A Neuropsychological Investigation of Verbal and Nonverbal Fluency: Perspectives on Asymmetries in Frontal Lobe Functioning

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A NEUROPSYCHOLOGICAL INVESTIGATION OF VERBAL AND NONVERBAL FLUENCY: PERSPECTIVES ON ASYMMETRIES IN FRONTAL LOBE FUNCTIONING

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ABSTRACT

The neuropsychological construct of fluency refers to productivity under timed and limited search conditions. Verbal fluency tasks, such as the Controlled Oral Word Association Test (COWAT), require production of words under specific constraints (i.e. words that begin with "F"), whereas nonverbal fluency tests, such as the Design Fluency Test (DFT), require generation of unique and unnameable designs. Asymmetric deficits have been obtained, with verbal impairments associated with left frontal pathology and nonverbal impairments with right frontal involvement. These fluency constructs, however, have not been systematically examined in conjunction with one another, or with other frontally-mediated tasks. Therefore, this experiment evaluated verbal and nonverbal fluency, and their relationship to tasks purported to be sensitive to frontal lobe functioning. A double dissociation was predicted; the COWAT would be associated with left but not right frontal tasks, but the reverse pattern would be evident for the DFT. Left frontal tasks included the Trail-Making Tests and the

Stroop Color-Word Test, whereas right frontal tasks consisted of the Ruff Figural Fluency Test (RFFT) and newly created measures of facial accuracy and intensity. Bilateral motor tasks (i.e. dynamometer and finger tapping) were also evaluated.

In this sample of male college students (N = 60), multivariate analyses (MANOVAs) indicated that the left-hemisphere variables successfully discriminated subjects classified as verbally fluent or verbally nonfluent, but did not do so with nonverbal fluency. The opposite pattern was obtained with right hemisphere variables, which was due to the RFFT rather than the facial measures. Measures of facial accuracy and intensity, as well as motor tasks, were minimally related to either of the fluency measures. Additionally, univariate analyses (ANOVAs) revealed that verbally fluent subjects performed better than verbally nonfluent subjects on Trails B, but not A, and on selected components of the Stroop.

These findings are discussed in regard to their capacity to demonstrate asymmetries in frontal lobe functioning. Relationships between the presumed frontal measures and fluency constructs is also used to examine the unique ways in which fluency measures may challenge the frontal lobes in higher-order cognitive processing. Recommendations for the development of improved verbal and nonverbal fluency measures are provided.

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INTRODUCTION

Fluency is a neuropsychological construct which refers to the productivity of material, including that of a verbal or nonverbal nature, to confrontation under timed and limited search conditions (Strub & Black, 1985). Most simply, verbal fluency tests require listing of words that begin with a particular letter or items in a category (e.g. animals), whereas nonverbal fluency tasks require generation of unnameable designs or drawings. Performance is maximized when individuals are behaviorally and cognitively spontaneous, organize their output, employ problem-solving strategies and, once a strategy has been completed, are able to readily shift to an another strategy. Without these capabilities, output tends to be impoverished with generation of few unique designs or words, and/or perseverative, with frequent repetitions of previous stimuli. Individuals with frontal lobe damage have been demonstrated to produce such output and are subsequently judged as impaired or nonfluent on these tasks (see Lezak, 1983).

More specifically, verbal fluency refers to the ability to produce oral or written verbal material without word finding pauses or failures in word searching (Strub & Black, 1985, p. 53). While aphasics often demonstrate impaired fluency, individuals with relatively normal expressive speech may show subtle impairments on formal testing (i.e. sparse verbal output). The classic verbal fluency test, the Controlled Oral Word Association Test (COWAT), requires subjects to name as many words as possible beginning with a given letter during a one-minute interval (Benton, 1968). This verbal fluency test requires a self-initiated memory search with successive shifts in mental set and is thought to tap a high level of word-finding efficiency which is particularly sensitive to left frontal dysfunction (see Borokowski, Benton, Spreen 1981; Strub & Black, 1985). Nonverbally, the fluency construct has been evaluated with the Design Fluency Test (DFT), a nonverbal analogue to the COWAT which requires production of unnameable designs (Jones-Gotman & Milner, 1977). As predicted, right frontal subjects were impaired on this task, but not on a verbal fluency task, whereas left frontal subjects were impaired on verbal fluency but not the DFT. This double dissociation suggests that functional asymmetries may exist in frontal lobe functioning. While the DFT is frequently employed clinically (Lezak, 1983), it has been minimally used for research purposes apparently due to scoring difficulties.

Though verbal and nonverbal fluency constructs are frequently employed in neuropsychology, they have yet to be simultaneously evaluated and related to other neuropsychological tests. In normals, for instance, subjects may be demonstrated to be verbally fluent and nonverbally nonfluent, and conversely, verbally nonfluent and nonverbally fluent. Such groupings have yet to be empirically demonstrated, but provide a potentially viable method of specifying anterior functioning. Based on such groupings, it is predicted that these groups would perform differentially on neuropsychological instruments putatively sensitive to right and left frontal lobe functioning. A differential pattern of responding based on these fluency groupings would extend and validate this construct, and implicate functional asymmetries in frontal lobe functioning.

Therefore, the purpose of this experiment was to extend the fluency construct by constructing subgroupings of subjects who are nonverbally fluent, but verbally nonfluent, and conversely, verbally fluent, but nonverbally nonfluent. It was hypothesized that each fluency grouping would demonstrate selective impairments on neuropsychological tasks purported to be associated with either left or right frontal lobe functioning. Specifically, subjects who are nonverbally nonfluent were predicted to perform relatively poorly on right frontal tasks, and verbally nonfluent subjects were predicted to perform relatively poorly on left frontal tasks. Facial expressiveness, both intensity and accuracy, and the Ruff Figural Fluency Test, were the variables thought to tap right anterior functioning. Trails A and Trails B and the Stroop Color-Word Test evaluated left anterior functioning. Other putative frontal lobe tasks which tap motoric functioning of each hand (i.e. strength, perseveration) were also administered. In subsequent sections, frontal lobe functioning will be briefly reviewed and the verbal and nonverbal fluency literatures examined.

The Frontal Lobes

The importance of the frontal lobes for human brain activity is reflected in their neuroanatomy. Their size, estimated to be 24% to 32% of the total cortical surface, is considerably larger than that of non-human primates and other mammals (Goldman-Rakic, 1984). The frontal lobes also have extensive reciprocal connections with other cortical, limbic and subcortical areas and are the only cerebral region with such comprehensive connections. Moreover, they are the latest brain area to phylogenetically develop and their anterior regions (i.e. the prefrontal cortex) have undergone much greater development in the human than in any other species (see Fuster, 1989, pp.3-32). Their unique anatomical and evolutionary status led Tilney (1928) to submit that the entire period of human existence could be viewed as the "age of the frontal lobe". The following review of the frontal lobes will focus on their anatomy and cognitive functions, the neuropsychological sequelae of their damage and, finally, how they have been conceptualized to mediate fluency.

The cortex and underlying white matter of the frontal lobes is the site of interconnections and feedback loops between the major sensory and motor systems, linking and integrating all components of behavior (Luria, 1973, pp. 187-221). Pathways carrying information about the external environment from the posterior cortex and information about internal states from the limbic system converge in the prefrontal cortex. The former connections may occur either by direct corticocortical afferents or via the thalamus and terminate primarily in dorsolateral cortex (i.e. the outer sides of the frontal lobe), whereas the latter mostly proceed via the dorsomedial thalamus and are transmitted more diffusely to either dorsolateral or orbitofrontal regions (i.e. between the hemispheres) (see Stuss & Benson [1984] for discussion of these connections). Based on these extensive connections, anterior regions of the frontal lobes are the site at which incoming information from all sources, including external and internal, is processed, integrated and entered into ongoing activity (Lezak, 1983, pp.78-80).

Given their anatomical connections and phylogenetic development, it is not surprising that early theorists considered the frontal lobes to mediate the highest cognitive activities. These included will, recent memory, abstract behavior, foresight and ethical behavior (Stuss & Benson, 1984, for review). A major controversy was thus provoked when Hebb (1939) reported that a small series of patients who had undergone surgical removal of frontal tissue showed no decrements on standardized intelligence testing. A massive body of literature has since examined this issue with a wide range of both negative and positive findings (see Stuss & Benson, 1984, pp. 195-199). Though the intellectual processes mediated by the frontal lobes have yet to be conclusively determined, Hebb's and similar subsequent findings have stimulated considerable research regarding the cognitive functions mediated by the frontal lobes.

Neuropsychological research has established that a wide range of cognitive functions may be compromised with frontal damage. Lezak (1983), however, claims the resulting deficits are less obvious than those observed with posterior damage and subtle deficits in how a frontal patient responds are often apparent versus the content or the what of responding. Failures on test items are thus more likely to result from faulty approaches to problems rather than from linguistic, memory and/or perceptual deficits. If so, Hebb's observations are limited by use of structured tests that primarily measured old learning and well-established skills rather than the ability to solve unfamiliar problems or to exercise judgment. Milner and Petrides (1984) argue that standardized intelligence tests measure convergent thinking in which a single correct answer for a question or problem exists, whereas tests of divergent thinking emphasize the number and variety of responses that can be produced to a single question. Such a test might require listing the different possible uses of a object, such as a brick, or listing all the words beginning with a target letter. These and similar divergent thinking tasks require the ability to think flexibly, to use inventive problem-solving approaches, to shift mental set and to organize thought processes. Deficits on tests tapping these functions are frequently noted secondary to frontal injury and will be specified below.

Behavioral and cognitive deficits associated with prefrontal damage tend to be supramodal, apparent in a number of modalities. Though similar impairments may occur with other cerebral lesions, these are apt to be associated with specific intellectual, sensory or motor disabilities. Accordingly, disturbances associated with frontal lobe damage can be roughly classified into five general, but overlapping, categories (Fuster, 1989, 127-141; Hecaen, 1962; Lezak, 1983, pp. 78-82). First, decreased behavioral spontaneity and initiative is typically apparent and, at the extreme, apathy, unresponsiveness and/or mutism may be present. Second, frontal patients have difficulties in making mental or behavioral shifts and lack what is frequently called "cognitive flexibility". The ensuing repetitive continuation of a behavior or specific responses to various questions, tasks or situations is referred to as perseveration. Third, frontal damage may be associated with difficulties in self-regulation or self-modulation of ongoing behavior as evidenced by impulsivity, disinhibition and difficulty in suppressing wrong or unwanted responses. Fourth, deficits in self-awareness may be apparent with impairments in perceiving errors, appreciating one's impact on others, and/or self-monitoring. Finally, these patients may demonstrate concrete thinking with abstraction deficits; objects, experiences and/or behaviors are interpreted in the most literal sense. Associated with such deficits are impairments in planning and strategy generation which make goal-directed behavior difficult. Overall, the above deficits are frequently not readily observed in standardized testing where an examiner directs the testing, structures the activities and makes discretionary decisions (Teuber, Battersby, & Bender, 1951). Rather, frontal lobe dysfunction is most obvious in tasks which require self-monitoring, cognitive flexibility, strategy generation and the ability to shift mental set. These "executive" frontal lobe functions are thus operative, often in subtle ways, in vast amounts of behavior and cognition.

Given the functions mediated by the frontal lobes, verbal and nonverbal fluency measures are simple, yet effective means of evaluating their integrity. Verbal fluency tests require subjects to name as many exemplars of a given category (i.e. words beginning with "F" or things found in a grocery store) as possible within a circumscribed time, whereas nonverbal measures require the invention of nonsense designs. Successful performance on these confrontational tests requires spontaneity (Zangwill, 1966), self-initiation of memory searches (Goodglass, 1986) and the organization of thought processes with development of a general strategy (Estes, 1974; Lezak, 1983, p. 330). Estes (1974) submits that successful performance on such tests depends on the ability to organize output in terms of clusters of meaningful words. Effective strategies with tests which require words to a specific letter might involve words beginning with the same initial consonant (e.g. content, contain, contend) or variations on a theme (e.g. sew, stitch, seam), whereas tests requiring items in a category (e.g. animals) might include use of general categories (e.g. farm, domestic or wild). Moreover, tests of this type dictate successive shifts in mental set as completion of one strategy requires initiation of another.

Without this cognitive flexibility, subjects perseverate or lapse into continual repetition of the same response. This ultimately results in impoverished output with a low number of items generated and probable judgment of the subject as nonfluent. In all, fluency tests are especially sensitive to strategy development and cognitive flexibility and are ideally suited for evaluation of frontal lobe functioning.

Fluency Constructs

Verbal Fluency

In a review of classical neurological research, Zangwill (1966) summarized the verbal disabilities in patients with left prefrontal lesions who were not considered clinically aphasic. He observed decreases in the spontaneity of speech, in the absence of an articulatory disorder, difficulty evoking the appropriate words or phrases and, in some cases, impairments of verbal thought processes. These impressions were later validated by early and systematic neuropsychological investigations. Milner (1964,1967) examined subjects who had undergone lobectomies of varying locus and extent for relief of focal seizures. Reductions in verbal fluency were observed in subjects with left prefrontal excisions compared with right prefrontal or left temporal excisions. Benton (1968) found that in nondysphasic patients with cerebrovascular disease, left frontal patients showed the most sparse performance on a verbal fluency measure. Relative to controls, 70% of the left anterior and 38% of the right anterior patients were classified as impaired on this task. While heightened verbal fluency impairments were evident in left anterior disease, the depressed right anterior scores suggested a potential bilateral component of this task. Furthermore, Perret (1974) and Pendleton, Heaton, Lehman, & Hulihan, (1982) found that subjects with any left hemisphere pathology performed significantly more poorly on verbal fluency tests than those with right hemisphere lesions, though both groups had lower scores than controls (cf. Miceli, Caltagirone, Gainotti, Masullo & Silveri, 1981). Subjects with focal frontal lobe lesions scored significantly lower than subjects with either focal temporal or posterior lesions, but left frontal lobe subjects demonstrated the greatest impairments. Pendleton et al. (1982) found these latter subjects to generate 27% less words than right frontal subjects. In all, this research indicates verbal fluency may be depressed with damage throughout either cerebrum, but is especially affected by left frontal involvement.

More recent experimental work has substantiated these findings in patients with diverse etiologies. Martin, Loring, Meador, and Lee (1990) evaluated verbal fluency in temporal lobe epileptics prior to and following unilateral anterior temporal lobectomy. Verbal fluency decreased for both right and left temporal groups following the procedure, but left hemisphere patients demonstrated heightened impairments at both pre and post tests (cf. Hermann & Wyler, 1988). Crockett, Bilsker, Hupwitz and Kozak (1986) found that subjects with frontal lobe pathology were more impaired on fluency measures than either nonfrontal or psychiatric patients. Though laterality was unfortunately not reported, verbal fluency was a better predictor of frontal pathology than either the Wisconsin Card Sorting Test or the Category Test. Similarly, Butler, Rorsman, Hill, and Tuma (1993) found simple (e.g. words generated to a single letter) and complex (e.g. possible jobs associated with an object) fluency measures to be impaired in subjects with frontal tumors. Laterality effects were not statistically analyzed due to the small sample size, though a trend indicated that left frontal subjects were more impaired than right frontal subjects. In schizophrenia, reduced verbal fluency has been observed (Beatty, Jocic, Monson, & Staton, 1993; Gruzelier, Seymour, Wilson, Jolley, & Hirsch, 1988; Kolb & Whishaw, 1983), providing behavioral substantiation of the purported frontal pathology (i.e. hypometabolism) in this disease (Berman, Illowsky & Weinberger, 1988). Overall, though the above experiments have not unequivocally evaluated laterality, they implicate the general importance of frontal lobe integrity for successful performance of verbal fluency tasks. Application of more sophisticated technologies has further specified the importance of these cerebral regions, particularly of the left hemisphere, for verbal fluency.

Positron emission tomography (PET) is a functional imaging procedure which measures activity-related changes in regional cerebral blood flow during behavioral or neuropsychological tasks. With this technology, Frith, Friston, Liddle, and Frackowiak (1991) and Petersen, Fox, Posner, Mintun, & Raichle (1988) found increased cerebral blood flow to the left dorsolateral prefrontal cortex during verbal fluency tasks. In an earlier PET experiment, Parks et al., (1988) found a 23% increase in cerebral glucose metabolism over the entire cortex during verbal fluency relative to a resting state. The greatest activation was observed bilaterally, in frontal and temporal regions, which led these researchers to postulate a "system" involved in verbal fluency. They suggested that this system incorporates a concentration of intersecting pathways within the frontal lobes which, based on clinical data, are most vulnerable to disruption with left frontal damage. Interestingly, an inverse correlation has been observed between verbal fluency and subsequent activation bilaterally in frontal (Boivin et al., 1992) and in both frontal and temporal lobes (Parks et al., 1988). These findings implicate that "verbally-fluent" brains may work more efficiently, generating lower metabolic rates. It should be observed, however, that these findings are correlational and not based on actual cerebral metabolism during the fluency tasks. Nonetheless, the PET literature indicates bilateral, but especially left frontal, increases in cerebral metabolism concurrent with performance on verbal fluency tasks.

Nonverbal Fluency

Despite methodological problems, the Design Fluency Test (DFT) remains the standard assessment tool for nonverbal fluency (Lezak, 1983, p. 520). In their classic experiment, Jones-Gotman and Milner (1977) found that subjects with right frontal and fronto-central damage were impaired on the DFT, as evidenced by generation of few unique designs, but not on verbal fluency measures (see also Jones-Gotman, 1990). A double dissociation was found as left frontal subjects were impaired on verbal fluency tests, but not the DFT. Similar findings in epileptic children after focal surgical resection were also reported by Jones-Gotman (1990), but have yet to be systematically analyzed due to sample size limitations. In a qualitative analysis of right frontal subjects' responses, Jones-Gotman and Milner (1977) observed the output to not only include a low number of novel designs, but to be marked with perseverative errors. It was concluded that these subjects perseverated and lapsed into stereotyped repetitions of initially produced designs, because original responses were difficult to generate. Similarly impaired output on the DFT has been observed in schizophrenia (Beatty et al., 1993; Kolb & Whishaw, 1993), in frontal dementia (Canavan, Janota, & Schurr, 1985; Neary, Snowden, Mann, Northen, Goulding & Macdermott, 1990), in Parkinson's disease (Taylor, Saint-Cyr, & Lang, 1986), in frontal tumors (Butler et al., 1993) and in right thalamic infarction (Speedie & Heilman, 1983). Though evidence of laterality effects are not conclusive, the DFT does appear sensitive to frontal lobe dysfunction and is one of the few neuropsychological tests purported to tap right frontal lobe functioning.

Despite the considerable theoretical influence of the DFT, a number of methodological problems have hampered its use. Perhaps the most troublesome issue is the scoring and coding of the designs which, because they may be similar, may make interjudge agreement on perseverations and ultimately the number of novel designs difficult (see Ruff, Light, & Evans, 1987). Unfortunately, many of the above experiments used only a single rater and hence did not examine this reliability issue. However, a number of researchers have recently examined this issue and employed multiple judges. Woodard, Axelrod and Henry (1992) and

Jones-Gotman (1990) found good to excellent reliabilities (.6 to .9) for raters instructed to use their independent understanding of the scoring criteria of the original DFT. Also, Taylor et al., (1986) obtained excellent interrater reliabilities (.97) with trained raters. Though more systematic research is essential to establish consensually adapted scoring criteria and training procedures, these experiments indicate that adequate to excellent interrater reliability is obtainable.

