Noun verb dissociation in Parkinson's disease.

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Central Executive Secondary Tasks in Object Recognition: An Analogue of the Unusual Views Deficit in the Neurologically Normal?

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The particular problem of recognition from unusual viewpoints, may well involve a substantial problem-solving component and employ frontal/central executive resources. The present study investigates this question using a dual-task technique. In Experiment 1, the reliability of an unusual views effect was demonstrated. Experiment 2 showed that a central executive secondary task selectively disrupts unusual views recognition. These results are discussed in the context of existing lesion and functional imaging findings.

INTRODUCTION

There remains ambiguity within cognitive neuroscience as to the issue of how we recognize objects across changes in viewpoint, and also the neurological substrate of this remarkable ability. Evidently, the ease and efficiency with which we achieve object constancy belies the complexity facing the human visual system. Converging evidence from artificial intelligence, single-cell neurophysiology, and neuroanatomical studies, together with human and animal neuropsychology, points to the suggestion that object constancy involves contributions from several cognitive systems and various regions of extrastriate visual cortex (e.g., Farah, 1990; Kosslyn, Alpert, Thompson, Chabris, Rauch, & Anderson, 1994; Leek, Rapp, & Caramazza, 1996; Logothetis & Sheinberg, 1996; McCarthy & Warrington, 1990). Research into the neurological substrate of this ability has its origin in Warrington and Taylor's (1973) investigations of patients with Unusual Views impairments, and has proven particularly instructive in our understanding of object constancy. The Unusual Views Deficit (UVD) is a neurological disorder whereby patients can successfully identify objects presented from canonical or usual views, but fail to recognize the same objects viewed from noncanonical or unusual views. It is notable that, in anatomical terms, the lesion site lies outside of the classical ventral regions involved in object recognition. Exactly which regions, outside of the ventral visual system, have yet to be fully specified. One suggestion is the role of the frontal lobes/central executive. For example, Farah (1990) suggested that unusual view recognition involves a substantial problem-solving component. Moreover, certain patients with frontal lesions show an UV deficit (Turnbull & McCarthy, 1996). Finally, functional imaging findings also add support for the hypothesis, in that unusual, but not usual, views elicit activation in the left dorso-lateral pre-frontal cortex, amongst other regions (Kosslyn et al., 1994). Turnbull, Carey and McCarthy (1997) have attempted to account for the UVD as a deficit of an additional resource(s). One such resource could be the central executive in Baddeley's Working Memory Model (Logie, 1995). If it is true that the central executive is an additional resource, used only in unusual, but not usual view recognition, then it should be possible to selectively disrupt unusual re-cognition by disrupting the central executive. The dual-task technique is a well-established tool in this respect. If these assumptions are correct, a central executive secondary task should selectively disrupt unusual, but not usual, view recognition.

EXPERIMENT 1: OBJECT RECOGNITION WITHOUT A CENTRAL EXECUTIVE SECONDARY TASK

Participant and Methods

Sixteen (10 female) undergraduates were recruited from the University of Wales, Bangor (mean age = 22.63 years, range 18–35). Stimuli were presented via computer screen and were taken from the Birmingham Object Recognition Battery (BORB) (Humphreys & Riddoch, 1993). These consisted of 24 line drawings of common objects: car; jug; fork; bus; nailbrush; elephant; watch; razor; corkscrew; pig; glasses; paintbrush; spoon; shoe; cup; peg; rhino; scissors; digger; pepper pot; cotton reel; saw; screwdriver; and horse. Each picture was presented from a usual and an unusual view, in each case, a foreshortened principal axis of elongation. All participants were tested on six blocks of 80 trials, which were pseudo-randomized across each block. Each trial was signalled by a fixation point (500 ms), followed by a blank screen (500 ms), presentation of an object name (750 ms), a blank screen (500 ms), and a BORB picture stimulus, which remained until response by keyboard. 50% of trials were ''same'' (where word and picture matched), and 50% ''different'' (where word and picture did not match).

Results

Incorrect responses and reaction times (RTs) greater than 2 *SD*s from the mean were removed from the data set. Analysis of the ''same'' trials showed a significant effect of view, $F(1, 15) = 42.86$, $p < .001$, as well as block, $F(5, 15) = 19.53$, $p < .001$ (See Fig. 1). Consistent with the RT data, error rates were significantly higher for the unusual condition (mean = 7.14%, range 0–25%), than the usual condition (mean = 3.94%, range 0–20%).

Comment

Results confirmed that RTs were higher when recognizing objects from unusual, compared to usual, views. Furthermore, on second and subsequent blocks, the effect of view remained present, though reduced, even on Block 6. This experiment demon-

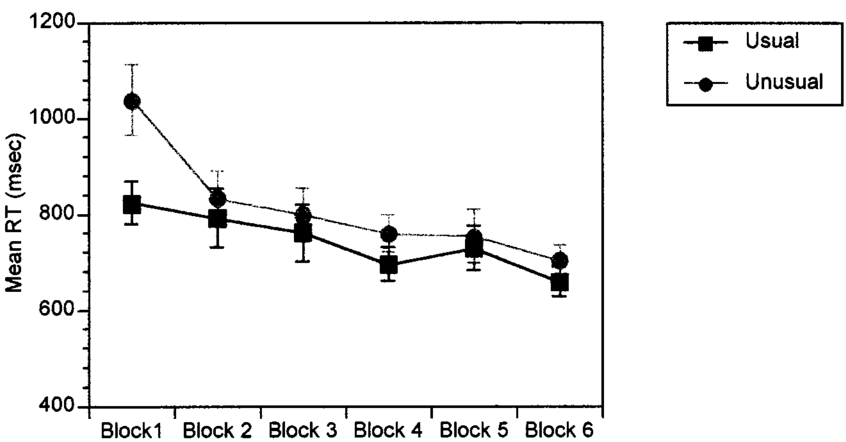

FIG. 1. Mean recognition RT across blocks for usual and unusual views with primary task alone.

strates that the unusual views effect can be found over multiple blocks of repeated presentation, and this is used as the primary task in Experiment 2.

EXPERIMENT 2: UNUSUAL VIEW RECOGNITION WITH THE PRIMARY TASK AND A CENTRAL EXECUTIVE SECONDARY TASK

This experiment employs random generation as a secondary task. Random generation is considered to fully stretch executive resources and represents the prototypical executive task (Baddeley, 1986; Baddeley & Della Sala, 1996), while having a low processing load on other working memory components (Vandierendonck, De Vooght, & Van der Goten, 1998).

Participants and Methods

Sixteen (11 female) undergraduates were recruited from the University of Wales, Bangor (mean age = 21.88 years, range 18–31 years). Primary stimuli and apparatus were identical to Experiment 1. As a secondary task, participants were also required to verbally generate sequences of digits randomly, with output recorded on tape. Participants were presented with four blocks of trials. Two blocks were completed without the secondary task. In the remaining two blocks, participants were required to verbally generate digits between 1 and 10, at a rate of one per second, consistently throughout each block, while concurrently performing the object recognition task manually. The order of presentation was counterbalanced using a Latin square design.

Results

Analysis was collapsed across blocks. Incorrect responses and RTs greater than 2 *SD*s from the mean were removed from the data set. As in Experiment 1, there was a significant effect of view, $F(1, 15) = 26.69$, $p < .001$, and also task condition, $F(1, 15) = 35.14$, $p < .001$. In addition, there was a significant interaction between the two conditions, $F(1, 15) = 4.70$, $p < .05$ (See Fig. 2). As in Experiment 1, analysis of errors showed a significant difference between usual (mean = 8.52%, range 0–35%), and unusual conditions (mean = 11.09%, range 0–35%).

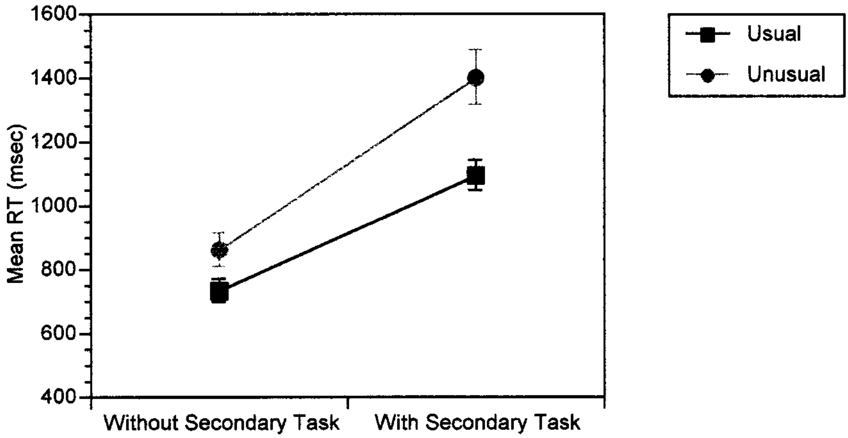

FIG. 2. Mean recognition RT for usual and unusual views with and without central executive secondary task.

