RESULTS

### *Picture Naming*

Four subjects with outlying poor naming performance were removed from the analyses (they were more than 3 standard deviations below the sample). A two-way ANOVA revealed significantly better naming of living than nonliving things ( $F = 192.78$ , [1, 54],  $p < .000$ ), no main effect for gender ( $F = 1.58$ , [1, 54],  $p = .21$ ), but an interaction between category and gender ( $F = 27.48$ , [1, 54],  $p < .000$ ). *Post hoc* analyses for the four subcategories revealed that female subjects named significantly more fruits and vegetables than males ( $F = 14.85$ , [1, 54],  $p < .000$ ); no other subcategory reached significance.

### *Imagery*

ANOVAs revealed no gender differences across any of the seven imagery modalities.

### *Relationship between Imagery and Naming*

Correlations were derived between naming for all subcategories and all imagery modalities (see Table 1).

TABLE 1  
Significant Correlations between Picture  
Naming and Imagery Vividness

Animals	Visual ( $r = -.34$ , $p = .01$ )
Fruits	Visual ( $r = -.47$ , $p = .000$ )
Praxic	Visual ( $r = -.35$ , $p = .007$ )
Nonpraxic	Visual ( $r = -.42$ , $p = .002$ )

## DISCUSSION

Normal subjects showed better naming of living than nonliving things, and female subjects showed better naming of living things (especially, fruits/vegetables) than males. Both findings accord with recent studies that have used different stimuli and presentation paradigms (Laws, 2000; Laws, 1999; Laws & Neve, 1999; Laws, in press). The gender-by-category interaction accords with gender stereotypical notions and may reflect differences in the experience, and hence familiarity, that males and females have with items in different subcategories (Albanese et al., 2000; Capitani et al., 2000; Laws, 2000; Laws, 1999; Laws, in press). Certainly, the interaction was not underpinned by any imagery-related gender differences.

Turning to the hypotheses about specific image modality-by-category naming associations, animal naming and visual imagery vividness were significantly correlated; however, visual imagery vividness correlated significantly with all four naming subcategories. Furthermore, no other imagery modality correlated with naming in any category. Hence, this study does not support specific image-modality by naming associations. Rather it accords with the notion that modality-specific visual representations are most strongly related to object recognition and naming (see Farah, 2000) and that this occurs regardless of item category.

Of course, these results do not alter the fact that some items will elicit responses in multiple sensory systems (possibly all including visual modality) and that normal subjects may rate items in this manner (see Tranel et al., 1997). Nevertheless, it seems that only individual differences in *visual* imagery vividness are predictive of actual naming performance.

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## Visual Similarity is Greater for Line Drawings of Nonliving Than Living Things: The Importance of Musical Instruments and Body Parts

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It has been argued that greater intra-category structural similarity for living things, and the subsequent “visual crowding,” makes them more difficult to recognize and name for neurologically damaged individuals and normal subjects (Humphreys et al., 1988). Nevertheless, the precise meaning and quantification of structural similarity remains unclear, as does the rationale for why it necessarily should be greater for living things. We derived a new measure of visual overlap from the Snodgrass and Vanderwart corpus of line drawings: the degree of pixel overlap within subcategories (Euclidean distance: ED). Contrary to existing notions of visual crowding and extant measures of contour overlap, within-category ED indicated less within-category visual overlap for living things. Furthermore, musical instruments clustered with living things (having low overlap), while body parts clustered with nonliving things (having high overlap). These counter-intuitive findings accord with patient data and thus, provide evidence for the psychological reality and utility of ED. © 2002 Elsevier Science (USA)

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### INTRODUCTION

It has been proposed that living things (e.g. animals, fruits) have greater intra-category structural similarity or visual overlap than nonliving things (e.g., tools, vehicles); and that this visual crowding within-category makes them more difficult to name and discriminate for neurologically damaged individuals, normal subjects, and even monkeys (Humphreys, Riddoch, & Quinlan, 1988; Gaffan & Heywood, 1993).

In an attempt to quantify an aspect of this, Humphreys et al. (1988) developed a measure of contour overlap (CO) for subcategories (e.g., animals, clothing) of items from the Snodgrass and Vanderwart (1980) corpus of line drawings. CO was derived by overlaying a grid on each item with every other item (from the same subcategory) and then calculating the average overlap as a function of the amount of contour in each picture—overlap appears to have been matched at a gross visible level. They found that contour overlap (and hence structural similarity) was greater for living than nonliving things; and argued that this “structural similarity” may underlie category-specific problems with living things.

Although Humphreys and Forde (in press) refer to CO as an “approximate measure of the similarities of the perceptual structure of objects within their categories,” it is not obvious how or why gross contour overlap alone more accurately represents structural similarity than total overlap, i.e., including internal details as well as contour. We therefore developed a measure of the total visual overlap (at pixel level) for each item with every other item within its subcategory (from the Snodgrass and Vanderwart corpus). This resulting measure of Euclidean Distance (ED) was examined to determine whether living things have greater visual overlap than nonliving things when total overlap is considered (rather than just contour overlap). It was hypothesized that ED would provide a precise measure of visual overlap between any two items: a measure of visual prototypicality, where items with lower mean EDs were more typical members of their category; and the standard deviation for an item would provide information about its relationship with other items in the comparison group.