Domain-Specific Variables

Left Hemisphere Variables

Trail Making Test Parts A and B. The Trail-Making Tests are among the most frequently administered neuropsychological measures. Trails A simply requires the sequencing of a set of numbers, whereas Trails B demands that numbers and letters be connected in an alternating sequence. These tasks require sustained attention, the ability to shift perceptual set, and psychomotor tracking and speed (Lezak, 1983). Trails B, with its requirement to rapidly shift set between numbers and letters, is thought to be particularly sensitive to left frontal lobe functioning (Stuss & Benson, 1984). Evidence for this hypothesis is mixed (Wheeler, Burke, & Reitan, 1963; Wedding, 1979). However, Huntzinger (1989) found verbally nonfluent dyslexic children to perform slower on Trails B, but not Trails A, compared to fluent dyslexic children and control subjects. Though the Trail-Making Tests are quite sensitive to the presence of brain damage, their ability to localize damage remains controversial (see Lezak, 1983, 556-559).

The Stroop Color-Word Test. The Stroop Color-Word Test is a frequently employed assessment tool used to evaluate a range of basic psychological processes, including mental processing speed, cognitive flexibility, resistance to interference, and cognitive complexity (Golden, 1978). It requires subjects to read words in Part 1 (Word), to name colors in Part 2 (Color), and to name the color words are printed in rather than the words themselves in Part 3 (Color-Word). This final part requires the suppression or inhibition of the habitual response of reading a word and using it according to its meaning. Research indicates that left hemisphere damaged subjects are impaired on all parts relative to right hemisphere subjects and controls (Golden, 1976; Nehemkis & Lewinsohn, 1972; Perret, 1974). Importantly, both Perret (1974) and Golden (1976) found left frontal subjects to demonstrate the greatest impairments on the Color-Word part. In general, the Stroop is sensitive to left hemisphere damage as it is a verbal task and, in particular, to left frontal damage in the Color-Word part because it requires inhibition of a habitual verbal response (Perret, 1974).

Right Hemisphere Variables

Affect Expression. Borod and colleagues are responsible for generating and standardizing much of the facial expression research (see Borod, 1993, for review). Borod, Koff, Lorch and Nicholas (1986) and Borod, Koff, Lorch, Nicholas and Welkowitz (1988) rated posed and spontaneous facial expressions to affect-inducing slides of right and left hemisphere damaged subjects. Relative to left hemisphere subjects, right hemisphere subjects were judged to be less accurate in posing the target affective face and, in the spontaneous condition, judges were significantly less able to identify the elicited emotion. In posed paradigms, similar accuracy impairments have been observed (Borod et al., 1990; Kent, Borod, Koff, Welkowitz & Alpert, 1988) as well as decreased expressiveness (Bruyer, 1981). These deficits have been demonstrated to be independent of buccofacial apraxia, paralysis or facial mobility (Borod et al., 1988). In spontaneous paradigms, right hemisphere subjects have been found to express affect less accurately and less intensely than left hemisphere subjects (Blonder, Burns, Bowers, Moore & Heilman, 1993; Buck & Duffy, 1980). Minimal valence effects (i.e. positive versus negative emotions) have been observed in the spontaneous paradigms, but the data are mixed in the posed paradigms, with support for selective impairments of negative (Bruyer, 1981) and positive affects (Borod et al., 1986). Though this valence issue is critical for theoretical purposes (see Davidson & Tomarken, 1989), it has yet to be fully resolved (see Borod, 1993). Overall, right hemisphere damaged subjects have been judged to display affect, whether in posed or spontaneous paradigms, less intensely and less accurately than left hemisphere subjects.

However, expressive differences between left and right hemisphere subjects have not consistently been observed in posed (Caltagirone et al., 1989; Kolb & Taylor, 1990) or spontaneous paradigms (Mammucari et al., 1988; Weddell, Trevarthen & Miller, 1988). Two of these experiments, however, demonstrated that, irrespective of laterality, anterior subjects were less expressive than posterior patients (Weddell et al., 1988; Kolb & Taylor, 1990). These findings contradict Borod's general thesis, though the methodologies of these, and similar experiments which have failed to find selective right hemisphere effects, have been critiqued (Borod, 1993; Buck, 1990; Tucker, 1993). Specifically, these experiments have relied heavily on the use of facial action coding procedures, particularly the Facial Affect Coding System (FACS) (Ekman & Friesen, 1978), which precisely detail each facial movement during an expressive display. Borod (1993) submits that these measures are less sensitive than judges' accuracy or intensity ratings of facial expressions. Piecemeal FACS measurements neglect the gestalt of the displayed face and fail to tap the complex skills humans use to perceive and to decode facial configurations (Dopson, Beckwith, Tucker & Bullard-Bates, 1984). Relative to facial action coding procedures, Buck (1990) notes that judges are more able to capture "the nuances of communicative facial expression" (p. 278). Furthermore, if the ultimate function of emotion is to communicate, as argued by some theorists (see Buck, 1990; Darwin, 1872), the use of human raters with familiarity in expressive interpretation would clearly be superior to coding systems. Overall, judges' accuracy and intensity ratings of expressed faces have been demonstrated to be sensitive to differences between left and right hemisphere impaired subjects.

In addition to these laboratory findings, Ross (1993) provides clinical support that right hemisphere damage results in impaired affect expression. He postulates an anterior-posterior emotional prosody circuit in the right hemisphere, which is organized for emotional expression and comprehension analogously to the organization of propositional speech in the left hemisphere. With right hemisphere damage, an aprosodia is hypothesized to occur with subsequent deficiencies in processing the prosody and intonation of speech. A motor aprosodia is a deficit in the ability to impart affective intonation or variation to speech, and it is thought to occur with anterior right hemisphere damage, whereas a receptive aprosodia refers to an inability to accurately perceive these components and it results from posterior damage (see Gorelick & Ross, 1987). Subjects with a motor aprosodia have flat, spontaneous speech without intonation, are unable to impart affect to neutral sentences, to make affective faces, or to covey affect via gesture (Ross, 1981; Ross & Mesulam, 1979; Ross & Rush, 1981, cases 2, 3, 4). Though affect perception remains intact, they are unable to convey affect via the above-listed finely-graded behaviors. These findings led Ross to conclude that anterior regions of the right hemisphere are critical for affect expression (Gorelick & Ross, 1987; Ross, 1993).

<u>The Ruff Figural Fluency Test</u>. The Ruff Figural Fluency Test (RFFT) is a structured nonverbal or figural fluency measure (Ruff, 1988). Given varying dot matrices, subjects are instructed to connect the dots in as many unique ways as possible within a set time period. Nonverbal fluency is the total number of unique designs generated minus the number of perseverations or designs repeated within each part. The test has been normed on children and adults with varying educational levels and has adequate psychometric properties (Evans, Ruff & Gualtier, 1985; Ruff,

Light, & Evans, 1987; Ruff, 1988; Vik & Ruff, 1988). Moreover, Ruff, Evans, & Marshall (1986) found figural fluency to be independent of motor speed, suggesting that this fluency measure is a function of cognitive rather than motoric processes. Figural fluency has also been found to be modestly correlated with performance, but not verbal IQ, (Ruff et al., 1987) and to be positively, but not significantly, related to verbal fluency (Ruff et al., 1986; Ruff et al., 1987; Vik & Ruff, 1988). This latter finding is important and implicates a potential dissociation between verbal and nonverbal fluency constructs, though it does require improved statistical confirmation.

Due to its recent development, only a small number of experiments have examined the RFFT in neurological populations. In a sample of brain-injured subjects, Ruff, Evans & Marshall (1986) found figural fluency to be linearly related to the degree of trauma, from mild to severe, with severe subjects generating the fewest figures. This finding validates the instrument's sensitivity to the extent of brain damage. More recently, Ruff, Allen, Farrow, Niemann, & Wylie (1994) found that subjects with right frontal damage were more impaired on the RFFT than left frontal and posterior subjects (Study 2). A handful of case studies also support this finding (Ruff et al., 1994, Study 1; Ruff, 1988).

Motor Variables

Dynamometer. A dynamometer is a device used to measure grip or hand strength (Dodrill, 1978). This simple task requires a motor response which is recognized as a function of precentral and premotor cortical areas (Stuss & Benson, 1984). These cortical areas control the contralateral distal extremities, and lateralized lesions are frequently associated with contralateral decreased strength, perseveration, and motor fatigue (Luria, 1973, pp. 176-186). More specifically, Huntzinger (1989) found verbally nonfluent dyslexic children to be weaker and to demonstrate greater perseveration across hands than fluent dyslexic children and control subjects. In normals, increased fatigue and perseveration have been observed at the left hand (Harrison & Pauly, 1990), whereas depressed women displayed significantly less perseveration at the left hand than nondepressed women (Crews & Harrison, 1994). These findings suggest that motor perseveration as assessed via the hand dynamometer may be sensitive to functional cerebral asymmetries.

Finger Tapping. The Finger Tapping Test (FTT) is a component of the Halstead-Reitan battery (Reitan & Davidson, 1974) and is probably the most widely used test of manual dexterity. The apparatus consists of a tapping key with a device for recording the number of taps. Brain damage has a general slowing effect on finger tapping rate (Dodrill, 1978) and lateralized lesions typically result in slowing of the tapping rate of the contralateral hand (Finlayson & Reitan, 1977; Haaland & Delaney, 1981).

Summary, Rationale, and Hypotheses

Fluency is a frequently employed construct in neuropsychology and evaluates the degree to which material, either verbal or nonverbal, can be effectively generated to confrontation. Because performance on fluency measures is thought to be maximized with initiative, cognitive flexibility and the use and development of strategies, they are hypothesized to be particularly sensitive to frontal lobe functioning. Considerable data indicate that verbal fluency is especially depressed with damage to anterior regions of the left hemisphere, though substantiation of compromised nonverbal fluency secondary to right frontal damage is somewhat less extensive. Nonetheless, these fluency measures have yet to be examined in conjunction with one another, and systematically with a range of other neuropsychological tasks purported to challenge the integrity of the frontal lobes. Their relationship with emotional expression, which may also tap frontal lobe functioning, has also not been explored. This experiment was therefore designed to address these issues, as well as the psychometric qualities of the Design Fluency Test, particularly interrater reliability. New measures designed to assess anterior functioning (i.e affect expression) were also evaluated for interrater reliability and their relationship with other more traditional frontal measures. Overall, this experiment sought to extend empirical and conceptual understanding of fluency.

To accomplish these goals, the experiment consisted of a 2 X 2 factorial design with factors of verbal fluency (high and low) and nonverbal fluency (high and low). Verbal fluency was assessed with the Controlled Oral Word Association Test (COWAT), and nonverbal fluency with Design Fluency Test (DFT). Four experimental groups were generated; High Verbal/High Nonverbal, High Verbal/Low Nonverbal, Low Verbal/High Nonverbal, and Low Verbal/Low Nonverbal. A series of MANOVAs were then be completed with these subject groups and sets of variables thought to asymmetrically challenge either the left or right hemisphere. As noted, left hemisphere variables included the Trail-Making Tests and the Stroop Color-Word Test, whereas right hemisphere variables consisted of facial accuracy and intensity measures and the Ruff Figural Fluency Test. Motor tasks, which were hypothesized to asymmetrically challenge each hemisphere, were separately conducted for each hand. See Tables 1-3 for a summary of all variables.

Subject groupings in this experiment were based on a rich tradition in neuropsychology, in which subjects are classified according to the presence or absence of a particular deficit or lesion. This "lesion" approach assumes that other brain structures and/or cognitive functions are intact, thus isolating the deficit in question (see Heilman & Valenstein, 1994, pp. 9-10). A full investigation of the presumed sequelae of the lesion may then be conducted. A related approach isolates the cognitive function of interest via statistical control or covariation of other variables. The grouping approach used in this experiment therefore remains faithful to clinically useful markers (i.e. high or low scores on fluency measures), while controlling for the other fluency measure. Such an approach was hypothesized to select subjects who also demonstrate significant strengths or deficits on the associated frontal tasks. This approach is particularly suited for research with a non-clinical population, in which the extremes of a distribution are desired. Relative to a more homogenous sample, these subjects would be more likely to prominently display the cognitive manifestations of interest.

More specifically, to maximize sensitivity of the fluency criterion measures, only subjects in the top or bottom thirds of each fluency distribution were selected.

For instance, if a subject scored at the 90 percentile on the verbal fluency measure, and at the 15 percentile on the nonverbal fluency measure, he was placed in the High Verbal /Low Nonverbal group. Subjects who scored in the middle of either fluency measure's distribution were excluded from the experiment. As such, it was hypothesized that High Verbal/Low Nonverbal subjects will demonstrate better performance on left-hemisphere tasks versus Low Verbal/High Nonverbal subjects. Conversely, this latter group was hypothesized to evidence better performance on right hemisphere tasks. In addition, each group was predicted to perform better on motor tasks at the contralateral hand (e.g. High Verbal/Low Nonverbal subjects will perform better than other groups with the right hand).

METHODS

Subjects

Sixty strongly right-hand dominant male introductory psychology students participated. Subjects were free of current or past neurological or psychiatric disease, and had never been diagnosed with a learning disability. Subjects' average age was 19.57 (SD = 1.49) and their average handedness score was 9.24 (SD = 3.80). Use of these subjects was motivated by the presumed heightened functional lateralization of the male brain (Harrison & Gorelczenko, 1990; see McGlone, 1980). A complete description of subject characteristics is provided in the Results section.

Session 1

Approximately twenty to thirty male subjects were mass tested at each session. The following were administered during this first testing session; informed consent form (Appendix B), laterality or handedness questionnaire (Appendix C), neurological screening (Appendix D) and the verbal and non-verbal fluency measures. The laterality questionnaire (Coran, Porac & Duncan, 1979) is a behaviorally validated 13-item questionnaire which assesses four types of lateral preference; hand, foot, eye and ear. Average concordance between this self-report instrument and behavioral measures is .90. Self-report items are scored +1 for right, -1 for left and 0 for both hand dominance. Criterion for right-sidedness and inclusion in the experiment was a total score of +6 or above (max = 13). The neurological screening assesses for a past history of neurological disorders and/or problems. Verbal and nonverbal fluency measures are detailed below.

All subjects received credit for their participation in this forty-five minute session. Following this session, fluency protocols were scored and subjects who met the criteria for any of the fluency grouping categories were contacted for the subsequent neuropsychological testing session. These subjects also met the laterality criteria and were neurologically intact. Subjects excluded from the experiment due to these criteria and/or failure to qualify for a fluency grouping were not contacted for further testing.

Fluency Materials and Subgroupings

Verbal fluency. The Controlled Oral Word Association Test (COWAT) assesses oral or written production of words beginning with a designated letter (Benton & Hamsher, 1976). It consists of three trials in which subjects are instructed to write as many words as possible in one minute beginning with a specified letter (F,A, and S). Proper names, numbers and the same word with different endings are not permitted. The final score is the sum of all acceptable words produced across trials. Though this is the most frequently employed test of verbal fluency, similar findings (i.e. depressed verbal fluency with left anterior damage) have been obtained with protocol variants using either different letters or time limits (see Borokowski, Benton & Spreen, 1981). These procedural variations have yet to be empirically differentiated in their sensitivity to left anterior damage. Nonetheless, the present experiment used the most commonly employed letters (FAS), but extended the time limit to three minutes per letter. This longer time period was hypothesized to be more sensitive to frontal dysfunction as the requirement to shift set, to make successive memory searches, and to generate unique responses increased. This nine minute sample also equaled the time constraints of DFT, which enhanced parity between the fluency measures. See Appendix E.

Nonverbal fluency. The Design Fluency Test (DFT) includes free and fixed conditions (Jones-Gotman & Milner, 1977). In the former, subjects are instructed to generate as many unique, but unnameable designs as possible in five minutes. The fixed condition requires generation of unnameable four-line designs in four minutes. Perseverative responses are considered when two designs vary on only one component or are mere rotations of another design. The nonverbal fluency score is the sum of unique designs generated in the fixed and free conditions, minus the number of nameable and perseverative designs. See Appendix F.

Session 2

This one-half hour individual session consisted of neuropsychological and affective testing. Brief procedural outlines and scoring criteria for each task are highlighted below. Relatively more time is spent discussing affect expression given that it is a newly developed measure.

Left Hemisphere Variables

Trail-Making Test Parts A & B

Procedure. The test was administered in two parts. In Trails A, subjects were asked to draw lines connecting randomly distributed numbered circles (1-25). In Trails B, subjects were instructed to connect randomly distributed numbers (1-13) and letters (A-L) by using an alternating number-letter sequence. Subjects were instructed to work as quickly as possible on both tasks. See Appendix J.

Scoring. Separate scores were obtained for Parts A and B, and they consist of the time in seconds required to complete the respective connections. Errors were not included in statistical analyses, due to their very small number.

The Stroop Color-Word Test

Procedure. The Stroop Color-Word Test consists of three pages, each with 100 items arranged in five columns of 20 items each. On the first page the items are color words (red,green and blue) randomly arranged and printed in black ink. Subjects were asked to read as many items as possible in 45 seconds. Page 2 consists of XXXXs printed in either red, green or blue ink. Subjects were asked to identify as many colors as possible in 45 seconds. The last page consists of the words on the first page printed in the colors on the second page, with the caveat that no word be printed in the color it represents (e.g. red could be printed in blue, but not red ink). On this page, subjects were requested to name the color of ink that the word was printed in, rather than reading the actual word.

Scoring. Three raw scores were obtained; a word reading score (the number of items completed in 45 seconds on page 1), a color naming score (the number of items completed in 45 seconds on page 2) and a color-word naming score (the number of items completed in 45 seconds on Page 3). See Appendix N.

Right Hemisphere Variables

Affect Expression

Procedure. Modeled after Borod et al. (1986), subjects were required to pose seven emotional faces; happy, interested, surprise, angry, sad, fear, and disgust. Each face was generated twice. Subjects were instructed to pose the face as intensely and accurately as possible. Each face was posed, held for five seconds, and separated from the subsequent face by ten seconds. Three pseudorandomized orders of faces were employed such that no more than two positive or negative faces were presented in sequence. A practice trial including each face familiarized subjects with the protocol. Testing was completed in a sound-attenuated chamber where the subject was seated in a comfortable chair and the was experimenter stationed behind a one-way mirror. Subjects faced the one-way mirror and, to reduce extraneous stimuli and noise, a white curtain was hung on all sides of the chair. A small hole in the curtain, not in the subject's sight line, allowed videotaping. Subjects were led through the affect expression protocol and proceedings were videotaped with a Panasonic WV-CD20 CCTV camera with a Panasonic WV-LA8B lens. See Appendix H.