Discussion

Both experiments show a consistent finding of slower RT and higher error rate in unusual, but not usual, views. To our knowledge, this is the first time that a dual-task methodology has been employed to selectively influence object recognition from unusual views. It was predicted that disruption of the central executive system would produce a decrement in recognition performance selectively for unusual view stimuli. This was confirmed by the significant interaction between task and view in Experiment 2. This finding may be regarded as akin to the UVD deficits seen in neurological patients, where the secondary task acts as a 'functional' lesion, selectively disrupting unusual recognition. Results confirm suggestions from the neurological lesion literature (Farah, 1990; Turnbull & McCarthy, 1996), as well as the functional imaging literature (Kosslyn et al., 1994), that the central executive and/or frontal lobes are selectively involved in the recognition of objects from unusual views.

However, there have been suggestions that the central executive may not be considered a unitary entity (Baddeley & Logie, 1999; Schneider, 1999), and it may be that some components of central executive function are more directly involved in unusual view recognition than others. The dual-task technique, proposed in the present study, offers the possibility of custom-designing secondary tasks which target specific aspects of central executive function to allow us to test this hypothesis more directly. In addition, it would be predicted that *any* sources of disruption to central executive function should selectively effect unusual view recognition. The most obvious example of this is focal brain lesion. However, to the best of our knowledge, no systematic investigation of unusual recognition in patients with focal lesions restricted to the frontal lobes has been attempted. Also, functional disruption of the central executive by, for example, transcranial magnetic stimulation (TMS) to frontal regions, should also produce such an effect. It has been demonstrated that TMS over the frontal lobes disrupts executive function and increases nonrandomness (Jahanshahi & Dirnberger, 1999). Thus, we would predict that TMS over the frontal lobes would selectively disrupt unusual view recognition.

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This is doi:10.1006/brcg.2001.1359.

Hemispheric Asymmetry for Global and Local Processing: Language Is Less Important Than One Might Think

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There have been consistent findings of hemispheric asymmetry in global/local processing, in both neurological patients and the neurologically normal. However, with one exception, these studies have used purely linguistic stimuli (letters made up of letters). The present study investigates lateral asymmetry for processing of global/local objects with less ‘‘linguistic’’ properties (e.g., letters made up of shapes, and shapes made up of letters) using a change detection paradigm. In each case the classic pattern of hemispheric asymmetry was found. These results are discussed in the context of the relative importance of hemispheric asymmetry for both global/local and linguistic information.

INTRODUCTION

Hemispheric processing for global and local information is well documented (see Ivry & Robertson, 1998 for review) with the consistent finding that the left hemisphere is specialised for local processing and the right hemisphere for global processing. In these studies local information is generally defined as the overall configuration of an object, and local information is defined as the component parts which make up the object, typically using the hierarchical stimuli of Navon (1977), where large global letters comprise of smaller local letters.

Studies with neurologically normal subjects have almost invariably shown a global information processing advantage in the right hemisphere (left visual field) and a local information processing advantage in the left hemisphere (right visual field, e.g., Martin, 1979; Van Kleeck, 1989; Martinez et al., 1997; Sergent, 1982). This has also been backed up with evidence from neurological studies where patients with left hemisphere damage have shown deficits in local processing, and those with right hemisphere damage have shown global deficits (McFie & Zangwill, 1960; Delis et al., 1986; Delis et al., 1988).

The majority of studies in this area use hierarchical *letter* stimuli (e.g., Navon, 1977; Martin, 1979). Therefore, it may be that the hemispheric asymmetry effects are a result of stimulus type, and reflect the well-known left hemisphere advantage for processing linguistic information. In this context, one interesting study is that of Fink et al. (1997), who investigated the processing of hierarchical stimuli that were *not* letters, specifically stimuli that were shapes made up of shapes. Using a functional imaging technique (PET) Fink et al. (1997) found that the global information of object stimuli produced a *reverse* pattern of that previously found using letter stimuli. The global information appeared to be preferentially processed in the left hemisphere, and the local information processed in the right hemisphere. This suggests that stimulus type may be an important factor in determining allocation of information processing in the left and right hemispheres

However, the implications of Fink et al.'s (1997) imaging study have yet to be systematically investigated using the well-established cognitive psychology tasks on which so many global and local studies have been based. In addition, Fink's stimuli differ from the classic Navon study at *both* the global and local level—contrasting letters made up of letters, with shapes made up of shapes. The additional possibilities, of letters made up of shapes and shapes made up of letters, have not been studied. The present study systematically investigates these effects of stimulus type on global and local processing, and utilises a divided attention task based on the recently developed change detection ''flicker'' paradigm (Rensink et al., 1997). In this format, changes are made to hierarchical stimuli, and participants must indicate whether the change occurred at the global or local level.

EXPERIMENT 1: HIERARCHICAL LETTER STIMULI (LETTERS MADE UP OF LETTERS)

Experiment 1 investigates whether the change procedure can produce the well-established lateralization findings with hierarchical letter stimuli.

Method

Fifteen people (11 females) (mean age = 27 years, range = 19–40 years). All participants were right-handed (using the criteria of Annett, 1976). The stimuli were hierarchical letters (A, E, H, S, and P). All stimuli were presented bilaterally and all stimuli were incongruent. Each participant viewed two blocks, each containing 160 trials. Each trial consisted of: a fixation cross (500 ms), the first pair of stimuli (150 ms), a blank screen (100 ms) and then the second pair of stimuli (150 ms) (see Fig. 1).

The participant indicated (using a key press) whether a change had occurred between the first and the second image. A change could either occur to one of the large letters (global) or to one of the sets of smaller letters (local). There were five types of trial: (1) a no change trial, (2) a left global change trial, (3) a right global change trial, (4) a left local change trial, and (5) a right local change trial. Half the trials were no change and half were change trials.

Results

Mean percentage correct scores were used to calculate d prime (see Fig. 2.1). Analysis of variance for d′; indicated that response differed depending on the type of change. Higher d′ scores were obtained for global than local changes ($F(1, 14) = 28.293$, $p = .0001$). There was also a significant interaction between type of change

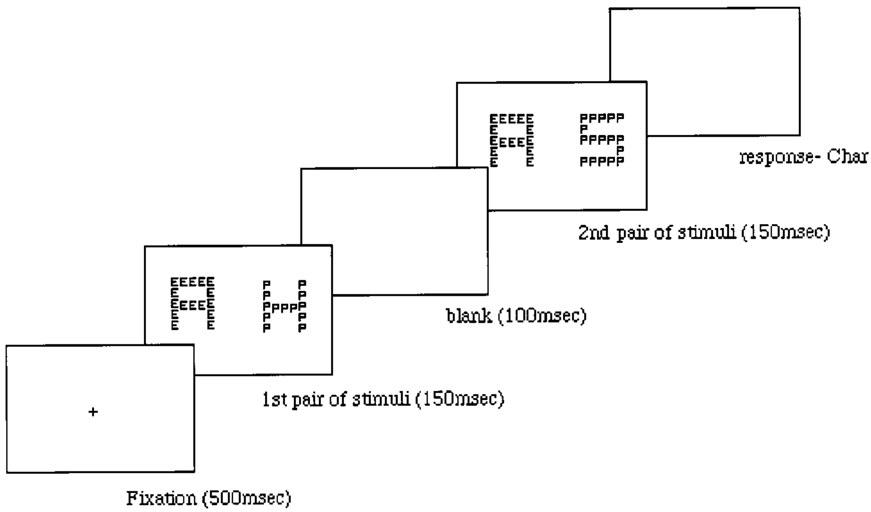

FIG. 1. An example of a trial in Experiment 1.