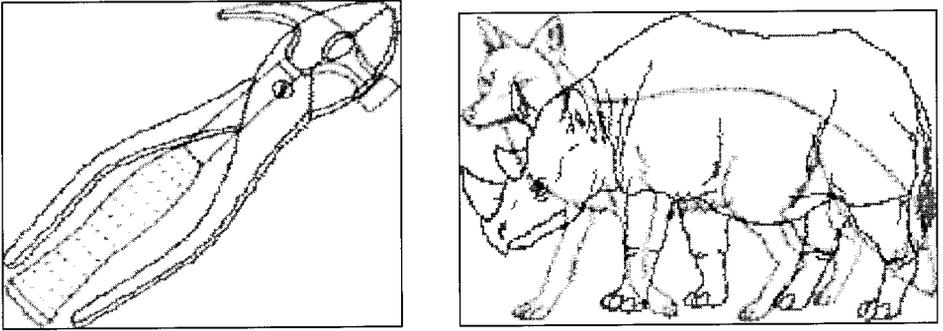


FIG. 1. Examples of overlapping figures in a nonliving (tools) and living (animals) subcategory.

## METHOD

The stimuli were digitized versions of 254 images from the Snodgrass and Vanderwart (1980) line drawing corpus, scanned at a resolution of 72 dpi from the source pictures. The images were standardized for size such that the maximal dimension of each image fitted exactly within a 256 by 256 pixel grid; they were not standardized for orientation since most studies use the images in their standard presentation. The images were stored in *binary* bitmap format such that pixels could be either white (0) or black (1).

## CALCULATING EUCLIDEAN DISTANCE (ED)

The Euclidean Distance between any two pictures was calculated by comparing the value of each pixel and then subtracting the value in the first picture from that of the second. The difference value was then squared and summed for all pixels in the array. The ED between the two pictures is the square root of the sum of squared differences (see Fig. 1). Within-category mean and standard deviation ED values were calculated for items in 6 living and 5 nonliving subcategories: animals, insects, birds, body-parts, fruit, vegetables, furniture, vehicles, musical instruments, tools, clothing (as defined by Snodgrass and Vanderwart).

## RESULTS

ED correlated significantly with visual complexity ( $r = .52$ ), i.e., as within-category similarity increases, visual complexity decreases. CO did not correlate with ED ( $r = .043$ ) or with visual complexity ( $r = .003$ ).

Although ED did not significantly differ across living and nonliving things ( $t = -1.6$ ,  $df = 130$ ,  $p = .11$ : mean = 12.01 [ $SD = 1.43$ ] vs 11.85 [ $SD = 1.71$ ]), a second analysis after removing body parts and musical instruments (which are known to be unusual categories within the living and nonliving domains) revealed significantly greater ED for living than nonliving things ( $t = 3.9$  [ $df = 118$ ]  $p < .000$ : 12.3 [ $SD = 1.17$ ] vs 11.41 [ $SD = 1.39$ ]). Moreover, these subcategories were unusual on the dimension of ED (see Fig. 2), i.e., musical instruments clustering with living things (having low overlap) and body-parts with nonliving things (having low overlap). By contrast, these two subcategories were both low in contour overlap.

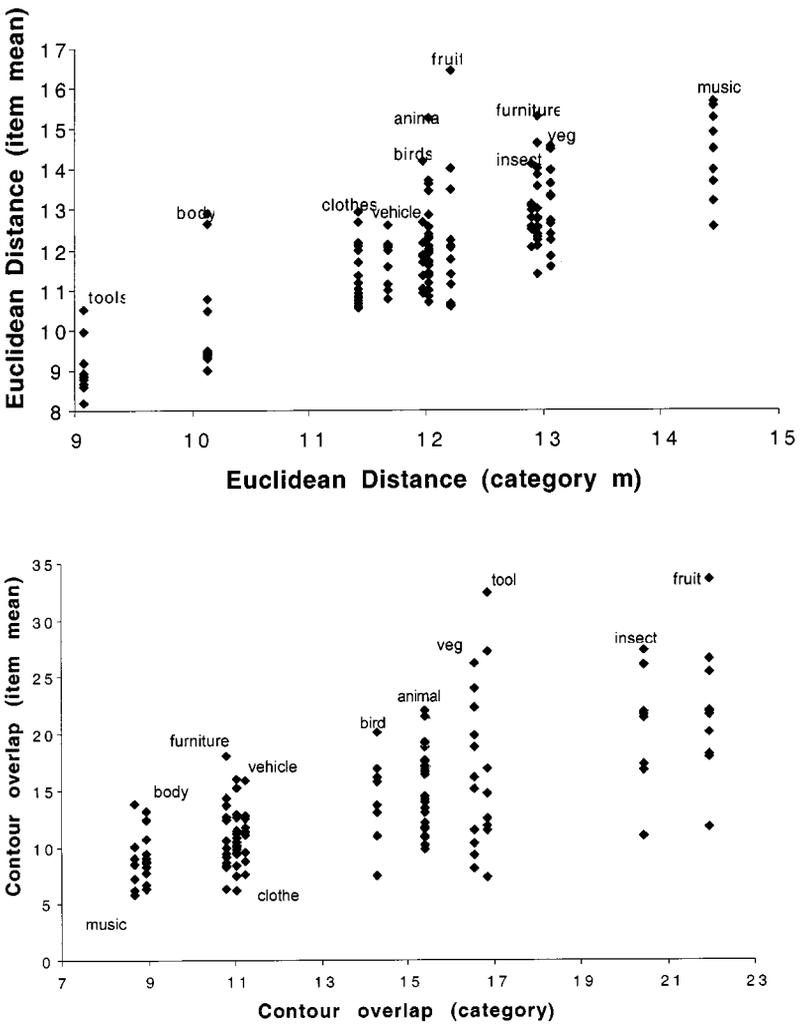


FIG. 2. Mean values for subcategories plotted against item values for Euclidean Distance and Contour Overlap.