Scoring. Scoring procedures were also based on research by Borod et al., (1986). Videotaped faces generated by each subject were scored by two judges, blind to experimental group, on accuracy and intensity. A total of 14 faces (2 of each affect) were generated by each subject. Raters were blind as to which affective face the subject had been instructed to produce. For each rater, accuracy was defined as the percentage of correct decisions regarding which face the subject was instructed to make. For example, if the rater correctly identified 7 of 14 faces, the accuracy score was 50%. Intensity was assessed on a five-point Likert scale for each face, ranging from "No Intensity--Flat" to "Extremely Intense", and averaged across all faces for each subject. The accuracy and intensity scores were averaged across raters. Raters demonstrated adequate reliability on pilot subjects and Ekman's Pictures of Facial Affect (Ekman, 1976). See Appendix I.

Ruff Figural Fluency Test

Procedure. The RFTT consists of five parts, each containing different stimulus presentations (i.e. dot matrices). In each part, the identical 35 dot matrices are arranged in a 5 X 7 array. Three samples of the stimuli for each part are displayed to allow practice trials. Subjects were instructed to connect the dots in as many unique ways as possible within a set time period. See Appendix M.

Scoring. The total number of unique designs were tallied as well as the number of perseverations (i.e. repetitions of the same design within a single test sheet). Accuracy of scoring was ensured by systematically checking each design against the remaining productions. Two scores were marked in the margin of each test sheet; for example 15/2 would indicate 15 unique designs and two perseverations on a given page. Nonverbal fluency was the total number of unique designs generated across the five parts minus the number of perseverations or repeated designs within each part.

Motor Variables

Dynamometer

Procedure. Full or maximum grip strength was assessed for each hand by asking subjects to squeeze the dynamometer as hard as possible using an overhand grip. To assess perseveration, subjects were next instructed to squeeze the dynamometer again with the same hand, but just half as hard as they squeezed it the first time. The full and half-grip strength procedures were then repeated with the other hand. Full hand-grip strength fatigue was assessed for each hand by having subject squeeze the device as hard as possible, using an overhand grip, five consecutive times. This procedure was then repeated for the other hand. For all hand-grip trials, strength was recorded in kilograms and the dynamometer's recording needle was reset to zero after each trial. The device's scale was always turned away from subject to prevent them from receiving feedback on their performance. Hand-testing order was counterbalanced across subjects.

Scoring. Two measures were obtained for each hand; a percent change or perseveration score from the first task and a strength score for the second task. The perseveration score was calculated with the following formula where "Hard" denotes the full-grip strength and "Half" denotes the half-grip strength:

$$\%\ \text{CHANGE} = \frac{\text{HARD} - \text{HALF}}{\text{HARD}} \times 100$$

If the half estimate is accurate, the percent change score equals 50. If the percent change score is less than 50, it reflects perseveration; lower values indicate heightened perseveration or an inability to precisely stop or inhibit responding. The perseveration score is expressed as a percentage.

In addition, two measures were obtained from the second dynamometer task; strength, the average grip strength across the five trials, and fatigue, the strength decrease across the five trials. This later measure was calculated by subtracting the grip strength at Trial 5 from the grip strength at Trial 1. See Appendix L.

Finger Tapping

Procedure. Each hand was test separately in five 10-second trials. Subjects were required to use only their index finger and to keep their wrist down on the tapping board. A practice trial was completed for each hand. Hand testing order was counterbalanced across subjects. See Appendix K.

Scoring. Two measures were obtained for each hand: manual dexterity (i.e. the average number of taps across the five trials), and fatigue (i.e. the decrease in the number of taps from Trial 1 to Trial 5). This final measure was calculated by subtracting the number of taps in Trial 5 from the number of taps in Trial 1.

Table 1

Summary of All Variables

Left Hemisphere	Right Hemisphere	Motor Tasks
Trails Part A	Facial Accuracy	Dynamometer
Trails Part B	Facial Intensity	A. Strength
Stroop Word	Ruff Figural Fluency	B. Fatigue
Stroop Color	Test	C. Persever.
Stroop Color-Word		Finger Tapping
		A. Strength
		B. Fatigue

Note: Persever. = Perseveration.

Note: Motor tasks were independently completed for each hand.

Table 2

Description of Left and Right Hemisphere Variables

Variable	Measure
Trails A	Time in secs. to complete
Trails B	Time in secs. to complete
Stroop Word	Number of items completed
Stroop Color	Number of items completed
Stroop Color-Word	Number of items completed
Ruff Figural Fluency	Number of unique items generated
Facial Accuracy	Accuracy averaged across 14 faces and 2 raters, expressed as a percentage
Facial Intensity	Intensity averaged across 14 faces and 2 raters, based on a 5-point Likert scale

Table 3

Summary of Motor Variables

Variable	Abbreviation	Formula
Ave. number of finger taps across 5 trials (Tr)	FTAVE	$\frac{Tr\ 1..+..Tr\ 5}{5}$
Finger tapping change across 5 trials	FTCHG	Taps on Tr1 - Taps on Tr5
Average strength in Kgs. across 5 trials	DYNOAVE	$\frac{Tr1 + . . . Tr5}{5}$
Dynamometer change across 5 trials	DYNOCHG	Kgs. on Tr1- Kgs. on Tr5
Perseveration for half-as-hard grip	DYNOPER	$\frac{Tr1 - Tr2}{Tr1} \times 100$

Note: The perseveration score is expressed as a percentage.

Note: Tr = Trial.

Note: Motor tasks were independently completed for each hand.

RESULTS

Sample Characteristics

A large number of male undergraduates (*N* = 169) were evaluated in several screening sessions, each with between 20 and 30 subjects. Five subjects were excluded because they had been diagnosed with a learning disability, and one subject was excluded due to a history of closed head injury. Verbal and nonverbal fluency scores were tallied for each subject, and compared with empirically derived cut-offs (at the 33rd and 67th percentiles) developed on a comparable sample of undergraduates, see Appendix G. Sixty subjects, fifteen per experimental group, comprised each of the following groups; High Verbal/High Nonverbal, High Verbal/Low Nonverbal, Low Verbal/High Nonverbal, and Low Verbal/Low Nonverbal.

As a manipulation check, a series of *t*-tests were completed on both fluency measures across groups. Verbally fluent subjects scored significantly higher on the Controlled Oral Word Association Test (COWAT) than verbally nonfluent subjects, t (58) = 12.62, p<.0001, but there was no significant difference on the Design Fluency Test (DFT), t (58) = .14, n.s.. Conversely, nonverbally fluent subjects performed significantly higher on the DFT, t (58) = 15.12, p<.0001, than nonverbally nonfluent subjects, but there was no significant difference on the COWAT, t (58) = .79, n.s..

This manipulation check indicates that the grouping procedure was effective in discriminating between the fluency scores of the groups. See Table 4 for means and standard deviations of the fluency variables. Furthermore, see Table 4 for intercorrelation between the fluency variables, and Table 5 for correlations between these variables and all measures employed in this experiment.

Statistical Approaches

To maximize interpretability, two approaches to data analyses were employed. In the multivariate analyses of variance approach (MANOVA), subjects were first grouped according to their scores on the criteria measures of verbal and nonverbal fluency into the following groups; High Verbal/High Nonverbal, High Verbal/Low Nonverbal, Low Verbal/High Nonverbal, Low Verbal/Low Nonverbal. A series of 2 X 2 MANOVAs with an alpha level of .05 were then performed on tests grouped by the cognitive domain they are purported to measure (i.e. right hemisphere, left hemisphere, right-hand motor, left hand-motor). The factors of each MANOVA were verbal fluency (high and low), nonverbal fluency (high and low) and Verbal Fluency X Nonverbal Fluency. If a MANOVA effect was significant, univariate analyses of variance (ANOVAs) and post-hoc tests with an alpha level of .05 were then examined. This approach was beneficial because it grouped several variables thought to tap a specific brain region and evaluated whether they reliably differentiated between the fluency groups.

There are potential problems with this MANOVA approach. First, because average or change scores were employed for several variables, the number of data points is reduced and potentially informative interactions may be missed. For instance, five trials of finger tapping were averaged into a single score, while averages across 7 different faces and 2 trials were employed for facial accuracy and intensity ratings. Similarly, because analyses were separately conducted using each component of the cognitive measures (e.g. Trail-Making Test Parts A and B), potential interactions between the fluency measures and these components may be missed. For example, verbally fluent and nonfluent subjects may perform equally on Trails A, but verbally nonfluent subjects may be relatively more impaired on Trails B. Analyses of this type are of conceptual interest, but can not be evaluated only using the MANOVA factors. Finally, the MANOVA approach does not directly compare right versus left hand motor performance, findings which are of interest, particularly as they might relate to the fluency measures and/or change across trials. Overall, to guard against neglecting potentially informative findings, a series of repeated measures univariate analyses of variance (ANOVAs) were completed for each variable. All levels of the variable were included (e.g. Trials 1 through 5 of finger tapping, all 7 facial affects, etc.). For each ANOVA, factors included both fluency measures, trial, and, if necessary, hand. As an example, for the Stroop Color-Word test, the factors included verbal fluency (high and low), nonverbal fluency (high and low), and each component of the Stroop Color-Word test (Word, Color, and Color-Word). The dependent variable was the number of items completed in each component of the test.

Multivariate Statistics

Left Hemisphere

A MANOVA performed on the purported left hemisphere tasks, Trails A, Trails B, Stroop-Word, Stroop-Color and Stroop Color-Word, was significant for verbal fluency (Wilks' L $\underline{F} = 3.56$, $\underline{p}<.008$). Univariate ANOVAs were significant on all five measures (all $\underline{p}$s<.019) with verbally fluent subjects performing more quickly on both parts of the Trail-Making tests and completing significantly more items on each part of the Stroop test. Neither the nonverbal fluency (Wilks' L $\underline{F} = 1.43$ $\underline{p}<.23$) nor the Verbal Fluency X Nonverbal Fluency MANOVA effects (Wilks' L $\underline{F} = <1$) were significant. See Table 7.

Right Hemisphere

A MANOVA performed on the purported right hemisphere tasks, the Ruff Figural Fluency Test, and the facial accuracy and intensity measures, was significant for nonverbal fluency, (Wilks' L _F_ = 2.91, _p_<.04). The only significant univariate ANOVA was the Ruff Figural Fluency Test, (_F_ = 8.19, _p_<.006), as nonverbally fluent subjects generated more designs than nonverbally nonfluent subjects. Neither the verbal fluency (Wilks' L _F_ = 2.45, _p_<.07) nor the Verbal Fluency X Nonverbal Fluency MANOVA effects (Wilks' L _F_ = <1) were significant. See Table 8.

Left-Hand Motor

A MANOVA was performed on the left-hand motor tasks; finger tapping average across 5 trials, finger tapping change, dynamometer average across 5 trials, dynamometer change, and dynamometer perseveration. See Table 3 for precise description of variables. Neither the verbal fluency, (Wilks' L _F_ = 1.08, _p_<.38), nor the nonverbal fluency MANOVA effects (Wilks' L _F_ = <1) were significant. See Table 9. However, the Verbal Fluency x Nonverbal Fluency effect was significant (Wilks' L _F_ = 3.01, _p_<.02). The only significant univariate ANOVA was for dynamometer perseveration (_F_ = 10.84, _p_<.002). Post-hoc testing indicated equal levels of perseveration for nonverbally fluent and nonfluent subjects, whereas verbally fluent subjects demonstrated significantly greater perseveration than verbally nonfluent subjects, see Figure 1. This finding was unexpected and is counterintuitive, as similar results were predicted for the contralateral (right) hand. Inferences about underlying cerebral functioning based on this finding should thus be generated cautiously, and bolstered with further empirical confirmation.

Right-Hand Motor

A MANOVA was performed on the right-hand motor tasks; finger tapping average across 5 trials, finger tapping change, dynamometer average across 5 trials, dynamometer change, and dynamometer perseveration. MANOVA effects of verbal fluency (Wilks' L *F* = <1), nonverbal fluency (Wilks' L *F* = <1), and the Verbal Fluency X Nonverbal Fluency interaction (Wilks' L *F* <1) were not significant. See Table 10.

Univariate Statistics

In these analyses, each variable was separately analyzed in a mixed-design analysis of variance (ANOVA) with factors of verbal fluency, nonverbal fluency, trial, and if necessary, hand. As noted above, all levels of each variable were analyzed in this fashion to allow for a more fine-grained data analysis. Redundant findings evident in the MANOVAs (i.e. main effects or interactions between the two fluency measures) are not discussed.

Trail-Making Tests

A 3 factor mixed-design ANOVA with fixed factors of verbal fluency (high and low) and nonverbal fluency (high and low), and with the repeated factor of trail (part A and part B) was performed using time in seconds as the dependent measure. The main effect of trail was highly significant, F (1,56) = 225.57, p<.0001, with reduced time required to complete Trails A versus Trails B. This finding is not surprising given the more complex demands of Trails B. The Verbal Fluency X Trail interaction approached significance, F (1,56) = 3.13, p<.08, see Figure 2. Post-hoc tests indicate that verbally fluent and nonfluent subjects performed equally on Trails A, but that verbally fluent subjects performed significantly better on Trails B. This finding is consistent with previous results from the same laboratory (Huntzinger, 1989). There are two possible explanations for this finding. First, Trails B, but not A, requires both numbers and letters to be sequenced. However minimal, the linguistic component of this task may thus more closely mimic the COWAT, which is an inherently verbal task. Moreover, Trails B is a decidedly more complex task than Trails A, as it requires the ability to shift set between two alternating tasks. This cognitive flexibility appears to more closely parallel the requirements of the COWAT, as performance is maximized when subjects make rapid, repeated searches through their verbal lexicon. Overall, while this interaction should be interpreted cautiously, it suggests that the link between Trails B and the COWAT may be secondary to linguistic and/or cognitive flexibility requirements.

Stroop Color-Word Test

A 3 factor mixed-design ANOVA with fixed factors of verbal fluency (high and low) and nonverbal fluency (high and low), and with the repeated factor of Stroop (Word, Color, Color-Word) was performed using the number of correctly completed items as the dependent measure. The main effect of Stroop was highly significant, F (2,112) = 1060.86, $p<.0001$, and post-hoc testing indicates that a significantly greater number of items were correctly completed in each condition. This finding was expected given the varying cognitive demands of each condition. The Verbal Fluency X Stroop interaction was significant, F (2,112) = 3.87, $p<.02$, see Figure 3. Post-hoc testing indicates that verbally fluent subjects completed significantly more items than verbally nonfluent subjects in each condition, but this effect only approached significance in the Color-Word condition. These findings indicate that verbally fluent subjects performed significantly better on Stroop components which tapped more pure measures of mental speed versus the component which required inhibition of an automatic response. This latter result appears to contradict the Trail-Making finding, in which the more complex Trails B was associated with the COWAT. However, it should be noted that the COWAT and Trail-Making Tests both require motor involvement, whereas the Stroop requires reading with oral output. As such, comparison of the Trail-Making tests and COWAT may be a somewhat more accurate comparison, given the relevant task demands. Nonetheless, verbally fluent subjects completed significantly more items in each condition of the Stroop, though this effect only approached significance in the Color-Word condition, relative to verbally nonfluent subjects.

Dynamometer Across 5 Trials

A 4 factor mixed-design ANOVA with fixed factors of verbal fluency (high and low) and nonverbal fluency (high and low) and with repeated factors of trial (1-5) and hand (left and right) was performed using strength in kilograms as the dependent measure. There was a significant Hand x Trial interaction, F (4,224) = 4.71, $p<.001$, see Figure 4. Post-hoc testing indicated a significant strength advantage for the right hand at each trial, as well as a tendency for the left hand to fatigue more than the right hand. There was a 10 percent strength diminution from Trial 1 to Trial 5 for the left hand, but only a 4.3 percent decrease for the right hand. Furthermore, the effect of hand was significant, F (1,56) = 37.63 $p<.0001$, with the expected right hand strength advantage obtained. The main effect of trial was also significant, F (4,224) = 24.71, $p<.0001$.

Dynamometer Perseveration

A 4 factor mixed-design ANOVA with fixed factors of verbal fluency (high and low) and nonverbal fluency (high and low) and with repeated factors of trial (1 and 2) and hand (left and right) was performed using strength in kilograms as the dependent measure. The Hand X Trial interaction was significant, $F(1,56) = 14.65$, $p<.0003$, see Figure 5. Post-hoc testing confined the significant difference to the first trial, with a right hand strength advantage. There was no difference on the second trial, which required subjects to squeeze half-as-hard. In fact, the perseveration index (Trial 1-Trial 2/Trial 1 x 100) was calculated for each hand. Perseveration indices were 34.9% for the right hand and 28.9% for the left hand, which indicates heightened left hand perseveration. This finding should be interpreted cautiously as there appeared to be a floor effect on the second trial. The difference between these scores may thus reflect the greater initial right hand grip strength of this sample, and thus a larger percent change (and hence less perseveration) across trials. The effect of trial was significant, $F(1,56) = 499.83$, $p<.0001$, with the expected strength advantage for the first trial, as was the effect of hand, $F\ (1,56) = 5.61$, $p<.02$, with the predicted strength advantage for the right hand.

Finger-Tapping

A 4 factor mixed-design ANOVA with fixed factors of verbal fluency (high and low) and nonverbal fluency (high and low) and with repeated factors of trial (1-5) and hand (right and left) was performed using the average number of taps in 10 seconds as the dependent measure. The main effect of hand was significant, F (1,56) = 30.19 $p<.0001$, with the expected advantage for the right hand. The 8.2% right hand advantage in the average number of taps is consistent with previous research (Bornstein, 1986). The main effect of trial was also significant, F (4,224) = 15.78, $p<.0001$. No interactions achieved significance.

Facial Analyses

Two 3 factor mixed-design ANOVAs with fixed factors of verbal fluency (high and low) and nonverbal fluency (high and low), and with the repeated factor of affect (happy, interested, sad, angry, surprise, disgust, and fear) were separately completed using facial accuracy and intensity measures as dependent measures. The main effect of affect was significant for both accuracy, F (6,335) = 8.74, $p<.0001$, and intensity, F (6,335) = 21.94, $p<.0001$. See Table 11 and Figures 6 and 7. As is evident, subjects generated happy faces significantly more accurately and more intensely than other faces. Interestingly, while subjects' accuracy scores for angry, surprised, and disgusted faces were rather low, these faces were also judged to be quite intense. The dissociation between accuracy and intensity measures, at least for these faces, indicates that subjects generated intense, but poorly configured faces which were difficult to discriminate. Furthermore, the Verbal Fluency X Affect interaction was significant for accuracy judgments, F (6, 335) = 2.07, $p < .05$. Relative to verbally nonfluent subjects' facial expressions, verbally fluent subjects' expressions were judged more accurately for interested and sad faces. No significant interactions were obtained for facial analyses using intensity as the dependent measure.

A separate set of analyses were completed with composite facial measures of positive (happy, interested, and surprised) and negative (sad, angry, disgust, and fear) affects. These analyses are based on evidence by Davidson (see Davidson & Tomarken, 1989), in which anterior cerebral regions are thought to be asymmetrically organized for affect (i.e. the left hemisphere for positive affect and the right hemisphere for negative affect). Main effects were significant for both accuracy, F (1,56) = 16.46, $p < .0002$, and intensity, F (1,56) = 9.39, $p < .0034$. These findings indicate that subjects generated positive faces more accurately and intensely than negative faces. No interactions were significant using these composite measures.