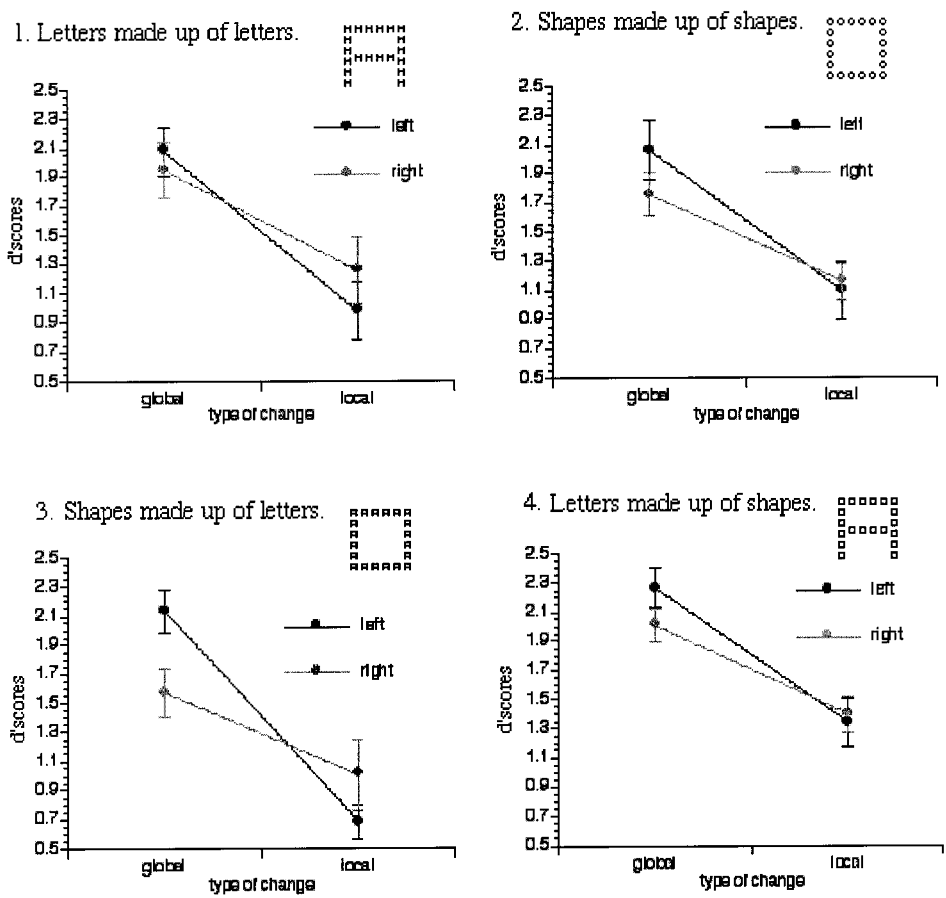

FIG. 2. Global and local change detection in the left and right visual field for each of the four experiments. Error bars represent ± 1 SE.

and visual field ($F(1, 14) = 4.940$, $p < .05$) with global changes detected more accurately in the left visual field.

Comment. The data from this experiment replicates the findings of Navon (1977) and Martin (1982), using a change detection procedure.

EXPERIMENT 2: HIERARCHICAL SHAPE STIMULI (SHAPES MADE UP OF SHAPES)

Experiment two attempts to replicate Fink et al. (1997).

Method

Fifteen people (14 females) participated (Mean age = 21 years, age range = 18–25 years. All participants were right-handed. The stimuli and procedure were the same as in experiment 1, but using hierarchical *shape* stimuli (see Fig. 2.2). The shapes used were circle, arrow, square, cross, and triangle.

Results

Again, higher d′ scores were obtained for global changes compared to local changes, ($F(1, 14) = 38.49$, $p = .0001$). Again, there was a significant interaction between type of change and visual field ($F(1, 14) = 6.734$, $p < .05$), with global changes detected more accurately in the left visual field (Fig. 2.2).

Comment. This experiment does *not* replicate the finding of Fink et al. (1977), and suggests that stimulus type may not influence hemispheric asymmetry of global and local processing.

EXPERIMENT 3 (SHAPES MADE UP OF LETTERS)

The final two experiments investigated the remaining two possibilities of stimulus type.

Method

Fifteen people (11 females) participated in each experiment (mean age = 25 years; range 18–37 years). All participants were right-handed. The procedure was the same as in experiment 1, but using shapes made up of letters (see Fig. 2.3).

Results

Again, higher d′ scores were obtained for global changes compared to local changes, ($F(1, 14) = 50.454$, $p = .0001$). Again, there was a significant interaction between type of change and visual field ($F(1, 14) = 18.385$, $p < .001$), with global changes detected more accurately in the left visual field (Fig. 2.3).

EXPERIMENT 4 (LETTERS MADE UP OF SHAPES)

Method

Fifteen people (14 females) participated in each experiment (mean age = 21 years; range 18–25 years). All participants were right-handed. Procedure was the same as in experiment 1 but using letters made up of shapes (see Fig. 2.4).

Results

Higher d′ scores were obtained for global changes compared to local changes ($F(1, 14) = 43.731$, $p < .0001$). Again, there was a significant interaction between type of change and visual field ($F(1, 14) = 5.438$, $p < .05$), with global changes were detected more accurately in the left visual field (Fig. 2.4).

Comment. The findings from Experiments 3 and 4 are consistent with those of Experiments 1 and 2.

DISCUSSION

Despite the difference of stimulus type, each experiment in this series produced a consistent pattern of results. Thus, global changes were more accurately detected in the LVF and local changes more accurately detected in the RVF. This reliable pattern of results suggests that the change detection paradigm is a valid tool for the investigation of hemispheric asymmetry for global/local stimuli. The findings of Experiment 2 clearly do *not* support Fink's claim that hemispheric asymmetry for global/local processing is reversed when the stimuli are composed of shapes rather than letters. This finding was reconfirmed in Experiments 3 and 4, which show precisely the same effect, regardless of the global/local arrangement of letter and shape stimuli. These findings suggest that the global/local effect appears to a more substantial predictor of lateral specialisation than that of linguistic versus nonlinguistic stimuli. However, the fact that our shapes in the present experiment were potentially ''verbalizable'' (i.e., ''square'') may argue against this. One suggestion might be to employ more abstract, nonverbalizable, shapes.

It is of some interest that the interaction between type of change and visual field was far larger in Experiment 3 than the other experiments. This may be due to the ''additive'' effects of the congruence of global/local and linguistic asymmetry. Thus, in Experiment 3 the local form (which should enjoy a left hemisphere advantage) is a letter and the global form (which should enjoy a right hemisphere advantage) is a shape. Consequently, there *may* be an effect of whether stimuli are ''linguistic'' or not, but this is a second order effect, that becomes clear only when it is congruent with the global/local effect.

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This is doi:10.1006/brcg.2001.1360.

Noun Verb Dissociation in Parkinson's Disease

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A noun/verb dissociation with a relative verb deficit was found in patients affected by Parkinson's disease, even in relatively early stages, when mental deterioration is not severe. This finding is compatible with earlier observations, according to which verbs are dealt with in more anterior regions with respect to nouns. It also supports the speculation that the coordination and the manipulation of information associated with a verb world rely on the fronto-striatal system.

INTRODUCTION

Patients with selective difficulties in retrieving verbs with respect to nouns have been, with some exceptions, shown to suffer from lesions in the anterior areas of the brain.

Patients exhibiting the opposite pattern, i.e., a relative difficulty with nouns, have been, instead, generally shown to suffer from more posterior lesions (see Daniele et al., 1994, for a review). The anatomical underpinnings of the noun/verb dissociation have been recently confirmed not only by studies on focal brain diseases, but also by observations on patients suffering of more diffuse, although unevenly spread cortical lesions. Thus Cappa and co-workers (1998) found that, while nouns are more sensitive than verbs to Alzheimer's disease, the opposite happens in frontotemporal dementia. Little if anything is however known from pathologies mostly concerning subcortical structures.

Cognitive deterioration in Parkinson's disease (PD), indeed, typically includes a wide range of deficits (Savage, 1997; Owen & Doyon, 1999) where problems concerning functions traditionally attributed to the frontal lobes seem however prominent. On the other hand, linguistic functions and lexical abilities in particular are generally considered to be largely spared, and only the deterioration of peripheral articulation has been always acknowledged. Only recently studies of verbal fluency (Piatt et al., 1999a, 1999b) have shown that action (verb) naming fluency tasks discriminate demented PD patients from non demented PD patients and healthy control subjects, whereas lexical and categorical fluency tasks do not. Those studies suggested that action fluency is sensitive to the frontostriatal pathophysiology associated with PD and that action fluency may serve as an indicator of executive functioning. Grossman (1998), indeed, has argued that verb naming deficit may reflect underlying executive system dysfunction that undermines the ability to mentally co-ordinate and manipulate the diverse range of information that may be associated with a verb. These last considerations call for the present investigation, whose aims is to check whether the noun/verb dissociation emerges, in PD, also in traditional naming tasks like picture naming.