## DISCUSSION

A novel measure (ED) reflecting visual characteristics of the Snodgrass and Vandervort corpus of line drawings was devised. Contrary to existing accounts of visual similarity/crowding and the measure of contour overlap (Humphreys et al., 1988; Gaffan & Heywood, 1993), ED shows that nonliving things have greater within-category visual similarity than living things. Indeed, ED was unrelated to contour overlap. The mean within-category ED for each subcategory clearly differentiated those items associated with nonliving thing disorders (having lower ED) from those associated with living thing disorders (having higher ED)<sup>1</sup>; this included musical instruments and body parts being located among living and nonliving things, respectively. Hence, these line drawings may be categorically separated at a low level of visual analysis that corresponds with the data from category-specific patients.

The pattern of results reported here are dependent upon the specific properties of

<sup>1</sup> One exception was 'furniture' which clustered among the living categories.

the Snodgrass and Vanderwart corpus, and we would not want to suggest that these data reflect actual properties of the referent objects. Nonetheless, most investigations of category-specific deficits have utilized this corpus and so, the results have implications for the factors that purportedly contribute toward emergent category effects. For example, they might be viewed as consistent with recent findings that normal subjects have better naming of living than nonliving things from this corpus (Laws & Neve, 1999; Laws, 1999; Laws, 2000).

One intriguing result from the analysis of ED, was that body parts and musical instruments were visually discriminable from all other subcategories (see Fig. 2); with body parts (and tools) having the greatest visual overlap and musical instruments the least. Moreover, body parts were closer in values to nonliving things, while musical instruments were closer in values to living things. This finding accords with the counter-intuitive patterns in patient data, both for living and nonliving thing cases, i.e., that musical instruments tend to be impaired along with living things and body parts with nonliving things; this finding adds weight to the psychological reality and potential utility of the measures developed here. In contrast, CO was lowest for musical instruments (8.69) and body parts (8.95). Within the model suggested by Humphreys and colleagues, living thing deficits reflect their having greater structural similarity and while this might account for why body parts are typically intact in patients with living thing disorders, it cannot incorporate the fact that musical instruments are often impaired since CO predicts they should remain unimpaired.

## ACKNOWLEDGMENTS

The ED ratings are available from the authors on request. We thank Professor Glyn Humphreys for generously providing us with the “contour overlap” rating.

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## Coherence of Hemispheric Function in Developmental Dyslexia

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Left parieto-occipital EEG leads record a frequency spectrum in dyslexics that is consistently different from the spectrum obtained from normals. It is suggested that these effects represent significant differences in the functional organization of these areas. EEG coherence values indicate that normals have significantly greater sharing between hemispheres at symmetrical locations. Dyslexics demonstrate significantly greater sharing within hemisphere than do normals. The data supports developmental dyslexia being a functional hemispheric disconnection syndrome. © 2002 Elsevier Science (USA)

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### INTRODUCTION

The nature of reading disability has been one of the most difficult and puzzling problems facing psychologists. Reading is a process requiring both linguistic and visual perceptual processing which are abilities normally attributed to control by different cerebral hemispheres (Leisman, 1976, 1978; Leisman & Schwartz, 1976, 1977; Leisman & Ashkenazi, 1980). The development of noninvasive techniques with which to study hemispheric specialization, while yielding considerable knowledge about hemispheric function and organization has, unfortunately provided conflicting knowledge of hemispheric processing in dyslexia.

The literature on cerebral asymmetry and reading disability has almost exclusively concentrated on the poor performance in the left hemispheres of poor readers although there is an understated implication of superior right hemisphere performance by the reading disabled. Marcel and Rajan (1975) among others report that poor readers are less lateralized for verbal material than good readers and showed poor performance in the left hemisphere on word recognition tasks. Neurophysiological studies have made an association between developmental reading problems and reduced or delayed left hemisphere specialization for language processing (Galaburda, Menard, & Rosen, 1994; Kusch et al., 1993; Leisman & Ashkenazi, 1980; Leisman & Zenhausern, 1982; Tallal & Katz, 1989; Hynd & Symrond-Cliekeman, 1989; Hynd et al., 1990; Larsen et al., 1990).

Post-mortem examinations have also indicated structural differences between the brains of good and impaired readers most evidenced in the planum temporale region (Galaburda et al., 1985; Kaufman & Galaburda, 1989; Duane 1989). These microdysgeneses seriously impair the normal pattern of architecture of dyslexics and remove the asymmetry normally observed between the enlarged language areas of the left temporoparietal region and the smaller homologous areas of the right hemisphere (Galaburda et al., 1985). The capacity for language is generally correlated with a significant development in the magnitude of the left temporoparietal region and an attrition of neurons in the right hemisphere. These neuronal casualties may produce the observed asymmetry between corresponding areas in the left and right hemispheres (Geschwind & Levitsky, 1968). The relative symmetry in the dyslexics' brains might reflect their impaired linguistic development.