Summary: Univariate Analyses

In summary, these univariate ANOVAs provide a more detailed examination of the data. Relative to verbally nonfluent subjects, verbally fluent subjects tended to perform better on Trails B, but not Trails A, and to complete significantly more items in each Stroop condition, though this finding only approached significance in the Color-Word condition. On motor tasks, the expected right-hand advantages were found in this right-hand dominant sample, though only one interaction was significant. On the dynamometer perseveration task, the Hand X Trial interaction revealed a significant difference on Trial 1, but not Trial 2, and, as such, greater left hand perseveration. Significant accuracy and intensity advantages were observed for the positive versus negative affects, though these differences did not vary with either of the fluency measures.

Psychometric Issues

Because this experiment included several new variables and one test with questionable reliability (DFT), a number of reliability checks were performed. First, reliability between trained raters on the Design Fluency Test (DFT) was calculated on a small sample of subjects ($\underline{n}$ = 23), see Table 12. As is evident, excellent reliabilities were obtained for most components of the DFT, which is consistent with previous research which has employed trained raters (see Woodard et al., 1992, for discussion of this issue). Lower, though still significant, reliabilities were found for the Free Nameable (.75) and the Fixed Perseveration (.72) conditions. These lower reliabilities may be a function of the lower number of items in each of these conditions. These findings are roughly consistent with pilot studies.

Though statistically significant, a problematic issue is the questionable interrater reliability for measures of facial accuracy and intensity. While values for facial intensity were quite good (from .78 to .82), they were lower for measures of facial accuracy (from .34 to .85), see Table 13. Interrater accuracy agreement was particularly poor for interested, surprised and disgusted, and fearful faces. Several issues arise from these levels of agreement, which will be discussed below.

DISCUSSION

This experiment was designed to examine verbal and nonverbal fluency and to assess whether a variety of frontal lobe tasks, with purported lateralizing ability, could reliably differentiated between these fluency measures. Subjects were assessed on both fluency measures and four experimental groups were constructed; High Verbal/High Nonverbal, High Verbal/Low Nonverbal, Low Verbal/High Nonverbal and Low Verbal/Low Nonverbal. As hypothesized, verbally fluent subjects performed better on tasks thought to tap left hemisphere functioning, including Trail-Making Tests and the Stroop Color-Word Test, than verbally nonfluent subjects. On right hemisphere tasks, nonverbally fluent subjects performed better on the Ruff Figural Fluency Test than nonverbally nonfluent subjects, but not on measures of facial intensity and accuracy. Because of the paucity of findings on motor tasks (there was one unpredicted finding) discussion of these will be limited. The focus of this section will be on the psychometric and conceptual implications of the fluency findings.

A bulk of neuropsychological research suggests that verbal fluency is particularly sensitive to left frontal lobe functioning (see Lezak, 1983). While the component neuropsychological mechanisms of verbal fluency tasks are not fully appreciated, Randolf, Bruan, Goldberg, & Chase (1993) indicated that an intact linguistic store (i.e. a lexicon) is essential, as well as the ability to effectively retrieve information from it. Moreover, the capability to search through this lexicon, which requires successive shifts in mental set and cognitive flexibility, is critical to prevent perseverative or stereotyped responses. The ability to generate the words as output, which in this experiment was in a written format, is also vital. Finally, a nonspecific component of this task is psychomotor/mental processing speed, as subjects who have the core neuropsychological competencies listed above, will obviously enhance their performance with faster processing speed.

Given the complex components of verbal fluency, it is instructive to assess how this task might be related to purported measures of left frontal lobe functioning. Both Trail-Making tests require attention, psychomotor speed and, in Trails B, the ability to alternate between sets of numbers and letters. There are no verbal demands in Trails A, and limited verbal demands in Trails B. The association between the COWAT and these tests thus does not appear to be a function of verbal processing, but rather the ability to perform speeded cognitive processing and, if necessary, to shift cognitive set. Sustained attention is also obviously required. The lack of a relationship between the COWAT and motor tasks, precludes significant involvement of psychomotor speed see (Table 5). Verbally fluent subjects are thus able to generate many words to confrontation, which is likely secondary to basic mental processing speed and the ability to remain cognitively flexible. It is interesting to note the DFT was not associated with the Trail-Making Tests, the implications of which will be described below.

The Stroop Color-Word test was the other left hemisphere task assessed in this experiment and it consists of three conditions; word reading, color reading and color-word-reading. Verbally fluent subjects performed better in each condition than verbally nonfluent subjects. Relative to the Trail-Making Tests, all conditions of this task consist of a heavy verbal component. This verbal component is quite different than the COWAT, however, as it requires reading items rather than generating them to confrontation. In the third and most important condition, the ability to inhibit or to suppress usual verbal responses is required. As such, all conditions require rapid reading or color-naming, which presupposes intact perceptual processes and the ability to produce items as oral output. Therefore, the relationship between the Stroop and the COWAT may simply be a function of cognitive processing speed. However, given the findings in the third condition, their relationship may also be a function of the ability to suppress more automatic responses (see Perret, 1974). This is relevant in the COWAT, as this competence is essential to effectively discontinue a search strategy and to begin an alternative. Without this capability, a large number of intrusions or incorrect responses would presumably be generated. Overall, the relationship between the COWAT and the Stroop Color-Word Test appears to be a function of non-specific factors (i.e. speeded cognitive processing), as well as the ability to inhibit automatic responses. A similar relationship was not consistently observed for the DFT, which will be highlighted below.

Nonverbal fluency, as assessed by the Design Fluency Test (DFT), was used as the right hemisphere criterion measure. Though the overall MANOVA was significant, this was solely due to the effect of the Ruff Figural Fluency Test (RFFT), and not the facial accuracy or intensity measures. Thus, nonverbally fluent subjects produced more designs on the RFFT than nonverbally nonfluent subjects, but did not express affect more intensely or more accurately. The effect for the RFFT is not surprising, given that both it and the DFT are measures of nonverbal fluency. Despite this similarity, each approaches the construct in a different fashion; the DFT is less structured and requires more flexibility, particularly in the Free Condition. Conversely, the RFFT requires subjects to connect a series of dots in as many unique ways as possible, providing increased structure to the task. Theoretically, this may thus be a less sensitive measure of frontal lobe functioning, because it does not require the subject to impose his or her own problem-solving approach to the task (see below). Nonetheless, the overall right hemisphere MANOVA is significant largely because of the RFFT effect.

Despite evidence to suggest that the DFT and facial measures of accuracy and intensity are subsumed by similar cerebral regions, no relationship between these variables was found. There are a number of possible explanations. First, either of these measures may simply not tap the targeted cerebral regions. As the facial measures were developed for this experiment and do not have a network of supporting research, relatively less is known of them and their relationship with other neuropsychological tasks. The validity of the facial measures is thus questionable and awaits further examination. Assessment of the validity of these measures is further hampered by low levels of interrater reliability, an issue which will be detailed below. Finally, this finding may simply be due to method variance, as the facial measures were the only tasks which were not simple paper-and-pencil or motor measures. It is reasonable to then infer that a wider-range of cognitive processes were tapped, and as a result, broader cerebral areas. If so, the poor performance of the facial measures may be due to their unique status in this experiment as the only task with complex motoric demands.

Similar to the facial measures, the motor tasks thought to have lateralizing significance also performed poorly in this experiment. This again may simply be due to method variance, as the motor tasks required rather circumscribed involvement of the distal extremities, with minimal higher-order cognitive processing. These motor tasks may thus not be sensitive to accurately evaluate functional cerebral asymmetries in normals, though their ability to do so in brain-damaged populations has been demonstrated (Haaland & Delaney, 1981). It should be noted that these motor measures are rarely used alone clinically, but supplement other neuropsychological data to bolster claims about potentially lateralized damage.

Nonverbal Fluency: Design Fluency Test (DFT)

The psychometric qualities of the Design Fluency Test (DFT) were a particular concern in this experiment. Despite concerns about interrater reliability, the present results demonstrate high rates of interrater agreement (in the range of .97) and suggest that trained scorers can reliably score the DFT. Though this finding is encouraging, it does not address the measure's validity. For example, a number of protocols had a small number of quite intricate and elaborate designs in the Free Condition. A limited number of such designs may reflect perseveration, as the subject may have been unable to generate new, unique designs, and thus continued to elaborate on the existing design. On the other hand, this overelaboration may be construed to reflect enhanced nonverbal fluency, as the subject generated an extremely complex figure with numerous components. These added components also appeared to tap the construct of nonverbal fluency, as they were unique and unnameable, though they were not counted as separate because they were part of a larger design. It should be noted that the instructions clearly stipulate that the task requires the execution of as many unique designs as possible. Assuming subjects were faithful to such directions, the more reasonable explanation for a low number of overelaborated designs is that subjects were unable to generate new designs. Overall, this issue is clearly problematic, and it raises a number of questions regarding the validity of the DFT.

This validity issue is particularly relevant for the Free Condition of the DFT, in which subjects are instructed to generate as many unique and unnameable designs as possible. Overly elaborate designs did not occur in the Fixed Condition, as subjects were limited to creating designs with only four lines. However, this apparent advantage of the Fixed Condition places greater structure and limits on the task and, in effect, may make it a less sensitive challenge to the integrity of the frontal lobes. The more instructions and parameters creates a less ambiguous, more structured task, in which subjects' initiative, cognitive flexibility, and problem-solving style are not as readily tapped. In fact, early studies with standardized intellectual tests did not demonstrate consistent decrements in frontal lobe patients, which may have been due to the tightly controlled nature of these tests (see Stuss & Benson, 1986, pp. 195-199). Therefore, even with the above-noted difficulties, tests such as the Free Condition of the DFT often reveal a subject's approach to a problem, problem-solving style, as well as his or her ability to flexibly generate unique material. These attributes may be determined via qualitative design analysis, but they are difficult to quantify and to submit to statistical analyses. Overall, this discussion highlights the paradox of the DFT and other purported frontal lobe tasks--the more accurately they tap purported frontal processes, the more psychometric and conceptual difficulties are likely to emerge.

Verbal Fluency: Controlled Oral Word Association Test (COWAT)

While the verbal fluency task employed in this experiment is relatively well-established (COWAT), there are several important issues to consider. Such a task presupposes the presence of an intact verbal lexicon, or store of material-specific memory, which is thought to be organized in a conceptually related framework (Estes, 1974). This model presupposes that all components of the lexicon are linked or associated via interlinking nodes. A concept, such as the letter category "F", consists of all the associated nodes, or words that begin with that letter

(Gruenewald & Lockhead, 1980). The cognitive processes activated during verbal fluency tasks may then be conceptualized as a memory search that involves the activation of specific lexicons, in conjunction with the simultaneous restriction of others. The COWAT thus requires the integrity of semantic stores, which are obviously verbal, and the capability to efficiently retrieve this material, which, as this experiment demonstrates, is dependent on many cognitive components. Research with Huntington's, Alzheimer's, and Parkinson's patients has demonstrated that semantic stores and retrieval processes are dissociable (Randolph et al., 1993). In this experiment, Alzheimer's disease, the only cortical dementia, was noted to include loss of semantic stores, which is a result of degenerative changes in perisylvian cortical regions, but no retrieval deficits. The COWAT is therefore thought to involve distinct neuropsychological processes, which have been dissociated in a neurologically impaired population. These processes, as well the other processes detailed above, are likely to be difficult to evaluate in normals.

This conceptualization of the COWAT raises considerable questions regarding its comparability to the DFT. Given that the designs to be generated on the DFT are to be unique and unnameable, it is unlikely that there is a lexicon, or store of material-specific information, for nonverbal material which the subject must search through. While the COWAT appears to tap the ability to quickly search through an existing set of stored material, the DFT may be more dependent on divergent thinking, the generation of novel solutions to ambiguous situations, and the formation of new cognitive categories (Butler et al., 1993). These latter neuropsychological processes tap variables associated with what some authors have referred to as creativity (Gardner, 1993, pp. 17-45). As a result, it is not surprising that the COWAT, but not the DFT, was sensitive to tasks with time constraints and which require speeded mental processing. The old dichotomy between speed and power tests may be relevant here, as the DFT may be thought of as a power test, in which ample time is given to complete the task, and the COWAT as a test of speeded cognitive processing. Overall, the neuropsychological mechanisms tapped by the COWAT and the DFT differ and, as a consequence, they are likely to challenge frontal lobe functioning in unique ways.

Advantages and Disadvantages of this Experiment

One particular deficiency of this experiment is the sample, a group of college males, which makes parcellation of the constituent components of the fluency tasks difficult. These tasks would benefit from future evaluation within neurologically impaired populations. For example, research with right-hemisphere damaged subjects (Joanette & Goulet, 1986), schizophrenics (Gruzelier et al., 1988), and patients with Alzheimer's, Parkinson's, and Huntington's disease (e.g. Gurd & Ward, 1989; Randolph, et al., 1993) has been helpful in beginning to scrutinize the many facets of fluency. In fact, dissociation of the elements of the fluency construct is likely to be most readily observed when individuals with known brain pathology have specific cerebral regions challenged. Furthermore, another promising research area is to use emerging brain-imaging technologies to evaluate brain regions selectively activated by these and related tasks (e.g. Petersen et al., 1988). The prohibitive expense of these procedures make such investigations difficult for most researchers. Nonetheless, the main difficult of this experiment was that the integrity of the frontal lobes presupposed in these normals does not allow precise parcellation of the neuropsychological processes thought to constitute fluency.

Another area of concern is the interrater reliability of the facial measures which were significant, but somewhat lower than expected. Despite pilot studies, the task proved to be more difficult than anticipated. In fact, several subjects were run through extra practice trials before they adequately comprehended the procedures. Also problematic were several subjects who demonstrated a marked lack of affective expressivity, as they were extremely "flat" and had difficulty generating even the most simple face. As a result, accuracy interrater reliabilities were most affected, though intensity measures were relatively good. Overall, interrater agreement for the facial measures was at a level which raises questions about the reliability of this newly developed task. With this level of reliability, assessment of the measure's validity is hence questionable, and the poor performance of this measure may simply reflect these psychometric difficulties rather than principles of cerebral organization.

Despite the above difficulties, the main contribution of this experiment is it's systematic examination of both verbal and nonverbal fluency constructs. To the author's knowledge, no previous work has examined the main neuropsychological instruments thought to tap these measures, particularly their reliability, their interrelationships, and their relationships with other purported frontal lobe tasks. This experiment was unique in that it completed the latter analyses for verbal and nonverbal fluency measures by controlling for the other fluency measure, and thus presumably the nonspecific effects of fluency (e.g. generativity, flexibility). This was not done statistically, but in a manner sensitive to a long-traditional of a process-oriented neuropsychological assessment. In addition, this research provides a specific rationale and protocol for examining facial accuracy and intensity, constructs thought to be related to right frontal lobe functioning. While these measures performed quite poorly relative to other measures, further research in this area may help elucidate the processes by which facial expressivity is mediated. In all, this experiment provides empirical and theoretical advances to our understanding of fluency, while attempting to remain sensitive to the clinical role often played by these neuropsychological constructs.

Fluency: Theoretical Considerations and Future Directions

A future goal for frontal lobe tasks is to balance psychometric integrity and task parameters which tap the relevant neuropsychological processes. For nonverbal fluency, a potential method for achieving this in the Free Condition of the DFT is to impose time limits for the execution of each design. This would presumably eliminate overly elaborate designs. For instance, subjects might be given a small pad of paper and instructed to generate a unique design on each sheet. They would be given an allotted time for each design, after which they would be instructed to turn to the next sheet and to generate another design. This time requirement would make the task somewhat more structured, but it would limit the requirements placed on the execution of each design in a relatively nonevasive manner. This modification would thus still allow the DFT to be sensitive to the generativity and flexibility hypothesized to be components of fluency. However, as is evident from this simple suggestion, by decreasing the parameters by which subjects have to generate designs, variations in subjects' approaches to these designs would also presumably decrease. This is the paradox of frontal lobes tasks--as the experimental parameters are decreased and the psychometric qualities of the task presumably improved, individual variations in problem-solving approaches are also reduced.

Given questions about the comparability of the DFT and the COWAT, a more reasonable measure of verbal fluency may be to require subjects to generate a story to command. The measure of interest could be molecular, the number of words generated, or more molar, such as the number of complete statements generated. This task would presumably control for the aspect of the COWAT which requires subjects to search through a specifically identified verbal lexicon (i.e, words that begin with a particular letter). It would also be a more sensitive measure of the ability to generate unique and original material, similar to the DFT, rather than simply listing words. A similar task has been previously employed in the neurolinguistic literature

(Kaczmarek, 1982; Kaczmarek, 1984), and it requires brain-damaged subjects to generate a story on a familiar topic. Dependent measures included the percentage of simple and developed sentence utterances. As might be hypothesized, left dorsolateral and orbitofrontal patients generated less material than patients with lesions elsewhere, including the right frontal lobe. Similar to the Free Condition of the DFT, the inherent advantage of such a task is that it has relatively few parameters and allows substantial variability in subjects' approaches, thus tapping generativity, problem-solving, and flexibility. Nonetheless, this task is also likely to be hampered by the psychometric and conceptual problems associated with the DFT. However, a somewhat more structured task exists as part of the Multilingual Aphasia Examination, which requires generation of a story to a presented picture (Benton & Hamsher, 1976). While subjects' production is typically used to evaluate spelling, grammar, and syntax, other measures could be developed to tap fluency. Overall, this discussion highlights some of the inherent difficulties involved in attempting to accurately assess frontally mediated processes.

Summary

This experiment demonstrated that variables thought to assess frontal lobe function reliably differentiated between subjects grouped according to verbal and nonverbal fluency measures. As hypothesized, subjects high on verbal, but not nonverbal fluency, performed better on neuropsychological tasks thought to tap left frontal lobe functioning. Similarly, subjects high on nonverbal fluency performed better on right frontal tasks, but this effect was accounted for by the Ruff Figural Fluency Test. This experiment thus demonstrated the ability of the fluency measures to discriminate between neuropsychological tasks thought to asymmetrically tap frontal lobe functioning. These findings thus extend the constructs of both verbal and nonverbal fluency, and by extension, conceptualizations of how the frontal lobes may be involved in complex, higher-order cognition. While considerable effort was spent discussing the unique ways in which each task was associated with the fluency measures, further research is needed to evaluate the distinct constituent elements of these tasks. Neurologically impaired patients, with discrete ares of involvement (i.e. subcortical vs. cortical), would likely be useful in further parcelling these multifaceted tasks.

Table 4

Verbal Fluency (COWAT) and Nonverbal Fluency (DFT) Scores by Experimental Group

	COWAT		DFT	
Group	Mean	SD	Mean	SD
High Verbal/ High Nonverbal	97.53	18.08	47.13	7.71
High Verbal/ Low Nonverbal	92.97	8.02	21.80	6.77
Low Verbal/ High Nonverbal	61.67	6.31	46.93	6.63
Low Verbal/ Low Nonverbal	58.60	4.51	21.80	4.65

Table 5

Correlations of Fluency Variables

Task	1	2	3	4	5
1. Verbal	.				
2. Design Total	.09	.			
3. Design Free	.00	.92+	.		
4. Design Fix	.20*	.78+	.49+	.	
5. RFFT	.19*	.35+	.26*	.38+	.