METHODS

A widely used test for checking the noun/verb dissociation in Italian, that is included in the Miceli, Burani, and Laudanna battery (1990), was used for the present study. The experimental material consisted of 52 pictures of objects and 50 pictures of actions to be orally named. Participants received a score of 2 if they could correctly name the picture within 10 s and a score of 1 if they could however provide the correct answer within 1 min. The above procedure does not easily allow to establish whether a naming deficit originates in the output lexicon or at an earlier stage (Hillis, 2001). In order to collect more precise information another test was devised. In this second test, participants had to repeat 25 names of objects and 25 names of actions spoken by the examiner, after a 10-s interval, filled by backward counting, starting from a given number. Since this task provides the full phonological form and does not necessarily require semantic mediation, the argument can be made that the failure would derive from reactivating the output lexicon. A dissociation between noun and verb resulting from this test would therefore point to a deficit at the lexical output level. On the other hand, no difference between noun and verb would be picked out in this way if the deficit originates at a pre-lexical level.

PARTICIPANTS

Twenty-two PD patients with a mean age of 64.27 ($SD = 9.40$) years and 8.81 ($SD = 4.29$) years of education participated in this study. The mean duration of their disease was 11.45 ($SD = 6.75$) years. Their mean score on the MMSE was 26.40 ($SD = 2.66$) and on the Raven's PM 38 was 25.72 ($SD = 8.98$). Twenty age and education matched nonneurological patients acted as control group.

RESULTS

Results are shown in Table 1. A two way ANOVA revealed that in naming the PD group was worse than the Control group ($p < .0001$); actions were named significantly worse than objects ($p < .0001$); a significant interaction was also found ($p < .0001$). Post-hoc analysis via *t* test showed that, while the PD group was worse in naming actions than in naming objects ($p < .001$), no such difference was there for the Control group. No significant difference between names of objects and actions was found in the delayed repetition test in the PD group. In this case Controls were excluded from statistics since they did not commit any error. The PD group was then divided in two subgroups, of respectively, 10 and 12 subjects, on the basis of their performance on the MMSE: a score of above 25 in the first subgroup and of 25 and below in the second subgroup. In both subgroups the noun/verb dissociation was significant ($p < .005$) in the picture naming test, while it was not significant in the delayed repetition test. A similar splitting was performed on the basis of the subjects'

TABLE 1
Adjusted Mean Scores in Picture Naming and Delayed Repetition

	Picture naming			Delayed repetition	
Group	*N* subjects	Nouns	Verbs	Nouns	Verbs
Controls	20	102.40	102.40	25	25
Pdpatients	22	89.63	74.41	21.25	21.00
PD, MMSE less than 25	10	86.00	68.20	19.00	20.00
PD, MMSE 25 or more	12	92.66	79.58	22.75	21.83
PD, PM38 less than 25	11	88.09	73.45	19.27	20.45
PD, PM38	11	91.18	75.36	22.81	21.54
PD, more than 8 yrs	11	87.45	71.54	22.09	21.00
PD, less than 8 yrs	11	91.81	77.27	20.00	21.00

performance on the Raven's PM 38, a score of 25 being the cut-off. Both the two subgroups, each consisting of 11 subjects showed a significant ($p < .005$) noun/verb dissociation in picture naming and no differences in delayed repetition. The PD group was finally divided in two subgroups, each again consisting of 11 subjects, according to the duration of the disease (more or less than 8 years). Again, while the noun/verb dissociation was significant ($p < .005$), in both subgroups, in picture naming, no significant difference was found in delayed repetition.

DISCUSSION

A convincing noun/verb dissociation with a relative verb deficit in a picture naming task was shown in PD. An alternative interpretation of this effect as a resource artefact (Shallice, 1988; McCloskey, 2001), due to intrinsically heavier processing demands of action naming with respect to object naming, does not appear to be plausible, since Cappa et al. (1998) demonstrated the opposite dissociation in Alzheimer patients, who are obviously a resource lacking population.

The relative verb deficit appears before PD patients show clear signs of dementia, in the first decade of disease. The locus of the functional damage seems to be at the prelexical level: converging evidence from other techniques is needed to confirm this point. These conclusions would however be compatible with earlier anatomical observations and with the above-mentioned ideas: the co-ordination and the manipulation of information associated with a verb heavily rely on the fronto-striatal system. Whether and how factors like verb argument structure are dealt with in such a system remains grounds for further investigations.

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This is doi:10.1006/brcg.2001.1361.

Language after Temporal or Frontal Lobe Surgery in Children with Epilepsy

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The purpose of this study was to compare language function in children undergoing temporal or frontal lobe surgery to control intractable epilepsy. Language measures (expressive vocabulary, receptive vocabulary, comprehension, reading, spelling, phonemic fluency, and category fluency) were administered to 9 children with frontal lobe epilepsy (mean age: 10.8 $\pm$ 2.7 years) and 10 children with temporal lobe epilepsy (11.5 $\pm$ 2.6 years). The results indicate that no differences exist, in language function, before and after surgery between children with frontal and temporal lobe epilepsy (all $p \geq .05$). Children with left hemisphere lesions had significantly lower scores than those with right on category fluency and comprehension, but laterality effects were not seen on the other measures. In both groups, language function was not significantly affected by surgery.

Surgical intervention for intractable epilepsy during childhood has become an increasingly viable option because of technological advances that provide improved seizure classification and patient selection. Research investigating the effects of surgery in children has examined intelligence and memory but, to date, little attention had been paid to language following surgery. In adults, deficits in language skills have been found with lesions to the left (dominant) hemisphere. Impairment in word finding (Davies et al., 1998; Langfitt & Rausch, 1996) is well described. Persisting impairments in word finding were noted in 25% of patients with left speech-dominant anterotemporal lobectomy after a one-year follow-up assessment (Langfitt & Rausch, 1996). Milner (1988) described a preoperative word fluency deficit in a group of surgical candidates with left frontal-lobe epilepsy. More recently, Helmstaedter et al. (1998) reported that while most postoperative deficits were transient, postoperative impairments in verbal fluency, comprehension, and verbal reasoning persisted at a three-month follow-up in patients with frontal lobe epilepsy.

Language-related cognitive declines have been reported in children following temporal lobe resection (Dlugos et al., 1999). Comprehensive preoperative and postoperative neuropsychological assessments were completed in eight children (5 left temporal, 3 right temporal) with a mean age of 13 years. All five patients with left-sided lesions demonstrated significant language-related declines on postoperative testing. Impairments were noted in verbal IQ (1 child), verbal learning (4 children), naming (1 child), and reading comprehension (1 child). However, many of the tasks in which impairments were noted were not pure language measures; for example, the most commonly occurring deficit was observed on a verbal learning task (4 children) which made minimal demands on language processing skills. Therefore, it is difficult to draw conclusions as to whether the impairments observed represent language-related deficits or are related to other cognitive processes.

The purpose of the present study was to investigate language function in a group of children with epilepsy before and after surgery to the temporal or frontal lobe.

METHODS

The participants were children followed through the Epilepsy Program at the Hospital for Sick Children in Toronto. Children with Full Scale IQs less than 70 were excluded. Nine children (5 left, 4 right) had documented frontal lobe epilepsy and ten children (5 left, 5 right) had temporal lobe epilepsy. Preoperative evaluations included video and surface electroencephalogram recordings, structural neuroimaging, and neuropsychologic testing. Table 1 provides details of the two groups. The participants in both groups were comparable in seizure frequency preoperatively, the number of antiepileptic medications taken before surgery, and Full Scale IQ. All children had left hemisphere speech representation.

The language measures were: the vocabulary subtest and verbal IQ from the Wechsler Intelligence Scale for Children (Wechsler, 1991), reading and spelling from the Wide Range Achievement Test (Jastak, 1993), Word Fluency (F-A-S and Categories; Gaddes & Crockett, 1975), Peabody Picture Vocabulary Test (Dunn & Dunn, 1981), Token Test (DiSimoni, 1978), and the Test for the Reception of Grammar (Bishop, 1982). Analyses of variance (ANOVA) were used to test for significant differences related to side and site of lesion and effects of surgery.