Sandra Witelson (1976, 1977) contended that spatial form perception is bilaterally represented. This she concluded based on a lack of performance asymmetry among dyslexic boys on a dihaptic shapes perception test. This hypothesis was supported

by similar differences between dyslexic and normal boys on a spatial task in the visual modality (tachistoscopic presentation of human figures). Again, the lack of left visual field superiority in dyslexic boys suggested to Witelson the bilateral representation of spatial perception and processing in dyslexia. The present studies attempt to examine the nature of hemispheric interaction in dyslexia employing electrophysiologic means.

## METHOD

### *Subjects*

Twenty dyslexics between 7 and 10.9 years of age, and ( $X = 7.6$ ;  $SD = 1.8$ ; 19 boys, 1 girl) were selected. The dyslexic subjects attended the Institute for Learning Development at the Eye Institute of New Jersey. The dyslexics were those whose full-scale WISC-R IQs ranged between 90 and 124 ( $X = 104.23$ ;  $SD = 7.54$ ); Verbal I.Q. scores ranged between 96 and 116 ( $X = 98.28$ ;  $SD = 7.24$ ); Performance I.Q. scores ranged between 89 and 134 ( $X = 104.41$ ;  $SD = 8.76$ ). Each subject demonstrated one of Boder's (1973) subtypes and had better than 20/30 Snellen acuity as well as no evidence of ocular pathology or eye movement abnormality. None of the subjects demonstrated mental retardation, cerebral palsy, or other overt neurological signs. Each of the subjects was two or more years deficient in reading ability in relation to mental age (on Stanford Achievement or Spache Reading Tests). In addition, each subject was administered Denkla and Rudel's (1976) tests of rapid automatized naming of colors, objects, numbers, and letters.

A second group of twenty normal subjects were also selected (7 to 11.11 years of age;  $X = 8.2$  years;  $SD = 2.3$ ; 16 male, 4 female). Each of the subjects read at grade level or better and demonstrated WISC-R full scale IQs ranging from 90 to 128 ( $X = 103.9$ ;  $SD = 8.01$ ); verbal range 88 to 131 ( $X = 101.69$ ;  $SD = 6.98$ ); performance range 84–117 ( $X = 98.47$ ;  $SD = 9.24$ ). None of the subjects demonstrated evidence of overt neurologic, ocular-pathologic, or eye movement disorder. Denkla and Rudel's (1976) tests were administered.

### *Procedure*

EEG was recorded from each of the subjects employing the 10-20 montage and ordinary silver/silver chloride skin electrodes. The data were subjected to and subjected to time series, cross series spectral estimation, and coherence analyses to determine the amount of sharing between two wave trains (Bendat & Piersol, 1971; Leisman & Ashkenazi, 1980).

The EEG activity was recorded under each of the following experimental conditions: rest-eyes closed and rest-eyes open while undergoing continuous performance tests (Leisman, 1973, 1974). Recordings were also obtained as subjects viewed projected items from the Stanford-Binet in which latencies for confrontation naming were also recorded (Leisman & Ashkenazi, 1980) and while subjects were also presented with grade appropriate paragraphs from the Spache Tests (1966) Diagnostic Reading Tests.

The EEG was recorded on an eight channel Grass model 7 polygraph (T.C. = 0.15 Hz. Filters out,  $50 \mu V = 5 \text{ mm}$ ). The raw EEG was stored on a Hewlett-Packard 1330A instrumentation tape recorder and was simultaneously A-D converted and ultimately processed by BMDX92 and BMD07M programs (Dixon, 1970). The EEG analyses were performed over 20 epochs of 5 sec each which were set by means of

a pulse delivered by a Digitimer signal generator. The sampling rate was set at 256 samples/s. The effective bandwidth of what turned out to be the critical P<sub>3</sub>-O<sub>1</sub>/P<sub>4</sub>-O<sub>2</sub> electrode monitored frequencies was 0.5 Hz and the power was computed logarithmically (0 db = 0.06 μV<sup>2</sup>/Hz) with the 0.05 confidence limit being 0.22 dB. Statistical tests for uncorrelated EEG data were also applied.

For coherences, the Z-transformed values of 2.0 corresponded to a coherence of 0.96 with the 0.05 confidence on this scale being approximately 0.4. The computer program read the power spectral density (PSD) values over frequency bands 0–32 Hz in steps of 1 Hz; computed statistically standardized normal distributions for a frequency spectrum of interest. Then a frequency associated with each PSD value was computed utilizing

$$F_k = BW/4|(k - 1) \leftrightarrow BW/2 \quad (1)$$

$$k = 1, 2, \dots N$$

where  $F_k$  is the associated frequency;  $BW$  is the bandwidth utilized in computation of PSD values. The value  $BW$  was obtained from the header record on the PSD tape;  $N$  is the number of PSD values contained in the data file. The frequency values were computed in a programmed iteration in which  $k$  varied from 1 to  $N$  in integer steps and computed frequency values were then stored in an array. To determine the amount of power at any frequency, the input PSD values were converted to power values of volts<sup>2</sup>. Computation of power utilized

$$P_k = \text{PSD}_k \leftrightarrow \Delta f_k \quad k = 1, 2, \dots N \quad (2)$$

where  $P_k$  is the power in volts<sup>2</sup>;  $\text{PSD}_k$  are the PSD values in volts<sup>2</sup>/unit bandwidth  $\Delta f = BW/2$  (Eq. (1)). Following the computation of the power values, a subroutine averaged the power values over selected frequency bands in

$$\bar{P}_k = \sum_{i=1/n}^m P_i \quad k = 1, 2, \dots L \quad (3)$$

where

- $P_k$  = average power in volts<sup>2</sup>
- $P_i$  = power values in selected band
- $i = 1, 2, \dots m$
- $n$  = number of power values in selected band
- $L$  = number of bands selected