* = .05. + = .001.

Note: RFFT = Ruff Figural Fluency Test.

Table 6

Correlations Between Verbal and Nonverbal Fluency and all Measures

Variable	Fluency Verbal	 Design	 RFFT
Trails A	-.30*	-.07	-.22
Trails B	-.27*	.12	-.26*
Stroop Word	.37+	-.27*	.02
Stroop Color	.35+	.19	-.03
Stroop Color-Word	.27*	.13	.14
RH Finger Tapping Ave.	.07	.00	.05
LH Finger Tapping Ave.	.14	-.04	-.09
RH Finger Tapping Change	.00	-.08	.03
LH Finger Tapping Change	-.05	.19	.08
RH Dyno Ave.	.00	-.10	-.11
LH Dyno Ave.	.08	-.02	-.09
RH Dyno. Change	.00	.09	.00
LH Dyno. Change	-.09	.15	.01
RH Dyno. Perseveration	-.08	.05	.08
LH Dyno. Perseveration	-.31*	.04	.01
Total Accuracy	-.04	-.16	-.06
Total Intensity	.21	.03	.17

* = $p<.05$. + = $p<.005$.

Table 7

Means and (Standard Deviations) of Left Hemisphere Variables by Experimental Group

	1	2	3	4
Variable	Means	Means	Means	Means
Trails A	18.47	21.40	23.47	23.93
	(3.25)	(5.26)	(8.54)	(5.44)
Trails B	40.40	45.60	59.60	47.93
	(11.73)	(11.81)	(26.17)	(13.89)
Stroop Word	111.87	117.80	100.40	105.93
	(10.61)	(13.21)	(14.15)	(11.45)
Stroop Color	84.40	85.00	76.47	76.87
	(8.58)	(7.08)	(11.59)	(8.50)
Stroop Color-Word	50.07	51.53	45.73	45.67
	(8.36)	(6.62)	(9.86)	(7.60)

Note: Group 1 = High Verbal/High Nonverbal. Group 2 = High Verbal/Low Nonverbal. Group 3 = Low Verbal/High Nonverbal. Group 4 = Low Verbal/Low Nonverbal.

Note: The measure for Trails A and B is the number of seconds required to complete each part, respectively. All Stroop tasks are the number of correctly read items in the allotted time.

Table 8

Means and (Standard Deviations) of Right Hemisphere Variables by Experimental Group

	1	2	3	4
Variable	Means	Means	Means	Means
RFFT	99.60	79.67	86.53	68.47
	(30.13)	(26.56)	(23.57)	(26.67)
F. ACCURACY	71.43	78.33	73.21	72.62
	(25.02)	(19.91)	(11.87)	(18.19)
F. INTENSITY	2.85	2.85	2.39	2.57
	(.59)	(.82)	(.48)	(.79)

Note: Group 1 = High Verbal/High Nonverbal. Group 2 = High Verbal/Low Nonverbal. Group 3 = Low Verbal/High Nonverbal. Group 4 = Low Verbal/Low Nonverbal.

Note: RFFT = Ruff Figural Fluency Test. F. ACCURACY = Facial accuracy averaged across 14 faces and 2 raters, expressed as a percentage. F. INTENSITY = Facial intensity, averaged across 14 faces and 2 raters. Ratings based on a 5-point Likert scale.

Table 9

Means and (Standard Deviations) of Left-Hand (LH) Motor Variables by Experimental Group

	1	2	3	4
Variable	Means	Means	Means	Means
LHFTAVE	47.76	47.96	45.81	46.52
	(5.03)	(5.24)	(4.84)	(4.45)
LHFTCHG	4.13	1.87	3.67	5.07
	(5.85)	(7.10)	(4.64)	(5.48)
LHDYNOAVE	39.03	42.24	41.04	38.17
	(5.35)	(6.11)	(6.05)	(7.33)
LHDYNOCHG	5.80	3.13	4.20	3.93
	(4.90)	(3.87)	(3.38)	(2.63)
LHDYNOPER	38.36	28.12	19.78	32.66
	(12.20)	(15.52)	(11.39)	(14.85)

Note: Group 1 = High Verbal/High Nonverbal. Group 2 = High Verbal/Low Nonverbal. Group 3 = Low Verbal/High Nonverbal. Group 4 = Low Verbal/Low Nonverbal.

Note: See Table 3 for description of motor variables.

Table 10

Means and (Standard Deviations) of Right-Hand Motor Variables by Experimental Group

	1	2	3	4
Variable	Means	Means	Means	Means
RHFTAVE	52.08	52.03	49.76	50.12
	(7.02)	(6.20)	(7.07)	(6.14)
RHFTCHG	4.93	3.87	3.67	2.07
	(6.60)	(15.57)	(6.09)	(7.07)
RHDYNOAVE	42.49	44.15	43.23	43.68
	(7.30)	(7.02)	(5.50)	(7.98)
RHDYNOCHG	3.93	.27	1.80	2.20
	(4.71)	(6.04)	(2.40)	(4.25)
RHDYNOPER	23.00	18.96	18.07	21.81
	(10.30)	(14.49)	(20.30)	(15.87)

Note: Group 1 = High Verbal/High Nonverbal. Group 2 = High Verbal/Low Nonverbal. Group 3 = Low Verbal/High Nonverbal. Group 4 = Low Verbal/Low Nonverbal.

Note: See Table 3 for description of motor variables.

Table 11

Intensity and Accuracy of Facial Judgments

	Intensity		Accuracy	
Face	Mean	SD	Mean	SD
Happy	2.97a	.76	90a	25
Interested	2.37bc	.70	70bc	31
Sad	2.28c	.79	74c	30
Angry	2.81a	.91	75c	33
Surprise	2.89a	.79	76c	25
Disgust	2.85a	.98	74c	32
Fear	2.57b	.76	59b	35

Note: Intensity and accuracy scores are averaged across 2 raters. Intensity scores are based on a 5-point Likert scale. Accuracy scores are expressed as percentages.

Note: Means with different subscripts within each column differ significantly at $p<.05$.

Table 12

Design Fluency Correlations (N=23) Among Two Raters

Variable	Correlation
Free Unique	.99*
Free Perseveration	.98*
Free Nameable	.75*
Fixed Unique	.98*
Fixed Perseveration	.72*
Fixed Nameable	.89*
Fixed Wrong	.93*
Total Unique	.98*

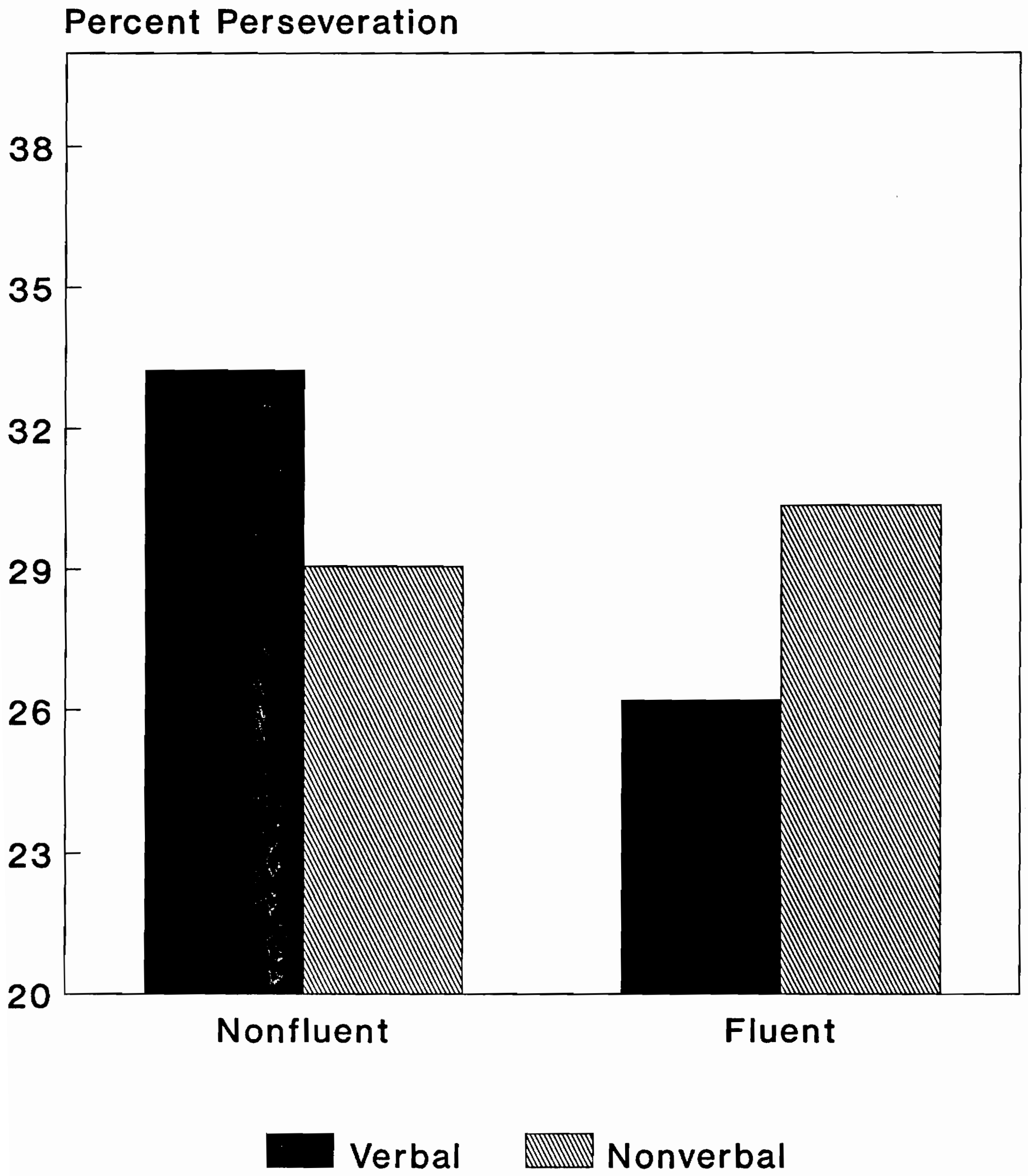
Note. Free = Free Condition. Fixed = Fixed Condition. Unique = Number of unique designs generated. Perseveration = Number of perseverative designs generated. Nameable = Number of nameable designs generated. Wrong = Number of designs with the wrong number of lines (only applicable in the Fixed Condition). Total Unique = Total number of unique designs generated across Free and Fixed Conditions.

Table 13

Accuracy and Intensity Correlations for Two Trained Raters for All Subjects (N = 60)

Affect	Accuracy	Intensity
Happy	.85*	.82*
Interested	.39+	.74*
Sad	.57*	.83*
Angry	.69*	.76*
Surprise	.34+	.80*
Disgust	.43+	.81*
Fear	.46+	.78*

* = $p<.0001$, + $p<.01$.



Perseveration by Fluency Group

Figure 1

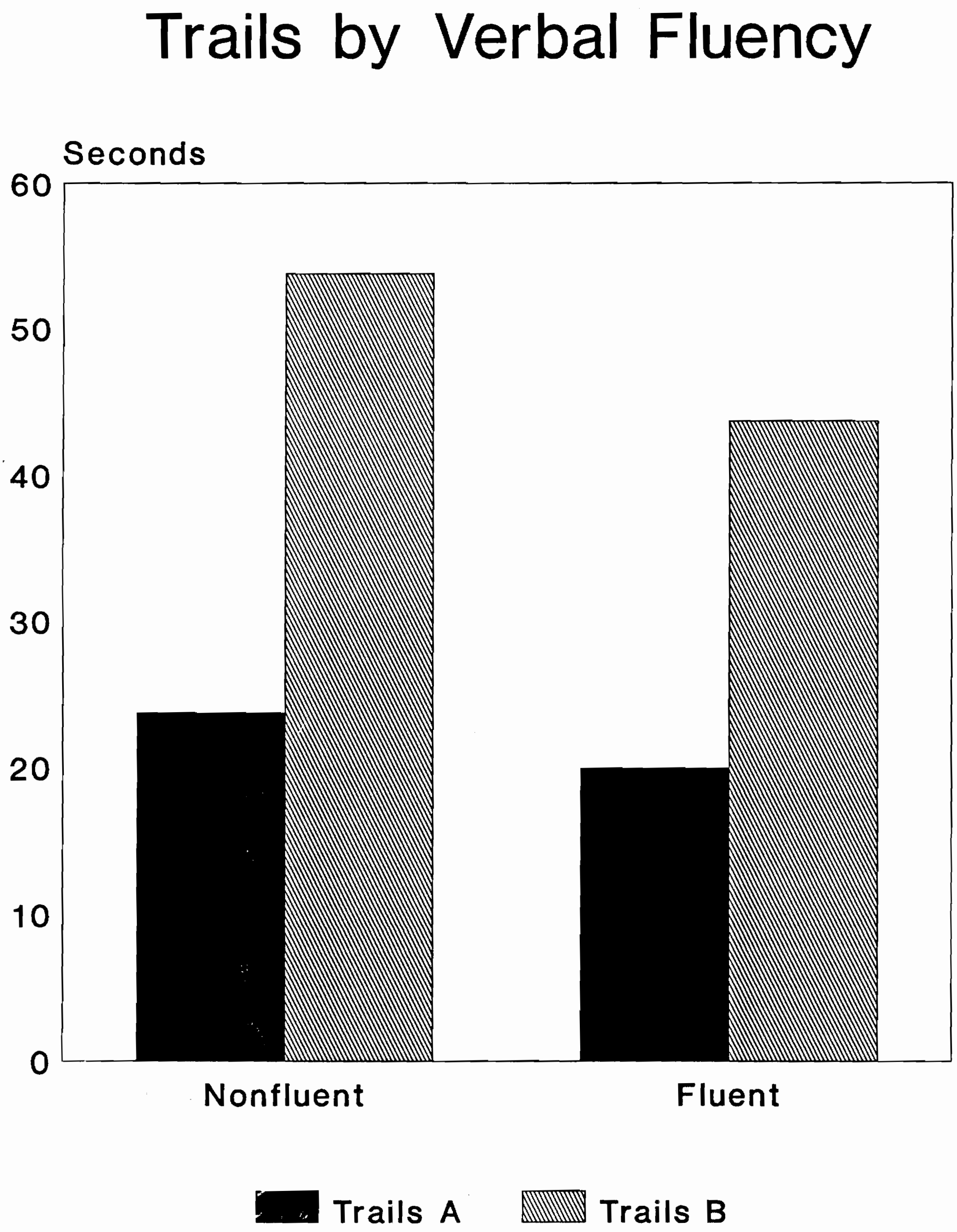

Trails by Verbal Fluency
Seconds
60
50
40
30
20
10
0
Nonfluent
Fluent
Trails A
Trails B

Figure 2

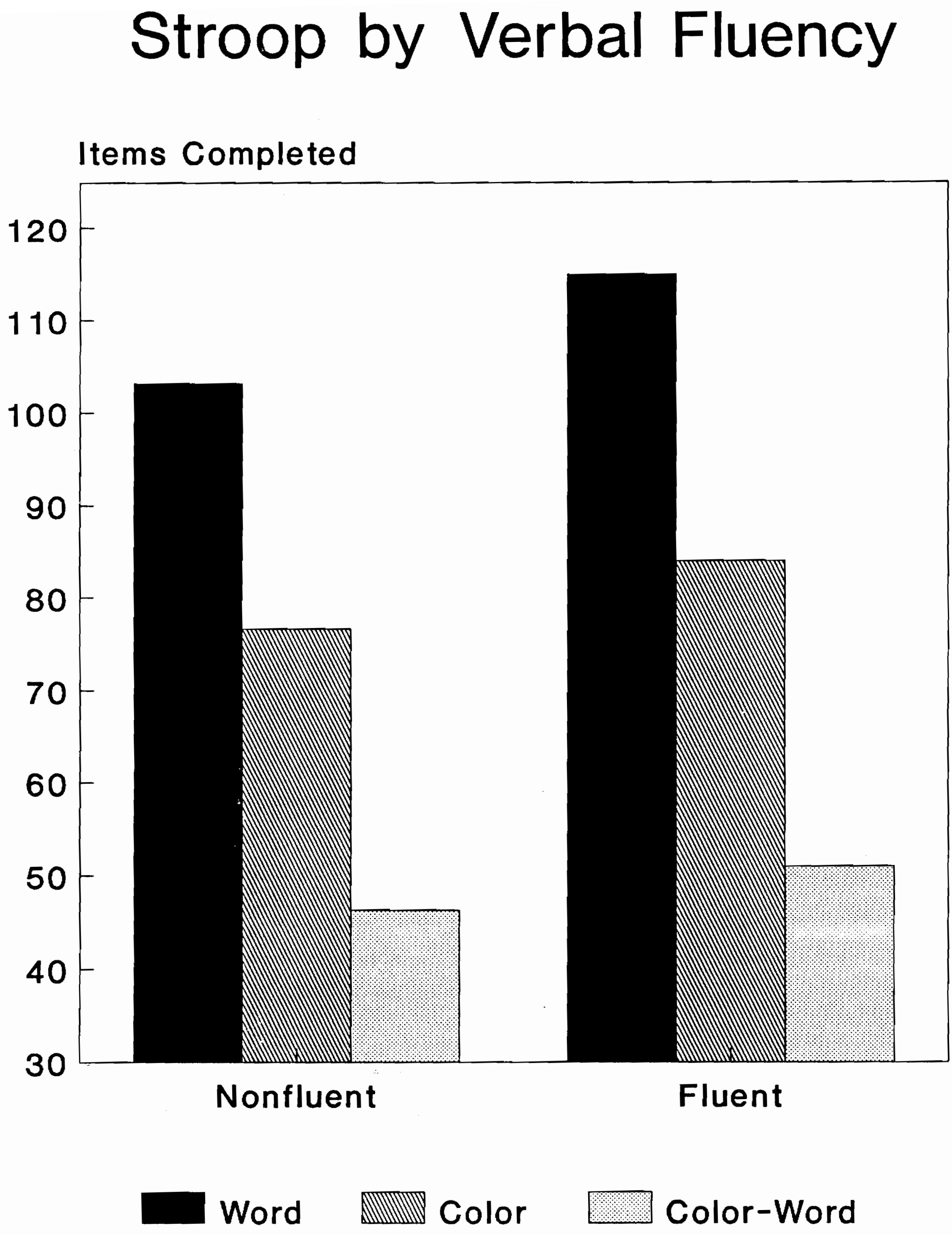

Stroop by Verbal Fluency
Items Completed
120
110
100
90
80
70
60
50
40
30
Nonfluent
Fluent
Word
Color
Color-Word