RESULTS

Table 2 shows the mean performance for both groups on all language measures both pre- and postoperatively. Preliminary analyses indicated that sex did not influ-

TABLE 1
Demographic Characteristics of the Participants in Both Groups

	Temporal (n = 10)	Frontal (n = 9)
Age at presurgical evaluation (years)	11.5 (2.6)	10.8 (2.7)
Range	7.5–15.8	4.9–13.1
Age at postsurgical evaluation (years)	12.8 (2.8)	12.2 (3.3)
Range	8.0–17.0	5.5–15.6
Age at seizure onset (years)	4.4 (2.1)	3.6 (2.9)
Range	1.1–7.25	0.5–8.33
Sex		
Males	2	2
Females	8	7

TABLE 2
Mean Performance (±*SD*) by the Two Groups Pre- and Postsurgery

	Temporal pre	Temporal post	Frontal pre	Frontal post
Verbal IQ[a]	94.6 (12.0)	93.8 (11.6)	89.4 (14.7)	90.8 (13.0)
Reading[a]	99.2 (12.6)	93.8 (16.9)	104.3 (15.5)	102.6 (5.1)
Spelling[a]	100.0 (9.8)	97.3 (15.5)	101.6 (12.1)	106.0 (5.9)
PPVT[a]	96.9 (14.9)	98.1 (14.7)	103.3 (13.4)	103.4 (12.3)
TROG[a]	91.2 (8.7)	95.8 (12.7)	104.3 (16.4)	93.2 (12.0)
Vocabulary[a]	8.9 (3.6)	8.4 (3.5)	8.0 (2.7)	9.0 (2.9)
Phonemic Fluency[b]	−0.35 (1.5)	−0.97 (1.3)	−0.70 (0.95)	−0.83 (1.4)
Category Fluency[b]	0.40 (1.2)	−0.09 (0.67)	−0.69 (0.67)	−0.37 (1.0)
Token[c]	54.6 (5.6)	57.3 (3.5)	51.7 (7.0)	50.7 (10.8)

[a] Scaled scores.
[b] *Z* scores.
[c] Raw score.

ence our results and this variable was not included in the subsequent analyses. The data were subjected to mixed measures ANOVAs, with site (frontal or temporal) and laterality (right or left) as between-subject factors and time of testing (pre- vs postoperative) as the within-subject factor. Differences in degrees of freedom reported in the analyses reflect the failure of participants to complete all tasks due to fatigue or time constraints. The results indicate that no significant differences existed between the two groups of children before and after surgery. A laterality effect, $F(1, 10) = 10.2$, $p = .01$, was seen on category fluency with children with left-sided lesions performing worse than children with right-sided lesions. Another laterality effect was seen on the token test, $F(1, 9) = 5.1$, $p = .05$, with children with left-sided lesions performing worse than children with right-sided lesions. Analyses revealed no effects of time of testing and no significant interactions.

Performance after surgery was also examined at an individual level in terms of significant improvements or declines as defined by a change in standard score by one standard deviation or greater. Children with left-sided lesions were no more likely to experience improvement or deterioration than were children with a right-sided epileptic focus. In children with temporal lobe lesions, declines were more likely to be seen on fluency tasks (5 children on phonetic fluency, 3 children on category fluency), but these declines were seen with both left and right-sided lesions. There was no differential effect of the locus of lesion on the frequency of increases or decreases in task performance.

DISCUSSION

This study included children who underwent either a temporal or frontal lobectomy to control intractable epilepsy. Analyses indicated that no significant differences existed between the two groups pre- or postoperatively. Laterality effects were seen on category fluency and comprehension with children with left-sided lesions performing worse than children with right-sided lesions. This finding is consistent with previous research on adults which has documented language deficits after lesions in the dominant (left) hemisphere (Helmstaedter et al., 1998; Langfitt & Rausch, 1996; Milner, 1988).

Laterality effects on cognitive measures in children undergoing epilepsy surgery have been examined only for temporal-lobe lesions, with studies reporting inconsistent findings (Adams et al., 1990; Dlugos et al., 1998; Meyer et al., 1986; Williams et al., 1998). In the present study, all of the children had left hemisphere dominant language and developed seizures at an early age, but did not experience significant changes after surgery. This finding that children's language abilities were unaffected by surgery suggests that in children with epilepsy, cerebral plasticity may influence brain reorganization leading to a greater preservation of abilities than would be seen in adults. This pattern of preserved function is not observed in adults where laterality of surgery has been reported to be a predictor of the extent and direction of postoperative word naming change (Langfitt et al., 1996).

Within both the frontal and temporal groups, individual children displayed specific deficits indicative of difficulties that require special attention. Both children with right- and left-sided lesions experienced language related cognitive declines which contrasted the results presented by Dlugos et al. (1999) where only children with left-sided lesions experienced postoperative deficits. Our results for the token test are similar to those reported by Lendt et al. (1999) who found that children with left-sided lesions made significantly more errors than children with right-sided lesions. Lendt et al. (1999) did not find a laterality effect on their word fluency task (a written measure), which is inconsistent with our findings. The discrepancies between these studies may arise from the small sample sizes reported and the different measures administered.

While the group mean scores on all measures fell within the average range and within the expectations based on FSIQ, for both groups, individual children did experience both clinically significant improvements and declines in language function after surgery. As a group, the children with temporal-lobe lesions showed slight declines in mean scores post-surgery on more tasks than did the group of children with frontal-lobe lesions, even though these changes were not significant. It remains to be seen whether these differences will become accentuated with increasing age, so that possible deficits might become apparent later in life.

The results need to be interpreted with caution due to small sample size. Replications of this study with increased numbers could better address the possible effect of laterality of cognitive outcome before and after surgery. The inclusion of a control group of children with intractable epilepsy who did not undergo surgery would allow for greater discussion of the nature and significance of the findings. Without a control group, it is not possible to determine whether the results reflect the effects of surgery or if they should be considered as part of the normal developmental progression in this population of children. Future studies should focus on prospective, longitudinal follow-up of children who have undergone surgery to control their seizures in an effort to describe possible further deficits that may occur over time.

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This is doi:10.1006/brcg.2001.1362.

Hand Preference in Simultaneous Unimanual Tasks: A Preliminary Examination

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The aim of the current investigation was to determine the pattern of hand use during simultaneous unimanual tasks. Two studies were conducted. The first experiment examined the pattern of hand use in a catching task, while performing a secondary writing task. Results showed that individuals had a decreased tendency to catch with their preferred hand when their preferred hand was occupied, in comparison to when the preferred hand was unoccupied. The second experiment examined the pattern of hand use during a support and reach task, where the use of both hands was required. Here, results indicated that participants preferred to support themselves with their nonpreferred hand and reach with preferred hand toward right hemispace. With respect to left hemispace, participants showed the reverse pattern. This pattern of hand use indicates an important role for the nonpreferred hand, which has been relatively unexplored by researchers.

INTRODUCTION

It is well known that humans tend to prefer one hand over the other when performing common, everyday, unimanual tasks, with approximately 90% of the population preferring their right hand for most tasks (Annett, 1985). Researchers typically measure handedness in one of two ways: (a) by asking participants which hand they prefer to use for a set of unimanual tasks, such as writing or hammering; or (b) by measuring the difference in performance abilities of the two hands. However, what both these measurement techniques fail to take into account is the notion that few, if any, tasks are truly unimanual (Guiard & Ferrand, 1996). For example, if one considers the typical tasks examined in handedness questionnaires, such as writing, opening a jar, hammering, and dealing cards, it is clear that all of these tasks also require the use of the nonpreferred hand as well. Relatively little work has examined the performance of the both hands during common, everyday tasks. The purpose of the current investigation was to conduct a preliminary examination the pattern of hand preference in humans when one hand is already occupied in a secondary task.

EXPERIMENT ONE

Method

Participants. Thirty-nine right-handed undergraduate students from the department of kinesiology and physical education at Wilfrid Laurier University participated in the current study. All participants completed the Waterloo Handedness Questionnaire to assess their hand preference.

Procedure. All participants completed two conditions. In the first condition, each participant was instructed to copy a passage onto a pad of paper. During the completion of the writing task, the experimenter gave a warning signal to the participant and then tossed a soft ball to the right, center, or left of the participant. The participant was instructed to catch the ball with one hand only. The second condition was conducted in the same manner, except that participants did not perform the secondary writing task. Three trials for each condition/direction combination were collected.

Results

Differences in the frequency of preferred hand use were tested in a 2 (condition) × 3 (direct) repeated measures ANOVA. In order to perform this type of analysis on a discontinuous dependent variable, the frequency of preferred hand use was expressed as a proportion of the total number of trials and an arc sine transformation was then applied to the data. The analysis revealed a main effect of condition ($F_{1, 38} = 5.674$, $p = .022$) where significantly more catches were made with the preferred hand in condition two. Furthermore, there was an effect of which direction the ball was thrown ($F_{2, 76} = 31.554$, $p < .01$). Here, individuals were more likely to catch the ball with their preferred hand when the ball was thrown to the right, and less likely to use their preferred hand when the ball was thrown to the left,

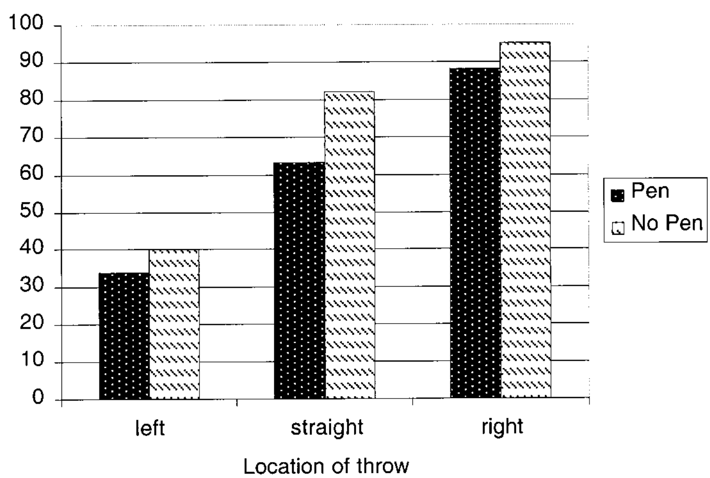

FIG. 1. Percentage of preferred-hand catches as a function of experimental condition and direction of throw in Experiment one.

as might be anticipated (see Fig. 1). No interaction between the two factors was found.