The final calculations performed were the standard deviation calculations from 1 to  $L$  bands. To calculate the standard deviation of each band, we used

$$\sigma_k = \sum_{i=1}^N P_i^2 - (N \leftrightarrow \bar{P}_k^2) \quad k = 1, 2, \dots L \quad (4)$$

where  $\sigma_k$  is the standard deviation;  $P_i$  are the power values in the selected band;  $N$  is the number of power values in the selected band;  $\bar{P}$  is the average power in the selected band.

A standardized normal distribution computation (Bendat & Piersol, 1971) was used to accomplish a test of uncorrelated data,

$$D = N_f \frac{-2}{n_1} \left| \frac{2}{n_2} \sqrt{\frac{1}{2}} \right| \log_{10} \frac{\hat{G}_1(f_i)}{\hat{G}_2(f_i)} \quad (5)$$

where  $D$  is the standardized normal distribution;  $N = BW/B_e$ ;  $BW$  is the bandwidth in Hz (Eq. (1));  $B_e$  is the resolution bandwidth (i.e., spectrum of interest) input via program header;  $n_1$  is the number of PSD values in the numerator time epoch;  $n_2$  is the number of PSD values in the denominator time epoch  $G_1 =$  PSD values in the numerator time epoch;  $G_2 =$  PSD values in the denominator time epoch. The statistic  $D$  has a standardized normal distribution,  $Z$ . That is,  $D = y(0, 1) = Z$ . The region of acceptance for the hypothesis that  $G_1(f) = G_2(f)$  is  $(-Z_{\alpha/2} \leq D \leq Z_{\alpha/2})$  where  $\alpha$  is the level of significance of the test.

## RESULTS

The program selected the autospectral density pattern over the left parieto-occipital region ( $P_3-O_1$ ) as the most consistent discriminating feature between dyslexic and normals under the rest-eyes closed condition ( $F(8, 19) = 3.75, p < .01$ ). None of Boder's (1973) clinical subtypes demonstrated any significant difference in EEG spectral data under any condition ( $p < .10$ ). The dyslexic data were, therefore pooled in this respect.

The analyses provided quantitative data concerning the maximum and average power in the dominant frequencies, their bandwidths, the values of their coherences, and the left-right asymmetries (cf. Table 1). Dyslexics (Fig. 1) demonstrated greater energy in the 3–7 Hz bands and in the 16–28 Hz bands than did normals with peaks appearing at around 6, 10, 17, and 24 Hz. Normals, on the other hand, demonstrated greater energy in the 9–12 Hz band than did dyslexics with a well developed peak in the alpha band at around 10 Hz. Simple effects and the Neuman-Keuls tests revealed no significant differences between groups by task ( $p < .10$ ) other than the data obtained under the rest-eyes closed condition at the  $P_3-O_1$  locations. The between groups frequency spectrum differences noted suggest that the functional organization of the parieto-occipital regions is different in dyslexics than in normals.

The coherence values (Table 1) demonstrated that the normals have greater shared activity *between* hemispheres at symmetrical locations whereas dyslexics demonstrate greater coherence *within* the same hemisphere during all tasks, but especially during the rest-eyes closed condition over  $P_3-O_1$  locations ( $F(8, 19) = 3.67, p < .01$ ). The diagonal coherences between hemispheres and sensory cortical areas other than parieto-occipital regions did not significantly differ ( $p < .10$ ) for or between normals and dyslexics. For normals, the largest coherences occurred between homologous leads over each hemisphere. Intrahemispheric coherences were largest for dyslexics over the left hemisphere under rest-eyes closed conditions, but not for dyslexics. In only 2 of the 20 dyslexic records was bilateral coherence present, with the coherence at a given frequency being less than that of the background activity.

There were also indications that the spectral EEG differences found between normals and dyslexics persist into adolescence and adulthood although there may be some degree of behavioral improvement (Fig. 2).

While Boder (1973) and Mattis et al. (1975) among others have reported on different forms that dyslexia may manifest, no significant differences were noted between

TABLE 1

Average Frequency (in Hz), Power (in dB), Left-Right Asymmetry of Power (in dB) between Hemisphere and within Hemisphere Coherence Values at P<sub>3</sub>-O<sub>1</sub>/P<sub>4</sub>-O<sub>2</sub> Locations for Dyslexics and Normals