Figure 3

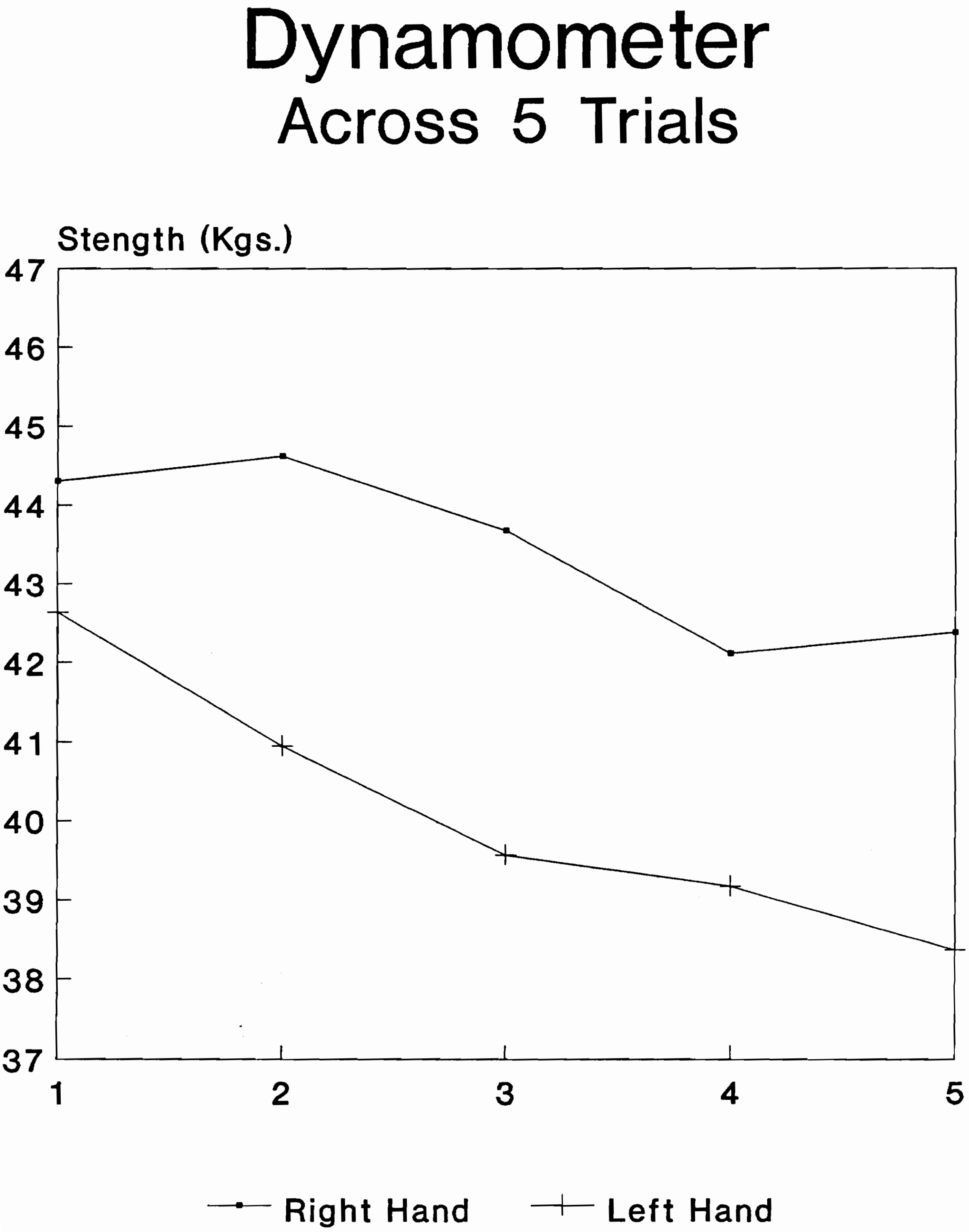
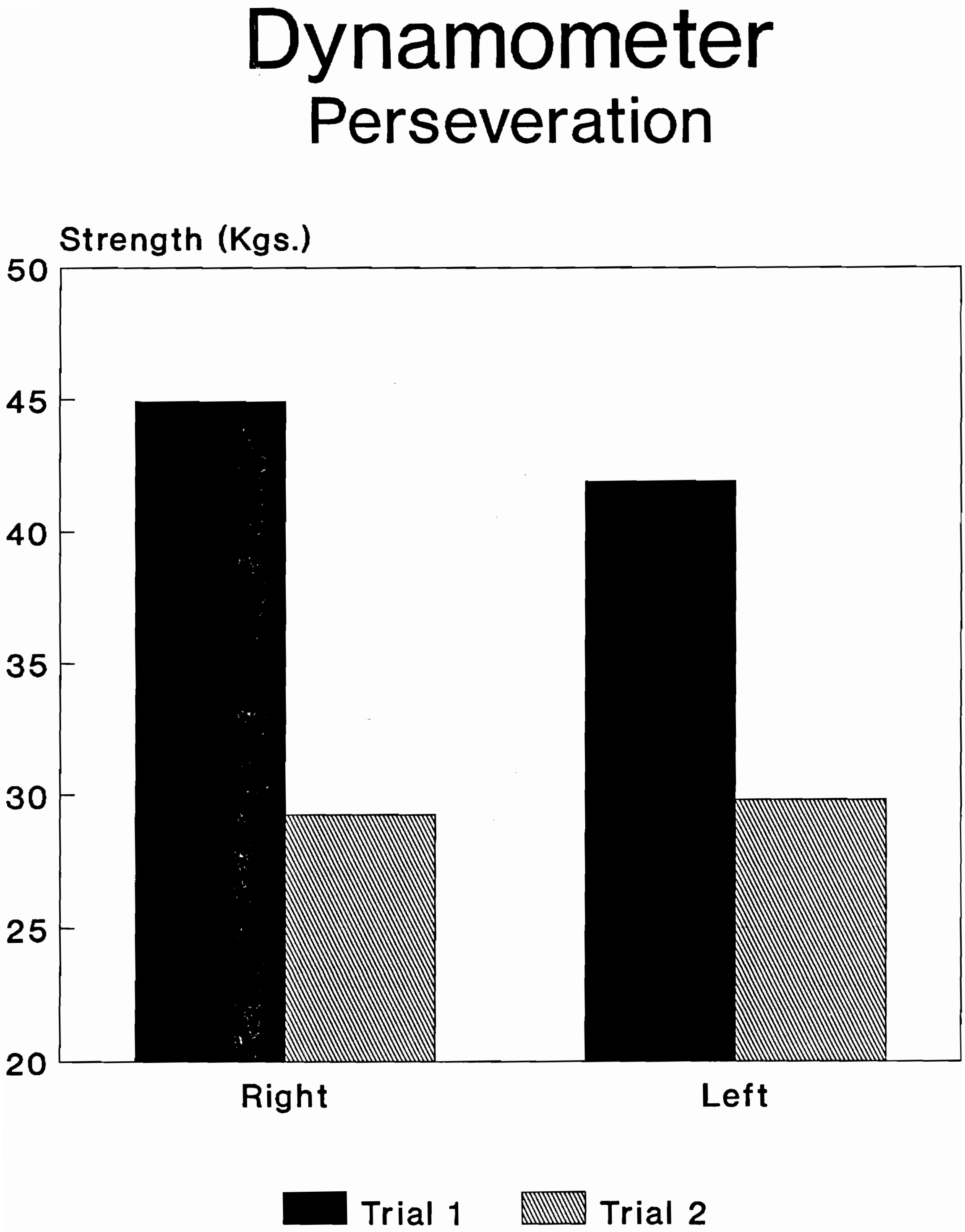

Dynamometer
Across 5 Trials
Stength (Kgs.)
47
46
45
44
43
42
41
40
39
38
37
1
2
3
4
5
Right Hand
Left Hand

Figure 4



Dynamometer
Perseveration

Figure 5

Accuracy Ratings

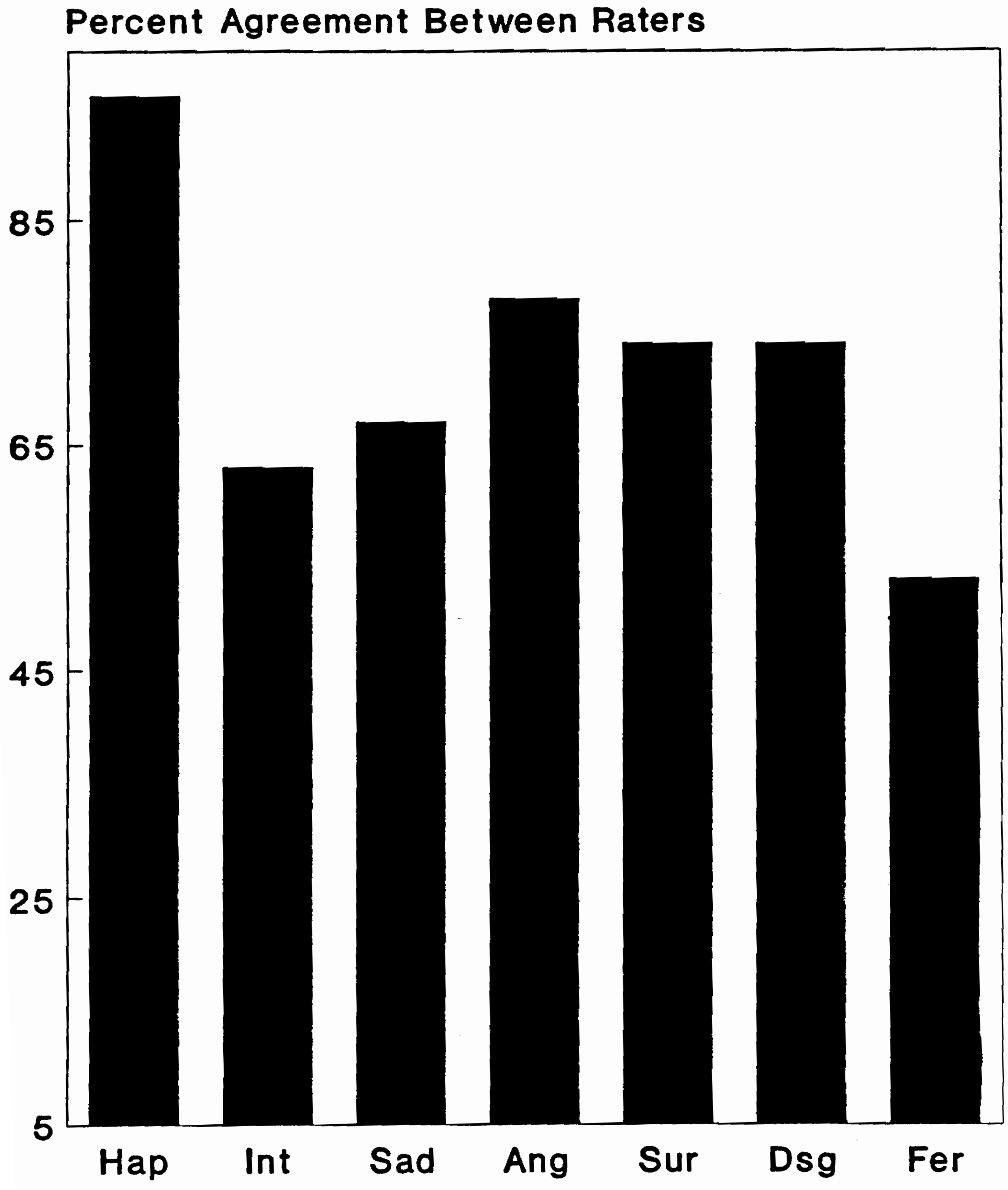


Figure 6

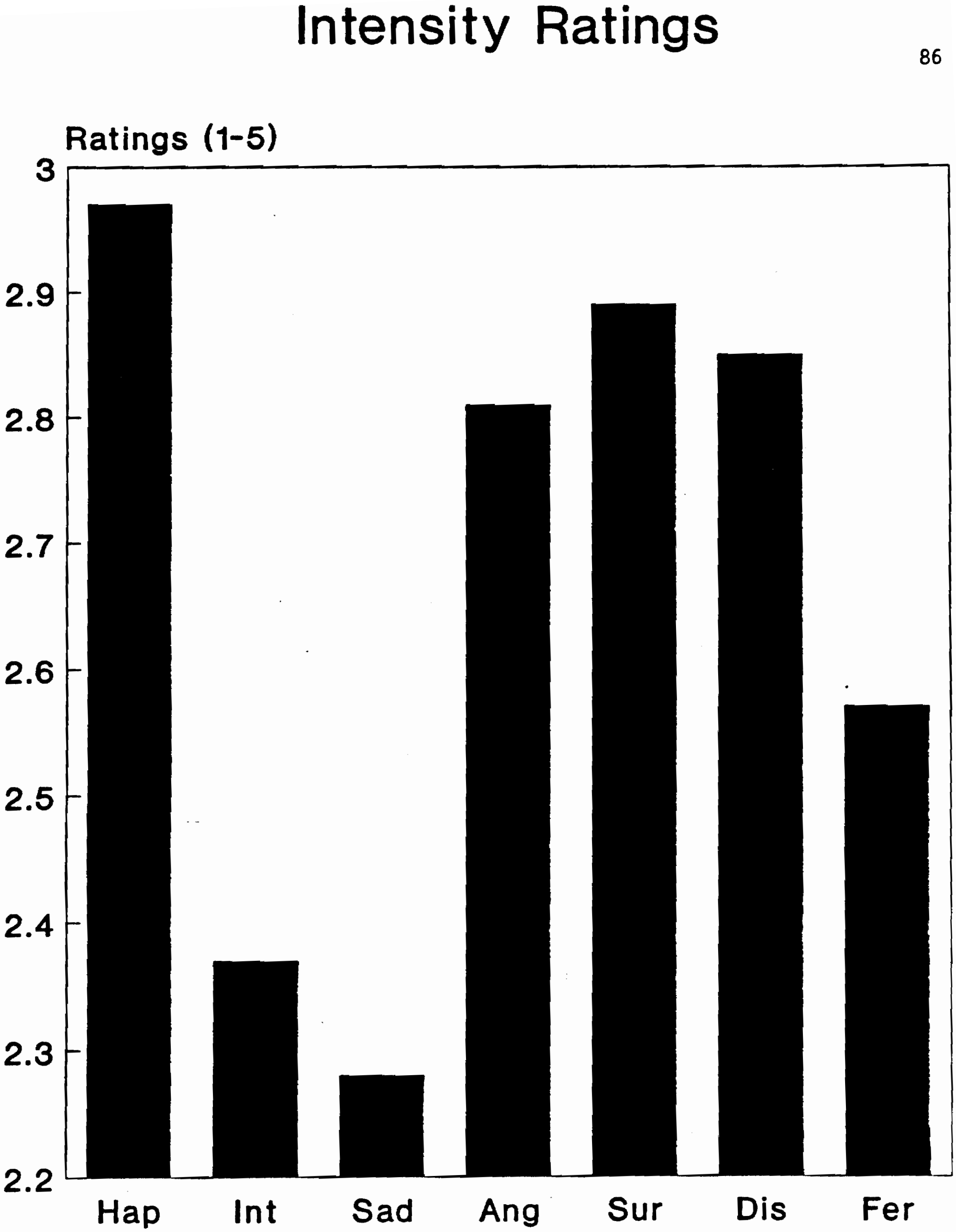

Intensity Ratings
Ratings (1-5)
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
Hap
Int
Sad
Ang
Sur
Dis
Fer

Figure 7

References

Beatty, W. W., Jocic, Z., Monson, N., & Staton, D. (1993). Memory and frontal lobe dysfunction in schizophrenia and schizoaffective disorder. _The Journal of Nervous and Mental Diseases_, _181_(7), 448-453.

Benton, A. L. (1968). Differential behavioral effects in frontal lobe disease. _Neuropsychologia_, _6_, 53-60.

Benton, A. L., & Hamsher, K. de S. (1976). _Multilingual aphasia examination_. Iowa City: University of Iowa.

Berman, K. F., Illowsky, B. P., & Weinberger, D. R. (1988). Physiologic dysfunction of dorsolateral prefrontal cortex in schizophrenia IV. Further evidence for regional and behavioral specificity. _Archives of General Psychiatry_, _45_, 616-622.

Blonder, L. Z., Burns, A., Bowers, D., Moore, R. W. & Heilman, K. M. (1993). Right hemisphere facial expressivity during natural conversation. _Brain and Cognition_, _21_, 44-56.

Boivin, M. J., Giordani, B., Berent, S., Amato, D. A., Lehtinen, S., Koeppe, R. A., Buchtel, H. A., Foster, N. L., & Kuhl, D. E. (1992). Verbal fluency and positron emission tomographic mapping of regional cerebral glucose metabolism. _Cortex_, _28_, 231-239.

Borod, J. C. (1993). Cerebral mechanisms underlying facial, prosodic, and lexical emotional expression: A review of neuropsychological studies and methodological issues. _Neuropsychology_, _7_(4), 445-463.

Borod, J. C., Koff, E., Lorch, M. P., Nicholas, M., & Welkowitz, J. (1988). Emotional and non-emotional facial behavior in patients with unilateral brain damage. _Journal of Neurology, Neurosurgery, and Psychiatry_, _51_, 826-832.

Borod, J. C., Koff, E., Lorch, M. P., & Nicholas, M. (1986). The expression and perception of facial emotion in brain-damaged patients. _Neuropsychologia_, _24_(2), 169-180.

Borod, J. C., Welkowitz, J., Alpert, M, Brozgold, A. Z,, Martin, C., Peselow, E., & Diller, L. (1990). Parameters of emotional processing in neuropsychological disorders: Conceptual issues and a battery of tests. _Journal of Communication Disorders_, _23_, 247-271.

Borokowski, J. G., Benton, A. L., & Spreen, O. (1981). Word fluency measure. In F. L. Darley (Ed.) _Evaluation of appraisal techniques in speech and language_ pathology. Reading, MA: Addison-Wesley Publishing Company.

Bruyer, R. (1981). Asymmetry of facial expression in brain-damaged subjects. Neuropsychologia, 19, 615-624.

Buck, R., & Duffy, R. J. (1980). Nonverbal communication of affect in brain-damaged patients. Cortex, 16, 351-362.

Buck, R. (1990). Using FACS vs. communication scores to measure spontaneous facial expression of emotion in brain-damaged patients: A reply to Mammucari et al., (1988). Cortex, 26, 275-280.

Butler, R. W., Rorsman, I., Hill, J. M., & Tuma, R. (1993). The effects of frontal brain impairment on fluency: Simple and complex paradigms. Neuropsychology, 7(4), 519-529.

Caltagirone, C., Ekman, P., Friesen, W., Gainotti, G., Mammucari, A., Pizzzamiglio, L., & Zoccolotti, P. (1989). Posed emotional expression in unilateral brain damaged patients. Cortex, 25, 653-663.

Canavan, A. G. M., Janota, I., & Schurr, P. H. (1985). Luria's frontal lobe syndrome: Psychological and anatomical considerations. Journal of Neurology, Neurosurgery, and Psychiatry, 8, 1049-1053.

Coren, S., Porac, C., & Duncan, P. (1979). A behaviorally validated self-report inventory to assess four types of lateral preference. Journal of Clinical Neuropsychology, 1, 55-64.