EXPERIMENT TWO

Method

Participants. Twenty-five right-handed undergraduate students from the department of kinesiology and physical education at Wilfrid Laurier University participated in the current study. All participants completed the Waterloo Handedness Questionnaire to assess their hand preference.

Materials and procedure. A cinder block, positioned against a wall, was used for the participants to stand on. There was a handicap rail placed on the wall for the participants to grasp and support their weight. A series of dowels anchored to the ceiling, consisting of three dowels placed at right angles to each other, was used to support three tennis balls and maintain consistent positioning at different distances (75 and 150 cm) and orientations (left, center, and right) with respect to the wall.

The task of the participant was to support themselves with the handicap rail while reaching for the balls. The participant completed three reaches for all three directions and both distances.

Results

Differences in the frequency of preferred hand use were tested in a 2 (condition) × 3 (direct) repeated measures ANOVA. In order to perform this type of analysis on a discontinuous dependent variable, the frequency of preferred hand use was expressed as a proportion of the total number of trials and an arc sine transformation was then applied to the data. The analysis revealed an effect of direction ($F_{2,56} = 176.45$, $p < .01$), where all reaches to the right were made with the right hand and all reaches to the left were made with the left hand (see Fig. 2). As well, individuals were more likely to use their preferred hand to reach down the center. All other findings were nonsignificant.

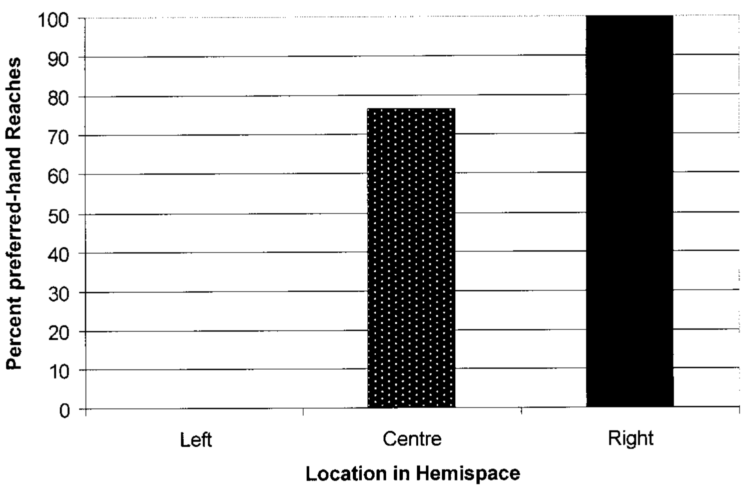

FIG. 2. Percentage of preferred-hand reaches as a function of direction, collapsed across distance, for Experiment two.

DISCUSSION

The purpose of this study was to explore (a) the pattern of hand preference while one hand is already occupied and (b) the pattern of hand preference during a support and reach task. With respect to the first purpose of the current work, the data revealed that participants preferred to use their preferred hand over 70% of the time when that hand was unoccupied. When the preferred hand was occupied, individuals continued to use their preferred hand just over 50% of the time. The use of the preferred hand also changed with respect to the location or direction in which the ball was thrown, such that individuals were more likely to use their nonpreferred hand when the ball was thrown to the left side of hemispace. With respect with the second purpose of the current investigation, individuals preferred to reach for an object with their dominant hand while supporting themselves with their nonpreferred hand.

In conclusion, the current studies show a reduction in the use of the preferred hand, depending upon the task and the location in hemispace the task is to be performed. It is clear that further work needs to address the relative roles of the preferred and nonpreferred hands.

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This is doi:10.1006/brcg.2001.1363.

Pushing the Limits of Task Difficulty for the Right and Left Hands in Manual Aiming

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The effects of task difficulty on the performance of the two hands in right-handers were examined in a manual-aiming paradigm. In order to examine both simple and complex tasks, movement amplitude, cursor size, and target size were manipulated, resulting in eight different indices of difficulty (as defined by Fitts' Law). Kinematic parameters examined included reaction time, movement time, time to and time after peak velocity, peak velocity, and resultant accuracy. Analysis revealed no differential effects of task difficulty on the overall movement times of the two hands. These results are discussed in light of current theories of manual asymmetries.

INTRODUCTION

Handedness has been a topic of continuing investigation and controversy for several decades. While some researchers have examined issues related to manual preference, others have pursued the avenue of examining manual performance or skill. Most of the research on manual performance has focused on understanding why the preferred hand exhibits a performance advantage over the nonpreferred hand for a multitude of tasks. Several theories have been proposed, including the preferential experience theory (e.g., Provins, 1997), the visual-feedback hypothesis (e.g., Flowers, 1975), and the motor output hypothesis (e.g., Annett, Annett, Hudson, & Turner, 1979; Elliott & Chua, 1996). However, at this point, there is no definitive explanation for the performance differences between the hands, nor why the magnitude of the performance difference appears to increase under certain specific task constraints.

One of the constraints currently under examination is task difficulty. Recently, there has been some controversy over how the two hands perform relative to one another as a function of increasing task difficulty. Early work suggested that the preferred-hand advantage increased significantly with increasing task difficulty (Annett et al., 1979; Flowers, 1975; Provins & Magliaro, 1989; Todor & Cisneros, 1985). For example, Flowers (1975) found no differences in performance abilities between the hands for a simple tapping task, but large performance differences between the hands for a complex manual aiming task. Similarly, Provins and Magliaro (1989) found that the differences between the hands for test of grip strength were smaller than the performance differences for a writing test. Both of these experiments support the notion that increasing task complexity increases the magnitude of the right-hand advantage. However, in neither of these studies was task difficulty quantified explicitly, rather the tasks were assumed by the authors to represent simple and complex tasks.

Only a few studies in the literature have manipulated task difficulty directly, using Fitts' Law (Fitts, 1954), in their investigations of manual asymmetries and task complexity. For example, Todor and Cisneros (1985) examined the performance of both hands across varying indices of difficulty and found that as index of difficulty increased, the relative difference between the two hands increased. Likewise, Annett et al. (1979) found in a peg-moving task that the differences between the hands became greater as the hole to peg ratio decreased, in other words, as the difficulty of the task increased.

More recent attempts to manipulate task difficulty have found that the performance difference between the hands does not increase with task difficulty (Van Horn & McManus, 1994; Bryden & Roy, 1999) as examined using several different peg-moving tasks. The nonsignificant findings of van Horn and McManus (1994) and Bryden and Roy (1999) contradict much of the previous literature (e.g., Annett et al., 1979). One plausible explanation is that the performance of the two hands has not been methodically investigated across a sufficient range of task difficulty. More specifically, one could speculate that the constant between-hand difference revealed in the studies of van Horn and McManus (1994) and Bryden and Roy (1999) are an artifact of having examined not only a limited range of indices of difficulty. Therefore, the following experiment was designed to examine systematically a wide range of task difficulty. A simple manual-aiming task was chosen because index of difficulty could be more simply manipulated than in a peg-moving task.

METHOD

Participants

Nine right-handed undergraduate and graduate students (age range 19 to 30 years) from the University of Waterloo participated in the present experiment, on a volunteer basis. Following the experiment, all participants completed the Waterloo Handedness Questionnaire Revised (Bryden, 1977), which was used to corroborate the participants self-professed handedness.

Apparatus

The manual aiming task was completed by having participants use a modified computer mouse on the graphics tablet, which moved a solid circle, or cursor, on a computer screen located approximately 50 cm away from the participants. The participant's task was to move the cursor onto a target (located either 25 or 100 mm from the starting position), such that the cursor (2 and 4 mm cursor sizes) overlaid the center of the target to which they were aiming. Each cursor size was presented with four different target sizes where the smallest target size matched the cursor size exactly and then target size increased in steps of 2 mm. Using Fitts' Law index of difficulty equation (Fitts, 1954), this resulted in eight different indices (3.06, 3.64, 4.64, 5.06, 5.64, 6.64, 12.49, and 14.29 bits of information). Five trials were presented for each amplitude/cursor/target combination, resulting in 80 trials for each hand. Reaction time (RT), movement time (MT), peak velocity of the hand (PV), time to peak velocity of the hand (TTPV), time after peak velocity (TAPV), percentage of movement time spent in deceleration (%TAPV), and resultant (RACC) were measured.