S	Dyslexic					Normal				
	Freq. (Hz)	Power (dB)	L-R (dB)	Bilat. coher.	W/in coher.	Freq. (Hz)	Power (dB)	L-R (dB)	Bilat. coher.	W/in coher.
1	09.2	12	-03	—	1.1	09.2	28	—	—	0.8
2	10.4	21	-04	—	1.8	10.8	24	—	2.4	—
3	11.7	22	10	—	2.4	12.7	18	—	1.9	—
4	09.8	18	04	—	1.6	10.9	20	-4	1.3	—
5	10.8	17	03	—	1.4	08.6	16	—	1.9	—
6	10.6	24	-01	—	0.8	08.9	08	—	1.8	—
7	10.6	28	-05	—	1.5	11.2	11	—	2.4	—
8	11.2	12	-07	—	2.1	11.7	13	-2	1.5	1.8
9	12.0	19	-04	—	1.9	10.0	12	—	1.3	—
10	09.8	14	—	0.7	0.6	10.7	15	-1	1.3	0.9
11	10.8	25	-02	—	1.0	10.6	11	—	1.2	1.4
12	11.7	22	—	1.0	—	12.0	09	—	0.8	1.1
13	08.7	13	-01	—	0.9	11.7	07	—	1.0	—
14	09.0	27	08	—	2.1	08.9	11	—	1.9	—
15	10.7	13	-04	—	2.4	09.5	10	—	1.7	0.6
16	10.3	08	-06	—	1.8	08.8	11	-2	2.1	—
17	09.5	22	-07	—	2.0	08.6	14	—	1.4	—
18	12.2	20	-07	—	1.9	09.3	09	—	1.8	—
19	11.9	09	-01	—	0.9	12.4	12	—	1.9	—
20	08.4	15	-04	—	1.6	11.6	10	—	0.9	—

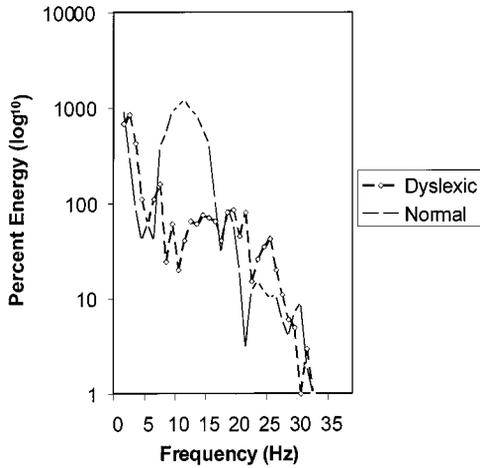
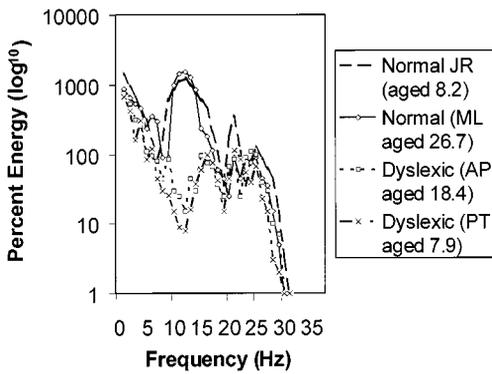


FIG. 1. Mean values of EEG autospectral density by frequency recorded from P<sub>3</sub>-O<sub>1</sub> electrode placements for normal and dyslexic subjects.



**FIG. 2.** EEG autospectral density for normal subject J.R. (aged 8.2 years), dyslexic subject A.P. (aged 18.4 years), dyslexic subject P.T. (aged 7.9 years), and normal subject M.L. (aged 26.7 years), recorded from  $P_3-O_1$  electrode placements.

dyslexics subtypes in the spectral EEG data although collectively, all the dyslexics were significantly different from the normals.

## DISCUSSION

The left parieto-occipital leads produced a frequency spectrum in the dyslexic, that appears consistently different from the data obtained from normals. This suggests that the functional organization of this area may be different in dyslexics than in normals.

The coherence values indicated that normals had greater shared activity *between* hemispheres at symmetrical locations, but significantly at the  $P_3-O_1/P_4-O_2$  locations and the dyslexics demonstrated greater coherence *within* the same hemisphere during all tasks, but significantly during the rest-eyes closed situation and at the  $P_3-O_1$  location.

The data becomes more impressive when taken in the light of Witelson's (1977) thoughts on the equivalence of the two cerebral hemispheres in dyslexia. One can, therefore, say that normals seem to have greater sharing (perhaps communication) between the two cerebral hemispheres and that dyslexics lack this sharing. One might explain the phenomena in terms of the master-slave relationship between the left and right hemispheres and that, the right is "slaved" to the left with respect to language. Dyslexia may be the result of objection to that slavery.

## ACKNOWLEDGMENT

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## Involvement of the Medial Prefrontal Cortex in Two Alternation Tasks Using Different Environments

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Spatial alternation performance in rats is usually evaluated with the T-Maze. The first aim of this study was to analyze the effect of a selective lesion of medial prefrontal cortex (mPFC) on performance in a T-maze. Second, we wanted to validate a new test using alternation in a water maze (AWM). The mPFC of 21 male Sprague–Dawley rats was lesioned bilaterally using *in situ* microinjection of ibotenic acid. Thirteen control rats received injections of the vehicle only. Results show that mPFC lesioned rats were significantly impaired in the T-Maze as well as in the AWM compared to controls. These results validate the AWM as a frontal cortex dependent task probing working memory and/or behavioral flexibility. We suggest that the AWM may be more powerful than the T-maze as an investigational tool, given that it can be easily compared to other water maze tasks that evaluate other (nonfrontal) cognitive modules. © 2002 Elsevier Science (USA)

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### INTRODUCTION

The medial prefrontal cortex (mPFC) is implicated in various emotional processes and in cognitive functions (Kolb, 1990). Evidence also shows that mPFC is involved in alternation behavior in humans (Verin et al., 1996) as well as in rats (Divac et al., 1975, Granon et al., 1994). In animal studies, the classical procedure used to test alternation is the T-Maze (Divac et al., 1975; Kolb, 1990), even though other procedures are used such as delayed nonmatching to sample tests (Granon et al., 1994). The two main purposes of the present report were to analyze the effects of mPFC lesions on T-maze performance and to validate the frontal dependence of a water maze version of the alternation task.