Crockett, D., Bilsker, D., Hurwitz, T. & Kozak, J. (1986). Clinical utility of three measures of frontal lobe dysfunction in neuropsychiatric samples. International Journal of Neuroscience, 30, 241-248.

Crews, W. D., & Harrison, D. W. (1994). Functional asymmetry in the motor performances of women: Neuropsychological effects of depression. Perceptual and Motor Skills, 78, 1315-1322.

Darwin, C. (1872). Expressions of the emotions in man and animals. London: John Murray.

Davidon, R. J., & Tomarken, A. J., (1989). Laterality and emotion: An electrophysiological approach. In F. Boller and J. Grafman (Eds), Handbook of Neuropsychology: Vol. 3 (pp. 419-441). Amsterdam: Elsevier.

Dodrill, C. B. (1978). The hand dynamometer as a neuropsychological measure. Journal of Consulting and Clinical Psychology, 46, 1432-1435.

Dopson, W., Beckwith, B., Tucker, D. M., & Bullard-Bates, P. (1984). Asymmetry of facial expression in spontaneous emotion. Cortex, 20, 243-252.

Ekman, P. & Friesen, W. V. (1976). Pictures of facial affect. Palo Alto, CA: Consulting Psychologist Press.

Ekman, P. & Friesen, W. V. (1978). The facial action coding system (FACS): A technique for the measurement of facial action. Palo Alto: Consulting Psychologists Press.

Estes, W. K. (1974). Learning theory and intelligence. American Psychologist, 29, 740-749.

Evans, W. R., Ruff, R. M., & Gualtieri, C. T. (1985). Verbal fluency and figural fluency in bright children. Perceptual and Motor Skills, 61, 699-709.

Finlayson, M. A., & Reitan, R. M. (1980). Effects of lateralized lesions on ipsilateral and contralateral motor functioning. Journal of Clinical Neuropsychology, 2, 237-243.

Frith, C. D., Friston, K. J., Liddle, P. F., & Frackowiak, R. S. J. (1991). A PET study of word finding. Neuropsychologia, 29(12), 1137-1148.

Fuster, J. M., (1989). The prefrontal cortex: Anatomy, physiology, and neuropsychology of the frontal lobe. (2nd ed.). New York: Raven Press.

Gardner, H. (1993). Creating minds: An anatomy of creativity seen through the lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Gandhi. New York: Basic Books.

Golden, C. J. (1976). Identification of brain disorders by the Stroop Color and Word Test. Journal of Clinical Psychology, 32(3), 654-658.

Golden, C. J. (1978). Stroop Color and Word Test: A manual for clinical and experimental uses (Number 30150M). Chicago, IL: Stoelting Company.

Goldman-Rakic, P. S. (1984). The frontal lobes: Uncharted provinces of the brain. Trends in Neuroscience, 7, 419-424.

Goldstein, K. (1948). Language and language disturbances. New York: Gurne & Stratton.

Goodglass, H. (1986). The flexible battery in neuropsychological assessment. In T. Incagnoli, G. Goldstein and C. J. Golden (Eds.). Clinical applications of neuropsychological test batteries. New York: Plenum Press.

Gorelick, P. B. & Ross, E. D. (1987). The aprosodias: Further functional-anatomical evidence for the organization of affective language in the right hemisphere. Journal of Neurology, Neurosurgery, and Psychiatry, 50, 553-560.

Gruenewald, P. J., & Lockhead, G. R. (1980). The free recall of category examples. Journal of Experimental Psychology: Human Learning and Memory. 6(3), 225-240.

Gruzlier, J., Seymour, K., Wilson, L., Jolley, A., & Hirsch, S. (1988). Impairments on neuropsychologic tests of temporohippocampal functions and word fluency in remitting schizophrenia and affective disorders. Archives of General Psychiatry, 45, 623-629.

Gurd, J. M. & Ward, C. D. (1989). Retrieval from semantic and letter-initial categories in patients with Parkinson's disease. Neuropsychologia, 27(5), 743-746.

Haaland, K. Y. & Delaney, H. D. (1981). Motor deficits after left or right hemisphere damage due to stroke or tumor. Neuropsychologia, 19, 17-27.

Hager, J., C., & Ekman, P. (1985). The asymmetry of facial actions is inconsistent with models of hemispheric specialization. Psychophysiology, 22(3), 307-318.

Harrison, D. W., & Gorelczenko, P. M. (1990). Functional asymmetry for facial affect perception in high and low hostile men and women. International Journal of Neuroscience, 55, 89-97.

Harrison, D. W., & Pauly, R. S. (1990). Manual dexterity, strength, fatigue, and perseveration: An initial test of asymmetry in cerebral activation. Perceptual and Motor Skills, 70, 739-744.

Hebb, D. O. (1939). Intelligence in man after large removals of cerebral tissue: Report of four left frontal cases. Journal of General Psychology, 21, 73-87.

Hecaen, H. (1962). Mental symptoms associated with tumors of the frontal lobe. In J. M. Warren & K. Akert (Eds.), The frontal granular and behavior. New York: McGraw-Hill.

Heilman, K. M., & Valenstein, E. (1994). Introduction. In K. M. Heilman & E. Valenstein (Eds.), Clinical Neuropsychology, (pp. 3-16). New York: Oxford University Press.

Hermann, B. P., & Wyler, A. R. (1988). Effects of anterior temporal lobectomy on language function: A controlled study. Annals of Neurology, 23, 585-588.

Huntzinger, R. M. (1989). The neuropsychological investigation of dyslexic readers: An experimental approach to subtyping. Unpublished dissertation, Virginia Polytechnic Institute and State University.

Joanette, Y. & Goulet, P. (1986). Criterion-specific reduction of verbal fluency in right brain-damaged right-handers. _Neuropsychologia_, _6_, 875-879.

Jones-Gotman, M., & Milner, B. (1977). Design fluency: The invention of nonsense drawings after focal cortical lesion. _Neuropsychologia_, _15_, 653-674.

Jones-Gotman, M. (1990). Presurgical psychological assessment in children: Special Tests. _Journal of Epilepsy_, _3_, S93-S102.

Kaczmarek, B. (1982). Word-frequency distribution in utterances of patients with local brain lesions. _Polish Psychological Bulletin_, _13_(4), 245-253.

Kaczmarek, B. (1984). Neurolinguistic analysis of verbal utterances in patients with focal lesions of frontal lobes. _Brain and Language_, _21_, 52-58.

Kent, J., Borod, J. C., Koff, E., Welkowitz, J., & Alpert, M. (1988). Posed facial emotional expression in brain-damaged patients. _International Journal of Neuroscience_, _43_, 81-87.

Kolb, B., & Taylor, L. (1990). Neocortical substrates of emotional behavior. In N. L. Stein, B. Leventhal, & T. Trabasso (Eds.), _Psychological and biological_ approaches to emotion (pp. 115-144). Hillsdale, NJ: Erlbaum.

Kolb, B., & Whishaw, I. Q. (1983). Performance of schizophrenic patients on tests sensitive to left or right frontal, temporal, or parietal function in neurological patients. The Journal of Nervous and Mental Disease, 171(7), 435-443.

Lezak, M. (1983). Neuropsychological assessment. New York; Oxford University Press.

Luria, A. R. (1966). Human brain and psychological processes. New York: Harper & Row.

Luria, A. R. (1973). The working brain: An introduction to neuropsychology. New York: Basic Books.

Martin, R. C., Loring, D. W., Meador, K. J., & Lee, G. P. (1990). The effects of lateralized temporal lobe dysfunction on formal and semantic word fluency. Neuropsychologia, 28(8), 823-829

Mammucari, A., Caltagirone, C., Ekman, P., Friesen, W., Gainotti, G., Pizzamiglio, L., & Zoccolotti, P. (1988). Spontaneous facial expression of emotion in brain-damaged patients. Cortex, 24, 521-533.

McGlone, J. (1980). Sex differences in human brain asymmetry: A critical survey. Behavioral and Brain Sciences, 3, 215-263.

Miceli, G., Caltagirone, C., Gainotti, G., Masullo, C., Silveri, M. C. (1981). Neuropsychological correlates of localized cerebral lesions in non-aphasic brain-damaged patients. Journal of Clinical Neuropsychology, 3(1), 53-63.

Milner, B. (1964). Some effects of frontal lobectomy in man. In J. M. Warren and K. Akhert (Eds.) The frontal granular cortex and behavior (pp. 313-324). New York: McGraw-Hill.

Milner, B. (1967). Brain mechanisms suggested by studies of temporal lobes. In C. H. Millikan and F. L. Darley (Eds.) Brain mechanisms underlying speech and language. New York: Grune and Stratton.

Milner, B., & Petrides, M. (1984). Behavioral effects of frontal-lobe lesions in man. Trends in Neuroscience, 7, 403-407.

Neary, D., Snowden, J. S., Mann, D. M. A., Northen, B., Goulding, P. J., & Macdermott, N. (1990). Frontal lobe dementia and motor neuron disease. Journal of Neurology, Neurosurgery, and Psychiatry, 53, 23-32.

Nehemkis, A. M., & Lewinsohn, P. M. (1972). Effects of left and right cerebral lesions on the naming process. Perceptual and Naming Skills, 35, 787-798.

Parks, R. W., Loewenstein, D. A., Dodrill, K. L., Barker, W. W., Yoshii, F., Chang, J. Y., Emran, A., Apicella, A., Sheramata, W. A., & Duara, R. (1988). Cerebral metabolic effects of a verbal fluency test: A PET scan study. _Journal of Clinical and Experimental Neuropsychology_, _10_(5), 565-575.

Pendleton, M. G., Heaton, R. K., Lehman, R. A. W. & Hulihan, D. (1982). Diagnostic utility of the Thurstone Word Fluency Test in neuropsychological evaluations. _Journal of Clinical Neuropsychology_, _4_(4), 307-317.

Perret, E. (1974). The left frontal lobe of man and the suppression of habitual responses in verbal categorical behavior. _Neuropsychologia_, _12_, 323-330.

Petersen, S. E., Fox, P. T., Posner, M. I., Mintun, M., & Raichle, M. E. (1988). Positron emission tomographic studies of the cortical anatomy of single-word processing. _Nature_, _331_, 585-589.

Randolph, C., Bruan, A. R., Goldberg, T. E., & Chase, T. N. (1993). Semantic fluency in Alzheimer's, Parkinson's, and Huntington's disease: Dissociation of storage and retrieval failures. _Neuropsychology_, _7_(1), 82-88.

Reitan, R. M. & Davidson, L. A. (1974). Clinical neuropsychology current status and applications. New York: Hemisphere.

Ross, E. D. (1981). The aprosodias: Functional-anatomic organization of the affective components of language in the right hemisphere. Archives of Neurology, 38, 561-569.

Ross, E. D. (1993). Nonverbal aspects of language. Neurological Clinics, 11(1), 9-23.

Ross, E. D. & Mesulam, M. (1979). Dominant language functions of the right hemisphere? Prosody and emotional gesturing. Archives of Neurology, 36, 144-148.

Ross, E. D., & Rush, J. (1981). Diagnosis and neuroanatomical correlates of depression in brain-damaged patients. Archives of General Psychiatry, 38, 1344-1354.

Ruff, R. (1988). Ruff Figural Fluency Test administration manual. Neuropsychological Resources.

Ruff, R., Evans, R., & Marshall, L. F. (1986). Impaired verbal and figural fluency after head injury. Archives of Clinical Neuropsychology, 1, 87-101.

Ruff, R., Allen, C. C., Farrow, C. E., Niemann, H., & Wylie, T. (1994). Figural fluency: Differential impairment in patients with left versus right frontal lobe lesions. _Archives of Clinical Neuropsychology_, _9_, 41-55.

Ruff, R. M., Light, R. H., & Evans, R. (1987). The Ruff Figural Fluency Test: A normative study with adults. _Developmental Neuropsychology_, _3_(1), 37-51.

Speedie, L. J., & Heilman, K. M. (1983). Anterograde memory deficits for visuospatial material after infarction of the right thalamus. _Archives of Neurology_, _40_, 183-186.

Strub, R. L., Black, F. W. (1985). _The mental status examination in neurology_. Philadelphia: F. A. Davis Company.

Stuss, D. T. & Benson, D. F. (1984). Neuropsychological studies of the frontal lobes. _Psychological Bulletin_, _95_(1), 3-28.

Stuss, D. T., & Benson, D. F. (1986). _The frontal lobes_. New York: Raven Press.

Taylor, A. E., Saint-Cyr, J. A., & Lang, A. E. (1986). Frontal lobe dysfunction in Parkinson's disease. _Brain_, _109_, 845-883.

Tueber, H. L., Battersby, W. S. & Bender, M. B. (1951). Performance of complex visual tasks after cerebral lesions. _Journal of Nervous and Mental Disease_, _114_, 413-429.

Woodard, J. L, Axelrod, B. N., & Rolando, H. R. (1992). Interrater reliability of scoring parameters for the Design Fluency Test. Neuropsychology, 6(2), 173-178.

Zangwill, O. L. (1966). Psychological deficits associated with frontal lobe lesions. International Journal of Neuroscience, 5, 395-402.

Appendix A

Pilot Studies

Two pilot studies were conducted. The first was designed to determine appropriate cutoffs for the experimental groups by administering the fluency measures to a large sample of subjects ($\underline{N} = 134$), see Appendix F. This sample consisted of both college-aged men ($\underline{n} = 61$) and women ($\underline{n} = 73$). There were no sex differences on the fluency measures, and the data were subsequently pooled and analyzed without regard for gender. In addition, this pilot study sought to determine whether adequate interrater reliability could be established for the Design Fluency Test (DFT). Two trained raters scored all the DFT protocols.

A second pilot study was conducted to determine whether adequate interrater reliability could be established for facial accuracy and intensity. Two raters first rated the affect and intensity of Ekman's Pictures of Facial Affect, standardized battery of affective faces (Ekman & Friesen, 1978). Next, these same raters rated faces generated by a small sample of subjects ($\underline{N} = 15$) run through the experimental protocol. Reliability measures for accuracy and intensity were obtained. Results of these pilot studies are presented in Appendix H.

Appendix B

Informed Consent to Participate in Research

RESEARCH PURPOSE:

You are invited to participate in an experiment evaluating how individuals express emotional via their facial gestures. You will be asked to make a number of emotional faces. This will aid in determining which parts of the brain are active in emotional generation. This form is designed to provide you with information about the study and to answer any questions.

EXPERIMENTAL PROCEDURE:

To accomplish the goals of the experiment, you will, if selected, be asked to participate in two experimental sessions. In the first, you will complete a number of cognitive tasks. In the second, you will be asked to complete the emotional task listed above and some other of cognitive tasks. These tasks will include generating lists of words and designs, finger tapping and completing some questionnaires. Each session should last for a about one-half hour.

DISCOMFORTS/RISKS FROM PARTICIPATION:

No medical or psychological risks are associated with this experiment.

BENEFITS:

This experiment will contribute to our understanding how emotion is generated. You will also receive extra credit for your participation and will be briefly debriefed following the experiment.

CONFIDENTIALITY OF RESULTS:

The results of this experiment will be held strictly confidential. At no time will the researchers release the results of the study to anyone other than individuals working on the project. The information you provide will have your name removed and only a subject number will identify you during analyses and for any research report. All video and audio tapes of the experiment will be viewed only by George J. Demakis and his research assistants and will be erased after the one month pilot test phase.

FREEDOM TO WITHDRAW:

You are free to withdraw your consent to participate and discontinue participation in the experiment at any time. No penalty will be imposed.

EXTRA CREDIT:

You will receive one extra credit point for each experimental session. If the experiment lasts for more than an hour you will receive two extra credit points. If at any time you withdraw your consent to participate, you will still receive extra credit.

USE OF RESEARCH MATERIAL:

The information accumulated by this research may be used for scientific or education purposes and information relating to your responses may be presented at scientific meetings and/or published in professional journals or books, or used for any other purpose which Virginia Tech's Department of Psychology considers proper in the interest of education, knowledge or research.

APPROVAL OF RESEARCH:

This research project has been approved by the Human Subjects Committee of the Department of Psychology and by the Institutional Review Board of Virginia Tech.

STATED PERMISSION FROM SUBJECT:

1. I have read and understand the above description of the experiment, had an opportunity to ask questions and had them answered, and hereby acknowledge the above and give my voluntary consent for participation in this study.

2. I understand that I am participating freely and fully understanding that I need not participate if I do not wish to, and if I participate I may withdraw at any time without penalty.

3. I understand that should I have any questions about this research and its conduct, I should contact any of the following:

Researcher:	George Demakis, M. S.	552-7327
Faculty Advisor:	David W. Harrison, Ph. D.	231-4422
Chair, Human Subjects:	R. J. Harvey, Ph. D.	231-6520
Chair, Institutional Review:	Ernie Stout	231-5281

Signature: ______________________________ Date:________

Subject ID # ________________________

Appendix C

Handedness Questionnaire

Hand

1. With which hand would you throw a ball to hit a target?
2. With which hand do you draw?
3. With which hand do you use an eraser on paper?
4. With which hand do you remove the top card when dealing?

Foot

1. With which foot do you kick a ball?
2. If you wanted to pick up a pebble with you toes, which foot would you use?
3. If you had to step up onto a chair, which foot would you place on the chair first.

Eye

1. Which eye would you use to peep through a keyhole?
2. If you had to look into a dark bottle to see how full it was, which eye would you use?
3. Which eye would you use to sight down a rifle?

Ear

1. If you wanted to listen in on a conversation going on behind a close door, which ear would you place against the door?
2. If you wanted to hear someone's heart beat, which ear would you place against their chest?
3. Into which ear would you place the earphone of a transistor radio?

Appendix D

Neurological History Questionnaire

Have you ever experienced or been diagnosed with any of the following, or are you experiencing any of the following at present? Please circle the appropriate response and explain any "Yes" answers below.

1. Visual difficulties, blurred vision or eye disorders Yes No
2. Blindness in either eye Yes No
3. If Yes to either of the above, have problems been corrected Yes No
4. Severe head trauma/injury Yes No
5. Stroke Yes No
6. Learning disabilities (problems of reading, writing, or comprehension) Yes No
7. Epilepsy or seizures Yes No
8. Paralysis Yes No
9. Neurological surgery Yes No

Please explain any "Yes" responses:

____

____

____

____

____

Appendix E

Controlled Oral Word Association Test

Administration

I AM GOING TO SAY A LETTER OF THE ALPHABET AND I WANT YOU TO WRITE AS QUICKLY AS YOU CAN ALL THE WORDS YOU CAN THINK OF THAT BEGIN WITH THAT LETTER. FOR INSTANCE, IF I SAY "B" YOU MIGHT SAY "BAD, BATTLE, BED" OR OTHER WORDS LIKE THAT. DO NOT USE WORDS WHICH ARE PROPER NAMES SUCH AS "BOSTON, BETTY, BUICK" OR NUMBERS. ALSO, DO NOT USE THE SAME WORD WITH A DIFFERENT PREFIX OR SUFFIX, SUCH AS "BEAT" OR "BEATING", OR THE SAME WORD IN A DIFFERENT TENSE, SUCH AS "FIGHT" OR "FOUGHT". YOU WILL HAVE THREE MINUTES FOR EACH LETTER AND I WILL NOTIFY YOU WHEN THE FIRST AND SECOND MINUTES HAVE PASSED. AFTER EACH MINUTE, PLEASE DRAW A LINE UNDER THE LAST WORD WRITTEN AND JUST CONTINUE GENERATING WORDS. ANY QUESTIONS? BEGIN WHEN I SAY THE FIRST LETTER. THE FIRST LETTER IS "F". GO AHEAD.

