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Atypicality in Perceptual-Motor Functions Among Developmental Disorder

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Abstract:-This research paper is concerned with atypical laterality in the field of perceptual- motor skill among stutterers, reveals about the anomalous pattern of lateralisation and severity of cerebral dysfunction in this population. The number of children diagnosed with developmental disorder such as dyslexia, autism, speech and language impairment and attention deficit disorder are increasing as these disorders become better defined in terms of their behavioural and motor characteristics. The studies of brain morphometry were stimulated by the landmark study of Geschwind and Levitsky (1968), which provided evidence of asymmetry in brain structure that, correlated with the well established functional asymmetry and found dominance of the left hemisphere for language related activity. Implicit in the notion those developmental disorders (stuttering) are associated with anomalous lateralisation pattern or atypical lateralisation pattern. Atypical laterality (i.e. the lack of a clear pattern of lateralisation) has been found to be characteristics of individual with speech and language disability (S & LD). The evidence of this has been based on handedness studies which have contain little information about the ability of people with S &LD to carry out interhemispheric task reflecting bilateral transfer or interference. The present study examined this capacity among stutterers by utilising bilateral transfer and interference paradigms. Right handed stutterers (IQ-90 to 110) and controls matched for age and sex were tested for bilateral transfer of motor skills in contralateral hands with a mirror drawing task. The subjects were also tested for their ability to perform a finger tapping task while processing verbal & non-verbal stimuli. The finding indicated that stutterers are significantly deficient relative to match controls in bilateral transfer of motor skills form their non-preferred (left) hand to their proffered (right) one. The effect of interference during performance of the dual; task was significantly greater in individuals with speech and language disabilities. Stutterers were found to perform better with their non- preferred hand than with their preferred hand. A within group comparison revealed that right handed performance was more affected by interferrence than left hand in these subjects.

Keywords:- *atypical laterality, interference, motor skills, transfer*

I. INTRODUCTION

Persistent developmental stuttering is disorder of speech fluency affecting approximately 1% of the adult population (Andrews and Harris, 1964; Blovdstem, 1995). The prevalence of stuttering, however, is even higher than this with estimates of between 4 and 5% of the population having

Stuttered at some point during development (Andrews and Harris, 1964). People who stutter are generally health and cognitively, psychiatrically and neurologically unimpaired. Speech requires fine control of physiological processes extending from the limbs to the lips, made all the more complicated because components of the vocal system also serve critical functions unrelated to speech (e.g. breathing, feeding and facial expression). Like any complex motor activity, speech is subject to disruptions at many levels due to both congenital and acquired deficits, including those leading to syndromes like dysarthria, apraxia, dysphonice and stuttering (Kent, 2000). Developmental stuttering is a speech disorder characterized by involuntary syllable repetition and prolongations, especially during connected speech, thereby impairing normally fluent speech. There is a high rate of recovery in children, but stuttering that persists into adolescence or adulthood is much more resistant to recovery (Ingham, 2001a). In stuttering, the most characteristic performance abnormality is the failure to properly initiate the speech motor plan. The problem is limited to successful initiation of the motor program. Importantly, stuttering is usually exhibited as a repetition of the initial sound of a word, the motor-system overactivity observed in stuttering is usually exhibited as a repetition of the initial sound of a word. The motor-system overactivity observed in stuttering has two potential explanations. First, repeated initiation of the speech-motor plan likely repeatedly activities some components of the speech motor system, resulting in overactivation. Second, there is now considerable evidence that increased skill is associated with a concomitant decrease in activation. (Jansma et al. 2001; Just et al; 1996; Raichll et al; 1994). In stuttering, it is likely that both effects come into play. The right laterality of the motor region hyperactivity also deserves comment. Studies from two labs have suggested that developmental stuttering might be associated with a structural lesion in the left hemisphere (Foundas et al., 2001, 2003; Semmer et al., 2002). In the presence of a left hemisphere

dysfunction, the right hemisphere assumes left hemisphere tasks at which it is intrinsically less competent (Gandour et al, 2003, 2004), resulting in over activation. A number of children diagnosed with developmental disorders such as dyslexia, autism speech & language impairement (stutterers) and attention deficit disorder, is increasing as these disorders become letter defined in terms of their behavioural or motor characteristics. Studies of brain marphometry were stimulated by the landmark study of Geschwind and Levistsky (1968), which provided evidence of an asymmetry in brain structure that correlated with the well established functional asymmetry and found dominance of the left hemisphere for language related activity. Implicit in the notion that developmental disorders (stuttering) are associated with anomalous lateralization pattern or atypical lateralization pattern. Atypical laterality (i.e. the lack of a clear pattern of lateralization) has been found to be a characteristics of individual with speech and language disability (S & LD). Two Theoretical perspectives have been put forward to explain atypical laterality in individuals with (S & LD). (1) Early cereberal insult; and (2) developmental / materational delay. The proponents of early cerebral insult in stutterer attribute the lack of lateralization to a failure to establish dominance for language in either hemisphere (Travis 1931 ; Orton 1937; Silva & Satz 1979) The Cerebral dominance hypo thesis of stuttering as initially stated by Travis (1934), is the notion that the speech apparatus of the person who stutter is constantly receiving competing signals arising from speech centers in the two cerebral hemispheres, rather than from one dominant hemisphere. Orton (1937) believed that the development of a dominant hemisphere could be facilitated by the training of one hand in motor skills, and that this would ultimately lead to an improvement in the disorder. Two important assumptions of Orton's (1937) reasoning are that 1) Cerebral dominance develops over time ; and 2) cultural or environmental influences on handedness can influence the development of cerebral dominance.Developmental theorists relate reduced lateralization to a maturational delay in the neuronal pathways and low intelligence (Leneberg 1969 ; Berman 1971; for a review, see pipe 1988). These theoretical perspectives were developed based on handedness studies of people with S & LD.