### MATERIAL AND METHODS

#### *Animals*

Thirty-five young male Sprague–Dawley rats (350–400 g) were used in this study. Animals were divided into two main groups; 13 of them were sham-operated and the 22 others were mPFC lesioned with bilateral microinjections of ibotenic acid.

#### *Lesioning Techniques*

Rats received atropine methylnitrate (0.4 mg/kg, i.p.) and were anesthetized 10 min later using halothane ventilation (1.5% in O<sub>2</sub>). They were then placed in a stereotaxic frame and a midsagittal incision was made. The coordinates of bregma and lambda were measured according to Paxinos and Watson (1986). A small surface of cranial bone was removed (AP = 1.5 to 5.0, L = ± 1.0 from midline). Ibotenic acid was injected under micromanipulation control, using a glass micropipette with the tip broken down to 80–100 µm and lowered into the mPFC according to the following skull-level coordinates: AP = 3.0, 3.75, 4.5 mm posterior to bregma, L = ± 0.5 mm from midsagittal sinus, DV = 4.5, 5.0 mm below cortex (Paxinos and Watson, 1986) for a total of six injection sites, three into each hemisphere. A polyethylene

tubing linked the pipette to a 5  $\mu$ l Hamilton microsyringe. The rate of infusion was 1  $\mu$ l/6 min. The pipette was moved up by 0.5 mm after injection of 0.5  $\mu$ l (or 3 min) and left there for one minute for diffusion away from the tip of the pipette (Dewar et al., 1997).

Twenty-two rats received ibotenic acid (2  $\mu$ g/ $\mu$ l) (Research Biochemicals International, Natick, MA, USA) and constituted the mPFC lesioned (mPFC1x) group. Thirteen rats received an equal volume of saline and constituted the sham operated (SO) control group. Procedures were approved by the Animal Research Ethical Committee of the research center.

Animals were housed under standard conditions (12:12 light–dark cycle, lights on at 07:00 h, room temperature at 22–24°C, food and water *ad libitum*). A period of 10 days elapsed between surgery and the beginning of the experimental protocol.

### *Behavioral Test Sessions*

All animals were tested in the T-maze. It was made of a runway (40 cm long, 15 cm wide) including a gated starting box (15 cm long) at one end and connecting midway to a perpendicular alley with two opposite 40 cm long arms at the other end. The walls were 15 cm high and the material used was clear opaque Plexiglas.

The T-maze procedure was similar to the original description by Divac et al. (1975). Animals were individually trained during two consecutive days and experimental data were collected on the next (third) day. Each of the three daily sessions consisted of two identical trials, 15 s apart, performed between 11:00 and 13:00 h. Rats were positioned in the starting box and released immediately. Animals could freely choose one of the two arms situated at the end of the runway. When all four paws were within one of the two arms, it was shut closed with a Plexiglas door for 60 s. Rats were then transferred in their home shoebox for 15 s during which the maze was cleaned to avoid olfactory cues. Rats were then returned to the starting box for the second trial where they could again freely choose between the two opposite arms. The dependent variable was the number of rats who used the alternate arm of the T-maze on the second trial of the third day. The same experimenter ran all experiments.

On the fourth day, a subgroup of rats (7 SO and 11 mPFC1x) were randomly selected to be tested in the alternation version of the Water Maze (AWM). This procedure was described in detail elsewhere (Beaulieu & Godbout, 2000). Briefly, rats were placed in a pool (150 cm diameter, 50 cm deep) filled up to 25 cm with water made opaque with powder milk and from which they had to escape by finding a submerged platform. The position of the platform alternated between two quadrant locations (i.e., the “initial” and the “alternate” position) while the rats were always started from the same position. Rats had six consecutive trials of 60 s to locate the platform. If a rat failed, it was placed on it by the experimenter and left there for 30 s. The inter-trial interval was 10–15 min. The dependent variables were the number of quadrants crossed, the number of successful trials, and the time taken to reach the platform.

### *Histology*

At the end of the experiment all animals were sacrificed, their brain was removed and frozen at  $-80^{\circ}\text{C}$ . Coronal sections (40  $\mu$ m) of the mPFC were cut on a cryostat

and subsequently stained with a formal-thionin solution to evaluate the site and extension of the lesion under light microscopic examination.

### Statistical Analyses

The performances of mPFCIx and SO rats were compared using a Chi-square test for the T-maze task and Mann–Whitney U-tests for the AMW. Results are presented as means  $\pm$  s.e.m.