Procedure

Participants were asked to begin to move the cursor displayed on the computer screen as soon as they heard the starting tone. Their task was to move as quickly and as accurately as possible to the target. It was stressed that the cursor must land on the target for the trial to be counted. Participants pressed a button on the mouse to indicate they had accomplished their goal of landing on the target.

RESULTS

Data Reduction

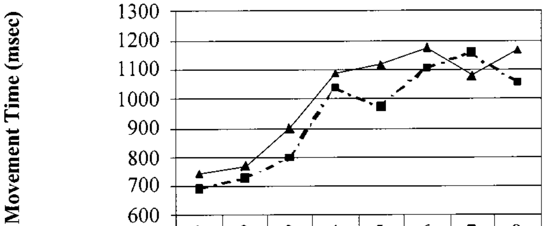
The data was initially filtered at 7 Hz using a second order dual-pass Butterworth filter. Reaction times were selected from each trial's velocity profile, where reaction time was equal to the point where the velocity curve deviated significantly from zero. Significant outliers of greater than two standard deviations were eliminated from the data set.

Analysis: Hand by Index of Difficulty

A repeated-measures analysis of variance was conducted with hand (2 levels) and difficulty (8 levels) as the factors of interest. A significant main effect for hand was

TABLE 1
F Ratios and Significance Levels for the ID Factor

Dependent variable	*F* ratio	Significance	Eta	Power
Movement time	16.975	0.0001	.496	1.00
Reaction time	9.149	0.0001	.478	1.00
Time to peak velocity	27.233	0.0001	.731	1.00
Peak velocity	226.48	0.0001	.958	1.00
Time after peak velocity	15.933	0.0001	.614	1.00
Percent time in decelaration	13.798	0.0001	.496	1.00
Resultant accuracy	8.335	0.0001	.455	1.00



Index of Difficulty (bits)	1	2	3	4	5	6	7	8
Right Hand	691	730	800	1037	975	1108	1159	1054
Left Hand	745	770	898	1090	1114	1177	1081	1168

Index of Difficulty (bits)

FIG. 1. Movement time as a function of index of difficulty for the right and left hands.

found for resultant accuracy ($F_{(1,10)} = 1.13$, $p = .024$), showing that accuracy was better for the nonpreferred left hand. A significant main effect of hand was also found for time to PV ($F_{(1,10)} = 13.309$, $p = .004$), where the left hand took significantly longer to reach peak velocity than the right hand. Significant main effects of difficulty were found all variables examined (mean squares, *F* ratios, and significance levels are presented in Table 1). In general, paired comparisons revealed that the most difficult conditions resulted in longer movement times, more time spent after peak velocity, lower peak velocities, and greater error. These findings indicate that the manipulations did indeed influence the difficulty of the task. Most importantly, however, no significant interactions between hand performance and task difficulty were found for movement time or any of the dependent measures examined.

DISCUSSION

In the current experiment, analysis revealed no interaction between index of difficulty and the hand with which the task was performed for the measure of movement time. Hence, the current experiment showed a constant between-hand difference for movement time across a broad range of task difficulty. The results thus appear to replicate the findings of van Horn and McManus (1994) and the first experiment of Bryden and Roy (1999), and indicate that the performance differences of the two hands remain relatively constant regardless of how difficult or easy a particular task may be.

The results of the current experiment seriously contradict the validity of one of the foremost feedback processing theories accounting for the right-hand advantage, which suggests that the right-hand/left-hemisphere system is superior at processing visual feedback. It has been argued that for low indices of difficulty, where the target size is large and the movement amplitude is small, very little, if any, visual feedback processing is required. Here it is thought that the movement is essentially ballistic in nature or preprogrammed. In contrast, it is assumed that visual processing is required to complete a task with a high index of difficulty. Therefore, if the advantage of the right-hand/left-hemisphere system was due to superior processing of visual feedback, one would expect large differences between the hands for both MT and TAPV for small targets, or for conditions with very little difference between the target and object size (low tolerance). Equally, one would expect negligible differences between the hands for these variables when the index of difficulty (targets very large, and amplitude small) was low and no visual feedback processing is required.

The research described here, however, appears to contradict the visual feedback theory of manual asymmetries, as no significant interactions between hand performance and task difficulty were found for either MT or TAPV.

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This is doi:10.1006/brcg.2001.1364.

Bias in Visual Attention Behavior in a Normal School-Aged Population

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Hemi-field visual-spatial attention was studied on a timed letter cancellation task in proficient readers from 7th to 9th grades. Participants maintained greater accuracy in identifying targets in the left quadrants (top/bottom) when compared with the right quadrants (top/bottom), revealing a leftward bias in their responses. Effects of gender and age were evident on performance; females scored significantly higher than males, and 9th graders scored significantly higher than 7th and 8th graders. Thus, a substantial shift in brain maturation may take place from 8th to 9th grades or from the ages of 13.0 to 14.11. Discriminative characteristics of the task are analyzed by assigning greater value to targets located in the top left quadrant. The 9th graders, as compared to the younger students, and the girls, as compared to the boys, evidenced a reading-direction-related bias toward systematic preference for the upper-left to lower-right quadrants.

INTRODUCTION

The terms ‘‘hemispatial neglect’’ or ‘‘visual neglect’’ describe a condition characterized by decreased attention or awareness to one side of space that often results in deficits evident in the daily activities of affected individuals. Most studies of the disorder have originated from individuals with right hemisphere damage, in whom inattention to the contralateral side of the lesion is the most prevalent symptom of the disorder (Weinstein & Friedland, 1977; McCarthy & Warrington, 1990; Heilman et al., 1993; Stone et al., 1993).

Few characteristics of the disorder are reported in children, because in them, its resolution after brain-damage tends to be rapid and often goes unreported. Ferro et al. (1984) stressed that hemispatial neglect in children can only be detected during its acute phase due to the transient nature of the disorder in a young population. Johnston and Shapiro report a single case study of a 14.3-year-old male with right rather than left hemispatial inattention particularly affecting reading following a left subdural hematoma at birth. Even fewer studies report on the characteristics of the development of visual-spatial attention in a normal population of children. VanVugt et al. (2000) studied the performance of normal 7- to 12-year-old children on a line bisection task, finding both gender- and age-related differences in the accuracy of their responses. Boys were reported to be more accurate in their bisection judgments when compared with girls, and also older children performed significantly better than the younger children.

Several questions arise when we try to understand visual attention mechanisms in a normal population, particularly children. Is attention equally distributed across the left, right, top and bottom fields of space on a visual search task, or can we find that visual attention is more concentrated on certain parts of the visual field? Furthermore, is visual attention still developing across adolescents, and are there gender differences in performance that can be appreciated?

As visual–spatial attention can be elicited and studied through various neuropsychological tasks and methods, we attempted to engender a reading-direction bias by deliberately employing letters on a cancellation task. This study seeks to explore the performance characteristics of a middle-school-aged population of normal children on a letter-cancellation task, taking into account reading-writing directional patterns, attentional focus, age, and gender.

The following questions are addressed:

1. What influence do age, grade level, and gender have on the performance of a timed letter-cancellation task?

2. To what extent are left-right and top-bottom patterns learned when reading and writing consistent with strategies employed on a letter-cancellation task that measures horizontal and vertical dimensions?

3. What are the discriminative characteristics of the letter-cancellation task in differentiating between participants who are systematic in their method of canceling targets from those who evidence more random patterns in target cancellation?

METHOD

Participants

Children in grades 7–9 aged 12.0–14.11 participated in this study. Of the 792 students, 51% were males. Participants selected were proficient readers and had maintained satisfactory academic progress. None had a history of learning problems, nor neurological, emotional, or sensory deficits that might affect performance.

Participants were instructed to complete a timed letter-cancellation task as one subtest of the attentional component of the Diagnostic Neuropsychological Battery of the University of La Habana (DNUH), a task previously applied in various populations (Cairo et al., 1999).

Stimuli

A total of 361 uppercase letters were arranged in 19 columns and 19 rows on a sheet measuring 216 mm in height and 268 mm in length. Targets consisted of 29 instances of the letter ‘‘P,’’ seven located in each of the four quadrants, plus one in the upper-left-most position.