Timing begins immediately and three minutes are allowed for each letter. When one minute is up, say "ONE MINUTE IS UP" and when two are up say "TWO MINUTES ARE UP". When the three minutes are up say "STOP". Wait about 5 seconds before beginning the next trial. Next, say; "BEGIN WHEN I SAY THE NEXT LETTER. THE NEXT LETTER IS "A". GO AHEAD. Allow three minutes for this letter. Follow this protocol with the letter "S". The score is the total number of acceptable words produced over the nine minutes.

Appendix F, Continued

Scoring

For each condition, the novel output score is defined as the total output minus the sum of all unacceptable designs. There are three categories of unacceptable designs; designs that can be named, designs drawn with the wrong number of lines (only in the fixed condition) and perseverative designs. Perseverative designs are those which differ from any other design by a single detail or which are simple rotations from previous designs. The nonverbal fluency score is the sum of the unique designs generated in the fixed and free conditions, minus the number of nameable and perseverative designs.

Appendix F, Continued

Design Fluency Test (DFT) Reliability

Two trained scorers independently rated the pilot subjects' (N = 134) DFT protocols. Correlations between their scoring are presented for all components of the Design Fluency Test.

Test	Correlation
Free Unique	.97+
Free Perseverative	.73+
Free Nameable	.83+
Fixed Unique	.97+
Fixed Perseverative	.62+
Fixed Nameable	.54+
Fixed Wrong	.94+
Design Total	.97+

+ = $p < .0001$.
Note: Design Total = Free Unique + Fixed Unique

Despite concerns about the reliability of the Design Fluency Test, these correlations indicate that excellent reliability may be obtained between trained raters. Because of this high degree of reliability for the pilot subjects, only one rater was used in the actual experiment. However, to ensure continued high reliability in the actual experiment, the second rater scored a random sample (n = 23) of the Design Fluency protocols, see Table 9. High reliabilities similar to the pilot study were obtained (rs = .72 - .99). In cases where both raters were employed in the experiment, only the scores of the first rater were used to determine the experimental group of the subject.

Appendix G

Verbal and Nonverbal Fluency Cutoffs Based on Pilot Testing

	Cutoffs	
Fluency	Bottom (33%)	Top (67%)
Verbal	68	80
Nonverbal	30	41

Note: Subjects who scored either below the bottom cutoff or above the top cutoff on _both_ fluency measures were retained for the experiment and contacted for further testing. Subjects who scored in the middle of either cutoff received experimental credit, but were not contacted for further testing. Thus, the upper third of the sample were considered "Fluent" and the bottom third of the sample "Nonfluent".

Appendix H

Protocol for Facial Expressiveness

IN THIS CONDITION, YOU WILL BE REQUIRED TO POSE A NUMBER OF POSITIVE AND NEGATIVE EMOTIONAL FACES. ATTEMPT TO MAKE EACH FACE AS INTENSELY AND ACCURATELY AS POSSIBLE AND HOLD IT FOR FIVE SECONDS. USE ONLY YOUR FACE, DO NOT GESTURE OR USE YOUR HANDS OR ARMS. A COMMAND WILL INFORM YOU WHICH FACE TO MAKE. FOR EXAMPLE, PRIOR TO A HAPPY FACE, THE COMMAND "LOOK HAPPY" WILL BE PRESENTED. MAKE THE FACE IMMEDIATELY AFTER THE COMMAND AND HOLD IT FOR FIVE SECONDS. ONCE YOU HAVE MADE THE FACE, HOLD IT AS CONSTANT AS POSSIBLE UNTIL THE EXPERIMENTER TELLS YOU TO STOP. A FIVE SECOND INTERVAL WILL SEPARATE EACH FACE. YOU WILL BE ASKED TO MAKE 7 DIFFERENT FACES TWO TIMES EACH. PRACTICE TRIALS FOR EACH FACE WILL NOW BE PRESENTED. YOU WILL BE INFORMED WHEN THE ACTUAL EXPERIMENT BEGINS. ANY QUESTIONS?

Appendix H, Continued

Practice and Experimental Trials For Faces

Practice Trials

1. Instruct the subject to make each of the following faces; happy, interested, sad, angry, disgusted, interested and surprised. The commands are, LOOK HAPPY, LOOK INTERESTED, LOOK SAD, LOOK ANGRY, LOOK DISGUSTED, LOOK INTERESTED AND LOOK SURPRISED. Allow five seconds per face. If the subject does not hold the face for five seconds, remind him to do so.

2. Following five seconds, instruct the subject to STOP.

3. Allow five seconds between faces and proceed with the next face.

4. If the subject is unable to make a particular face, return to that face after all the practice faces have been completed and repeat the practice trial.

5. After the practice trials are completed, say THE PRACTICE TRIALS HAVE ENDED AND THE EXPERIMENT WILL NOW BEGIN. REMEMBER, MAKE EACH FACE AS INTENSELY AND ACCURATELY AS POSSIBLE AND HOLD IT FOR FIVE SECONDS. YOU WILL MAKE EACH FACE TWICE. ANY QUESTIONS?

Experimental trials

1. Use one of the orders listed below and complete all the faces following the above instructions.

2. Remember to write which order was administered on the scoring sheet.

Appendix H, Continued

Presentation Order of Faces

Order #1

1. Interest
2. Sad
3. Disgust
4. Surprise
5. Fear
6. Happy
7. Anger
8. Surprise
9. Fear
10. Disgust
11. Happy
12. Sad
13. Anger
14. Interest

Order #2

1. Anger
2. Fear
3. Happy
4. Sad
5. Interest
6. Disgust
7. Surprise
8. Anger
9. Interest
10. Fear
11. Surprise
12. Sad
13. Happy
14. Disgust

Order #3

1. Interest
2. Sad
3. Disgust
4. Happy
5. Angry
6. Fear
7. Surprise
8. Disgust
9. Interest
10. Fear
11. Surprise
12. Happy
13. Angry
14. Sad

Appendix H, Continued

Scoring Criteria for Facial Expressiveness

A. Which affective face was generated by the subject?

1. Happy
2. Interested
3. Sad
4. Angry
5. Pleasant surprise
6. Disgust
7. Fear

B. Rate the intensity of the affective face:

1. No intensity--flat
2. Minimally intense
3. Somewhat intense
4. Very intense
5. Extremely intense

Appendix I

Facial Scoring Reliability

Reliability was established in two ways. First, Ekman's Pictures of Facial Affect were rated by both raters (Ekman & Friesen, 1976). In these 96 slides, targets pose one of 6 facial affects, either happy, sad, fear, anger, surprise or disgust. Each slide was shown for 10 seconds and raters were instructed to select the one emotion that best described the expressed emotion. It should be noted that interest, an emotion included in this experiment, is not included in Ekman's Pictures of Facial Affect.

Percent agreement with the expressed emotion and interrater agreement were calculated. Each rater was 91% accurate determining which of the six affects were expressed. Interrater agreement was 81% across all faces.

Reliabilities were also calculated for the 15 pilot subjects run through the facial expression protocol. To score the faces, raters viewed the videotaped recordings of the faces together. In tandem, they selected the most intense expression of the subject and made their facial judgments at that point. When a question existed as to the most intense facial expression, the senior author (GJD) ultimately made the decision. Average interrater agreement for the affect expressed across subjects was 72% (SD = 17%, Range, 43% - 100%). Interrater reliability, calculated via a simple correlation, for accuracy ratings across subjects was r = .76, whereas reliability for the intensity ratings was r = .85. Though these levels may appear somewhat low, the task was designed to ensure variability in these non-impaired subjects' performances. Interrater agreement scores are thus diminished with subjects who had significant difficulty with this task, though this is the variability of interest.

Appendix J

Trail Making Tests

Trails A: Practice

ON THIS PAGE ARE SOME NUMBERS. BEGIN AT NUMBER ONE [point to number 1] AND DRAW A LINE FROM ONE TO TWO [point to 2], TWO TO THREE [point to 3], THREE TO FOUR [point to 4], AND SO ON IN ORDER UNTIL YOU REACH THE END [point to the circle marked END]. DRAW THE LINES AS FAST AS YOU CAN, DO NOT LIFT THE PENCIL FROM THE PAPER. READY? BEGIN

If the subject competes the sample correctly, continue with Part A. If not, repeat the instructions.

Trails A: Part A

ON THIS PAGE ARE NUMBERS FROM ONE TO TWENTY-FIVE. DO THIS THE SAME WAY. BEGIN AT NUMBER ONE [point], AND DRAW A LINE FROM ONE TO TWO [point to 2], TWO TO THREE (point to 3), THREE TO FOUR (point to 4), AND SO ON IN ORDER UNTIL YOU REACH THE END (point). REMEMBER, WORK AS FAST AS YOU CAN. READY? BEGIN.

Begin timing as soon as the subject starts attending to the task. If an error is made, immediately call it to his attention and have him put his pencil back to the point preceding the mistake. Instruct him to then continue. When the task is completed, record the time in seconds and the number of errors in parentheses.

Trails B: Practice

ON THIS PAGE ARE SOME NUMBERS AND LETTERS. BEGIN AT NUMBER ONE (point) AND DRAW A LINE FROM ONE TO A (point to A), A TO TWO (point to 2), TWO TO B (point to B), B TO THREE (point to 3), THREE TO C (point to C), AND SO ON IN ORDER UNTIL YOU REACH THE END (point to circle marked END). REMEMBER, FIRST YOU HAVE A NUMBER (point to 1) THEN A LETTER (point to A), THEN A NUMBER (point to 2) THEN A LETTER (point to B) AND SO ON. DRAW THE LINES AS FAST AS YOU CAN. READY? BEGIN.

If the subject completes the sample correctly, continue with Part B. If not, proceed as instructed in Part A.

Appendix J, Continued

Trails B: Part B

ON THIS PAGE ARE BOTH NUMBERS AND LETTERS. DO THIS THE SAME WAY. BEGIN AT NUMBER ONE (point) AND DRAW A LINE FROM ONE TO A (point to A), A TO TWO (point to 2), TWO TO B (point to B), B TO THREE (point to 3), THREE TO C (point to C) AND SO ON IN ORDER UNTIL YOU REACH THE END (point to circle marked END). REMEMBER, FIRST YOU HAVE A NUMBER (point to 1) THEN A LETTER (point to A), THEN A NUMBER (point to 2) THEN A LETTER (point to B) AND SO ON. DO NOT SKIP AROUND, BUT GO FROM ONE CIRCLE TO THE NEXT IN THE PROPER ORDER. DRAW THE LINES AS FAST AS YOU CAN. READY? BEGIN.

Begin timing as soon as the subject starts attending to the task. Record the time in seconds and error in parentheses. If the subject makes an error, call it to his attention immediately and have him put his pencil back to the point where the mistake occurred. Instruct him to continue and, if he does not see his error, instruct him with any of the following commands:

1. DO YOU WANT TO GO TO A NUMBER OR LETTER?
2. WHAT WAS THE LAST NUMBER (LETTER)?
3. WHICH NUMBER (LETTER) COMES NEXT?

Appendix K

Finger Tapping

IN THIS TASK YOU ARE TO PRESS THE FOLLOWING KEY (present the tapping key) AS QUICKLY AS POSSIBLE ON A NUMBER OF SEPARATE TRIALS. USE ONLY YOUR INDEX FINGER AND KEEP YOUR WRIST DOWN ON THE BOARD (point to the board). YOU WILL BE INSTRUCTED TO BEGIN AND STOP BY THE EXAMINER. A PRACTICE TRIAL WILL NOW BE COMPLETED FOR EACH HAND. Begin each trial with a command of BEGIN and end each one with a command of STOP. Use a stopwatch or wristwatch and time each trial for 10 seconds. Do a practice trial for right hand and then the left. Following the practice trials, say THE EXPERIMENT WILL NOW BEGIN AND YOU WILL COMPLETE A NUMBER OF TRIALS FOR EACH HAND. WE WILL FIRST COMPLETE ALL THE RIGHT HAND TRIALS AND THEN DO THE LEFT HAND. Complete the trials with the right hand first and then the left hand. Write down the number of taps after each trial. Allow approximately ten seconds between trials.

Appendix L

Dynamometer Tasks

Practice

IN THIS TASK YOU ARE TO SQUEEZE THIS (present the dynamometer) AS HARD AS YOU CAN WITH YOUR RIGHT AND LEFT HAND. EACH HAND WILL BE TESTED SEPARATELY. A PRACTICE TRIAL WILL NOW BE COMPLETED FOR EACH HAND. Allow a practice trial for each hand. Make sure the scale is turned away from the subject. When completed say THE EXPERIMENT WILL NOW BEGIN.

Perseveration

I WANT YOU TO SQUEEZE THIS AS HARD AS YOU CAN WITH YOUR RIGHT HAND AND THEN I WANT YOU TO SQUEEZE IT HALF AS HARD WITH YOUR RIGHT HAND. I WILL RECORD THE SCORE AFTER EACH SQUEEZE. Record the score. Complete this procedure for the left hand.

Strength and Fatigue

NOW I WANT YOU TO SQUEEZE IT AS HARD AS YOU CAN WITH YOUR RIGHT HAND FIVE TIMES IN A ROW. I WILL RECORD YOUR SCORE AFTER EACH TRIAL. Complete five trials. Complete this procedure for the left hand.

Appendix M

Ruff Figural Fluency Test

Administration

Begin with sample items of Part 1.

IN FRONT OF YOU ARE THREE SQUARES, EACH CONTAINING FIVE DOTS. NOTE THAT THE ARRANGEMENT OF THE FIVE DOTS IS ALWAYS THE SAME. I WANT YOU TO CONNECT TWO OR MORE DOTS BY ALWAYS USING STRAIGHT LINES. YOU DO NOT NEED TO CONNECT ALL FIVE DOTS. THE PURPOSE OF THE TEST IS FOR YOU TO MAKE AS MANY DESIGNS OR FIGURES AS POSSIBLE, BUT EACH DESIGN HAS TO BE DIFFERENT IN SOME WAY FROM ALL THE OTHERS. ANY QUESTIONS?

Following completion of the sample, give feedback as to errors, i.e. if there are two identical designs, point out the duplicated designs and repeat the instructional set. If the sample designs are elaborate (e.g. all five dots are consistently connected) re-emphasize the instructions that a design can be drawn by connecting two or more dots. Following completion of the sample, turn to the test page and state:

TURN THE PAGE. DO NOT BEGIN UNTIL INSTRUCTED. ON THIS PAGE, DRAW AS MANY DIFFERENT DESIGNS OR FIGURES AS POSSIBLE. START IN THE UPPER LEFT SQUARE AND WORK FROM LEFT TO RIGHT. CONNECT AT LEAST TWO DOTS WITH A STRAIGHT LINE. YOU DO NOT NEED TO USE ALL FIVE DOTS. WORK AS QUICKLY AS POSSIBLE AND MAKE EVERY DESIGN DIFFERENT. GET READY--GO.

Allow one minute for each part of the test proper. When this time is up, say "STOP". Allow about 5 seconds and then instruct the subject; TURN THE PAGE AND COMPLETE THE PRACTICE TRIALS. Allow about 20 seconds for this. Then, TURN THE PAGE, START IN THE UPPER LEFT SQUARE AND WORK FROM LEFT TO RIGHT. WORK AS QUICKLY AS POSSIBLE AND MAKE EVERY DESIGN DIFFERENT. GET READY--GO.

Appendix N

Stroop Color and Word Test

Administration: Words

THIS IS A TEST OF HOW FAST YOU CAN READ THE WORDS ON THIS PAGE. AFTER I SAY BEGIN, YOU ARE TO READ DOWN THE COLUMNS STARTING WITH THE FIRST ONE UNTIL YOU COMPLETE IT AND THEN CONTINUE WITHOUT STOPPING DOWN THE REMAINING COLUMNS IN ORDER. IF YOU FINISH ALL THE COLUMNS BEFORE I SAY STOP, THEN RETURN TO THE FIRST COLUMN AND BEGIN AGAIN. REMEMBER, DO NOT STOP READING UNTIL I SAY STOP AND READ OUT LOUD AS QUICKLY AS YOU CAN. IF YOU MAKE A MISTAKE, I WILL SAY NO TO YOU. CORRECT YOUR ERROR AND CONTINUE WITHOUT STOPPING. ARE THERE ANY QUESTIONS? READY? BEGIN. After 45 seconds, say STOP.

Answers:

RED
GREEN
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Appendix N, Continued

Administration: Colors

THIS IS A TEST OF HOW FAST YOU CAN NAME THE COLORS ON THIS PAGE. YOU WILL COMPLETE THIS PAGE JUST AS YOU DID THE PREVIOUS PAGE, STARTING WITH THIS FIRST COLUMN. REMEMBER TO NAME THE COLORS OUT LOUD AS QUICKLY AS YOU CAN. ARE THERE ANY QUESTIONS? READY? BEGIN. After 45 seconds, say STOP.

Answers:

BLUE
RED
GREEN
BLUE
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RED
BLUE
RED
BLUE
GREEN
RED
GREEN
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Appendix N, Continued

Administration: Color-Word

THIS PAGE IS LIKE THE PAGE YOU JUST FINISHED. I WANT YOU TO NAME THE COLOR OF THE INK THE WORDS ARE PRINTED IN, IGNORING THE WORD THAT IS PRINTED IN EACH ITEM. FOR EXAMPLE, (point to the first item of the first column), THIS IS THE FIRST ITEM: WHAT WOULD YOU SAY? If the subject is correct, go on with the instructions. If incorrect, say: NO, THAT IS THE WORD THAT IS SPELLED THERE. I WANT YOU TO SAY THE COLOR OF THE INK THE WORD IS PRINTED IN. NOW (point to the same item) WHAT WOULD YOU SAY TO THIS ITEM? THAT'S CORRECT, (point to the second item), WHAT WOULD THE RESPONSE BE TO THIS ITEM? If correct, proceed; if incorrect, repeat above as many times as necessary until the subject understand or it becomes clear that it is impossible to go on. GOOD. YOU WILL DO THIS PAGE JUST LIKE THE OTHERS, STARTING WITH THE FIRST COLUMN (pointing) AND THEN GOING ON TO AS MANY COLUMNS AS YOU CAN. REMEMBER, IF YOU MAKE A MISTAKE, JUST CORRECT IT AND GO ON. ARE THERE ANY QUESTIONS? BEGIN. After 45 seconds, say STOP.

Answers:

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Vita

George John Demakis was born on October 18, 1967 in Oak Park, Illinois. He was graduated from Loyola University of Chicago in 1989 with a Bachelor's degree in Psychology. He received a Master's degree from Virginia Polytechnic Institute and State University in Psychology. He is currently completing a predoctoral internship at the University of Florida, Shands Hospital, in the Department of Clinical and Health Psychology.

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