## RESULTS

### Histology

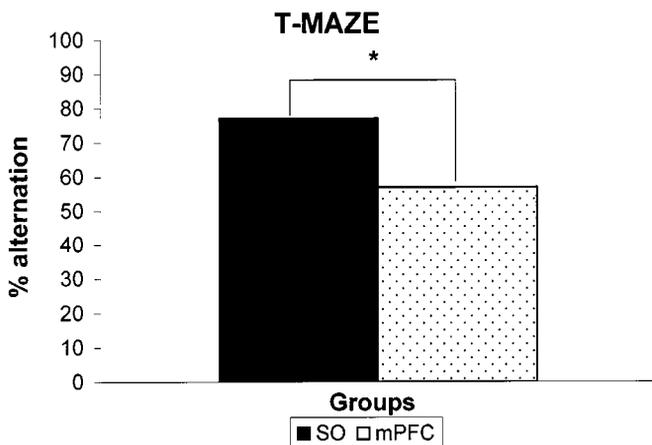
All but one mPFCIx rat showed correctly placed lesions in the mPFC within the rostral-caudal range defined as 4.70 to 1.70 mm anterior to bregma and the lateral range defined as  $-1.75$  to  $+1.75$  mm lateral to the midsagittal suture (Cg1, Cg3 and infralimbic). Therefore 21 mPFCIx rats were included in the statistical analysis.

### T-Maze Task

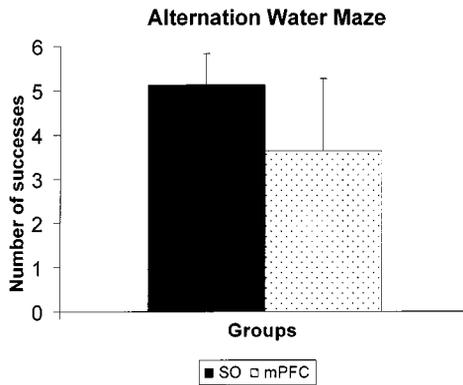
On the third day of training, sham-operated rats alternated above chance level, with a success rate of 76.9% ( $\chi^2 = 15,75$ ;  $df = 1$ ;  $p = .0001$ ) (See Fig. 1). In contrast, mPFCIx rats did not alternate above chance, with a success rate of only 57.1% ( $\chi^2 = 0,98$ ;  $df = 1$ ;  $p = .32$ ). The difference between the two groups was significant ( $\chi^2 = 22,59$ ;  $df = 1$ ;  $p = .00002$ ).

### Alternation Version of Water Maze

The number of successful trials was significantly lower in mPFCIx rats compared to SO rats ( $3.6 \pm 1.6$  versus  $5.4 \pm 0.7$ ;  $U = 16,5$ ;  $p < .05$ ) (see Fig. 2). The number of quadrants crossed ( $12.9 \pm 5,9$  and  $12.3 \pm 6.2$  for mPFCIx and control rats, respectively) and the time taken to reach the platform ( $47.4 \pm 13.2$  and  $45.6 \pm 17.0$  for



**FIG. 1.** Disruptive effect of mPFC lesions on T-maze alternation performance. Results are expressed in percentage of successful alternation.



**FIG. 2.** Effect of mPFC lesions on alternation performance in a water maze. Results are expressed in number of successes, i.e., the number of trials when rats reached the escape platform.

mPFC1x and control rats, respectively) were not significantly different between the two groups. On the other hand, both groups found the initial platform in the same amount of time ( $105.7 \pm 7.9$  versus  $102.0 \pm 6.6$  s) while mPFC1x rats needed more time than controls to find the alternate platform ( $134.4 \pm 9.2$  versus  $109.0 \pm 14.1$  s).

## DISCUSSION

This study shows that mPFC lesions with ibotenic acid induce an acute deficit in the acquisition of the T-maze alternation procedure, in agreement with previous studies (Rogizzio et al., 1998; Delatour & Gisquet-Verrier, 2000; Dias & Aggleton, 2000). More importantly, the present results show that mPFC1x rats were also impaired in the water maze version of the alternation task (AWM). The deficit observed in mPFC1x animals could not be attributed to a global and/or nonselective deficits since it has already been shown that mPFC-lesioned rats are not impaired in other cognitive task such as the allocentric version of the Morris water maze (Ethier et al., 2000), a task that rather requires the integrity of the hippocampal structures (Morris et al., 1982). Since mPFC1x rats were normal in terms of time taken to reach the initial platform and in the number of quadrant entries, cognitive deficits rather than visuo-motor alterations can be suspected. As a matter of fact, the T-maze literature has yielded a hypothesis according to which alternation impairments are caused by frontal cortex-related cognitive modules such as working memory deficits, associated with behavioral flexibility difficulties or attentional disorders (Granon et al., 1994; Dias & Aggleton, 2000). Results obtained on the AWM in the present study show that such deficits are indeed present in mPFC1x animals, i.e., (1) difficulties to inhibit an already acquired information (i.e., a facilitation toward the initial platform versus the alternate one); (2) difficulties to take into account or to focus attention on a new information (the alternate platform location). We interpret the fact that mPFC1x rats needed more time to reach the alternate position of the platform compared to its initial position as reflecting a working memory deficiency, i.e., animals were able to encode a first set information (location of the initial platform) but they could not reset it to memorize a new information (change of platform location toward the alternate position). Under such conditions, rats persevered in using the initially encoded information and did not adapt their strategy when the context changed. Whether attention shifting deficits were present in mPFC1x rats is beyond the interpretative power of the data presented

here, but the fact that lesioned and control rats performed equally in the initial platform location discard the possibility of a general attentional problem.

The present results showed that mPFC-lesioned animals were not able to solve an alternation task either in an aquatic or in a T-maze environment. This validates the AWM as a frontal-dependent task as well as an alternative to the classical version of the T-maze (Divac et al., 1975). The advantage of the AWM is that it yields supplementary behavioral measures that make it possible to readily evaluate visuo-motor performance and behavioral flexibility.

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