This task was administered to small groups of children, in quiet classrooms, by an examiner and one assistant. The sheet was placed faced down in front of each participant until instructions to start were given and the page was to be turned over. Participants were instructed that the sheet should be kept in front of them and aligned to the midplane of their own bodies at all times during the performance of the task. One minute was set as a limit for participants to cancel all ‘‘P’’ targets located within the stimulus sheet. Instructors did not indicate where participants should begin canceling the targets, thus allowing participants to select their own method of working through the task.

Discriminative Characteristics of the Stimuli

Three methods of analysis were employed:

1. the number of ‘‘P’’s canceled
2. a measure of sustained systematicity
3. a measure of reading-related bias.

The first method takes into account only the number of ‘‘P’’s canceled by participants. A raw score based on the total number of cancellations is thus obtained.

The second method is geared at discriminating students who work carefully and systematically through the task from those who may cancel targets in a more random manner. By ‘‘sustained systematicity’’ we refer to the fact that all targets prior to the last crossed out target are also canceled, thus providing a final score that encompasses all targets up to and including the final canceled ‘‘P.’’ A participant may obtain a maximum score of ‘‘1’’ for sustained systematicity in responding only if all ‘‘P’’ targets prior to the last ‘‘P’’ target are also canceled. A score of ‘‘1’’ would be derived by dividing the number of the last ‘‘P’’ target by the maximum possible score, which would be the same number. On the other hand, if one ‘‘P’’ was missed, by taking into account the missed target, we would divide 21 into 22 which would yield .96; if two ‘‘P’’s were missed, we would divide 21 into 23, obtaining a value of .91. Therefore, missed targets prior to the final ‘‘P’’ would result in a score that is diminished proportionately with the number of missed targets.

The reading-related method of response analysis focuses on the importance of the left visual field and left–right, top–bottom overlearned patterns in our population. A participant’s responses can thus be analyzed not only in terms of the raw scores and sustained systematicity in responding, but also by assigning a differential value to the errors committed based on the quadrant in which they occurred.

The presence of leftward and upward biases shows that increased attentional resources are allocated by most individuals in the top-left quadrant on such a task. When analyzing responses with discriminative purposes, we can therefore obtain a raw score that also takes into account the location-value of the missed targets, which we termed the Error Location Index. Whereas the former method (Sustained Systematicity Index) provides us with a measure of attention style, it is the latter (Error Location Index) that takes into account a strategy that may be conditioned by directionality in reading–writing patterns within our population.

We therefore generated a formula for scoring performance based on the location of missed targets. By assigning a value of 29 to the first ‘‘P’’ in the upper-left-most position, and 28, 27, etc. to subsequent ‘‘P’’s, a maximum value of 435 is possible. Summing the positional values of the various cancelled items (see Table 1) and subtracting this number from the cumulative maximum value (435), yields the difference. This difference is subsequently divided by the total maximum value. The highest possible score a participant may obtain is 1.0.

TABLE 1
Error Location Index to Calculate Performance Based on the Location of Missed Targets

	Error location index	
Location	Unit value	Cumulative value
L1	29	29
L2	28	57
L3	27	84
L4	26	110
L5	25	135
L6	24	159
L7	23	182
L8	22	204
L9	21	225
L10	20	245
L11	19	264
L12	18	282
L13	17	299
L14	16	315
L15	15	330
L16	14	344
L17	13	357
L18	12	369
L19	11	380
L20	10	390
L21	9	399
L22	8	407
L23	7	414
L24	6	420
L25	5	425
L26	4	429
L27	3	432
L28	2	434
L29	1	435

$$\frac{(435 - \text{missed})}{435} = \text{Performance} - \text{Score}$$

RESULTS

Demographic Variables and Directional Bias

Since the first question of our study was aimed at determining the influence of age/grade level, and gender on performance, statistical significance among the means was tested. A one-way ANOVA was performed for grade and separately for gender. Significant differences between the grades were found for performance in the letter cancellation task, $F(2, 789) = 13.28$, $p < .001$. Participants' scores according to grade level and age were such that seventh graders had mean scores (17.83) not significantly less than those of eighth graders (17.88), Tukey HSD test $p < .992$. Significantly higher scores were obtained by 9th graders (19.44), who outperformed 7th and 8th graders $p < .001$. This same level of significance was also evident when comparing the performance of 9th graders with that of 8th graders. A one-way ANOVA for gender revealed that females consistently outperformed males, $F(1) = 10.442$, $p < .001$ (see Fig. 1).

Directional Patterns

To what extent are overlearned reading and writing directional patterns reflected in the way that participants cancel targets in the letter cancellation task? Our predicted

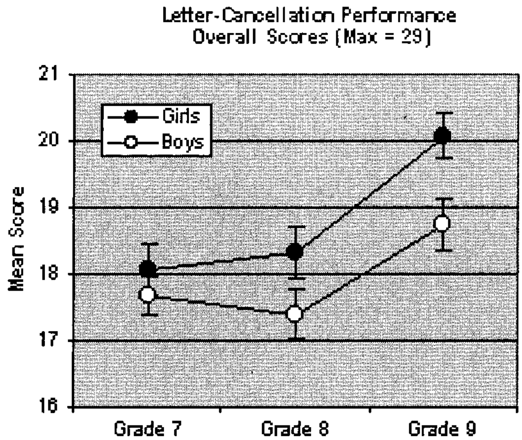

FIG. 1. Mean score performance on letter cancellation task by grade and gender.

results in terms of left–right and top–bottom reading/writing patterns in our population were that participants should perform with greater accuracy on the top-left (TL) quadrant, followed by the top-right (TR) quadrant, then the bottom-left (BL) quadrant, and finally the bottom-right (BR) quadrant which was the one predicted to evidence the lowest percentage of accuracy. In other words, we expected that both top quadrants would yield higher percentage of accurate responses when compared with bottom quadrants; and both left quadrants would reveal more accurate response rates when compared with their respective right quadrants. Our results were in partial accordance with our predictions, revealing preponderantly higher scores on the top quadrants when compared with the bottom ones (TL + TR = 72.2% vs BL + BR = 54.0%). Higher scores were also evident when summing the two left quadrants and comparing them with the corresponding right ones (TL + BL = 75.6% vs TR + BR = 52.1%). However, there was no difference between the scores in the LB and TR quadrants, suggesting that both horizontal and vertical processes play important roles in directing visual search behavior. Thus, our results confirm our predictions that both left–right and top–bottom reading direction may be part of the strategy used by middle-school participants on our letter cancellation task.

Results Reflecting Discriminative Characteristics of the Stimuli

Applying the Sustained Systematicity Index to measure performance across grades and gender, we find that our participants reach an average score of .72. Breakdown by gender revealed females performing somewhat higher than males (females = .73 vs males = .71). We can also see that scores on the Sustained Systematicity Index show steady improvement with increased age and grade level: 7th grade = .70; 8th grade = .72; 9th grade = .74.

Results obtained by applying the Error Location Index (reading related bias measure) are on a par with those obtained on the Sustained Systematicity Index. We find that when analyzing location values of the noncanceled targets, our participants reach an average score of .66. Females again perform somewhat higher than males (females = .67 vs males = .64). Scores on the Error Location Index consistently improve with increased age and grade level: 7th grade = .63; 8th grade = .66; 9th grade = .69.

DISCUSSION

We may assume brain mechanisms controlling hemi-field attention are contralaterally based because of the data from adults with brain damage. Interestingly, in that population substantially more evidence of left-visual field neglect is reported than right-visual-field neglect, since it is more common and severe following right-brain damage than left-brain damage (Robertson & Halligan, 1999). Kinsbourne (1987) accounts for this discrepancy by stating that directional attentional vectors of the left hemisphere are relatively stronger than those in the right hemisphere. When an activational imbalance is produced by hemispheric brain damage, failure of the right hemisphere to inhibit the left hemisphere is responsible for the strong rightward orienting tendency. The intact left hemisphere is thus unopposed and therefore left-sided neglect ensues. Such a picture is even more striking when one compares it to the results of the current study, which show a developing leftward bias in visual attention in a population of adolescent normals. Moreover, in addition to this left-side attentional bias, we find that the top-quadrant is also favored in our normal population. These two developing biases suggest that the influence of reading-writing direction shapes the deployment of visual spatial attention on a letter-cancellation task, progressively throughout early adolescence.

In conclusion, it appears that in early adolescence left-right and top-bottom directional patterns that are also present in reading and writing, influence the strategy used at various age levels by boys and girls on a letter-cancellation task. We propose two methods to evaluate the extent to which participants employ this strategy. Additional non-letter-cancellation tasks need to be employed with a similar population, and a similar task on readers of a right-to-left orthography should be conducted in order to confirm our interpretation.

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