It has been found that non-right handedness (deviation from the normal pattern of handedness) is significantly more common in people who stutter. This behalf was based on evidence at the time of an association between left handedness and developmental disabilities (Bryngelson, 1931; 1935; Dearbaru, 1993) Quinan, 1921; Travis and Lindsley, 1933) and the fact that there appeared to be a positive correlation between forced handedness changes and an abnormally high incidence of developing those disorders (Ballard, 1912; Brynglelson, 1935). Ballard (1912) in particular found that the rate of stuttering among children whose handedness and been forcibly switched from left to right was four times higher (4.3%) than among those whose handedness had not been interfered with (1.1). Bryngelson (1960) reported that of 152 male stutterers, 34% were ambidextrous" and 61% had been forcibly shifted from left to right handedness, whereas the same figures for fluent speakers were 4% and 5% respectively. However, the notion of atypical cerebral dominance in these individuals has not been substantiated b the findings of dichotic listening studies, a more direct measures of cerebral dominance. (Zekulen-Hartley 1982; Harnstein & Mosley 1986; See Pipe 1988). The inconsistency in the findings has given rise to the speculation that atypical lateralization may be a function of lowered bilateral organization rather than a failure to establish normal dominance or reversal of dominance in people with stuttering. The concept of lowered bilateral organization is operationalized for the sake of present study as: (I) a reduced ability to interhemispherically transfer motor skill from one lateral side of the body to the other ; (II) a reduced ability to perform two tasks which are mediated by the same hemisphere side, despite a normal pattern of cerebral dominance. Moscovitch (1986) stressed the importance of distinguishing between interhemispheric transfer and relative efficiency (or "direct access"; Zaidel, 1983) models of perceptual asymmetry. According to the interhemispheric transfer model, verbal material presented through the right ear or the right visual half-field has more direct access to the left hemisphere's language mechanisms than does information presented to the left ear or visual half field. Information presented initially to the non dominant hemisphere must thus cross the corpus callosum, and this is believed to be associated with both a time delay (manifested in slower response times) and a potential for loss of information (manifested in decreased accuracy). Failure to establish normal dominance denotes: (1) the inability to interhemispherically transfer motor skill from one lateral side of the body to the other; or (2) the inability to perform two tasks which are mediated by the same hemispheric side. Such inability refers to a split brain syndrome (a colossal transfer of information between hemispheres) at the functional level caused by either loss or over activation of functions (Gruzelier 1987). These two concept, i.e. lowered bilateral organization and failure to establish normal dominance, differ qualitatively for the dependent measure on an inter hemispheric task. Whereas the former refers to poor inter hemispheric task performance, the latter reflects a breakdown in such ability.

Functional measures of bilateral integration, as reflected by interhemispheric transfer, include perceptual tasks involving sensory modalities (e.g. dichotic listening studies with measures of callosal crossing time; for a review, see Walker & McGuire 1982). In behavioral measure, mirror drawing task has been taken for the study of interhemispheric relation, which allows bilateral transfer of simple motor skills may be examined. This task was originally devised by starch (1910) and was considered appropriate for measuring bilateral (inter

hemispheric transfer for many reasons. First, the task measures the magnitude of bilateral transfer keeping the level of performance constant (Mandal, et al, 1992). Secondly, it requires actions that interfere with normal motoric habit, a feature that minimizes any prior practice effect and emphasizes the transfer effect rather than the level of performance (Biswas et al, 1996). One of the major aims of the present study was to examine the bilateral transfer of motor skill among stutterers. It was hypothesized that the transfer of motor skill would be significantly reduced (as a function of the failure to establish normal dominance) in people with stuttering problem in comparison to matched controls on tasks which are independent of either group's basal level of performance. Alternatively there would be zero transfer of motor skills from one hand to other in people with stuttering. The normal pattern of lateralization is also reflected by response inhibition during dual tasks performances which are mutually exclusive in nature. The inability to perform two tasks concurrently has been an important research question in normal subjects because such interference allows us to understand the "functional architecture of the brain (Pashler 1994). Experiments were carried out on normal subjects by creating a temporary lesion in the brain with the help of an interference paradigm. By temporary lesion the present author ' refer to response inhibition caused by the processing of two mutually exclusive tasks that are mediated, primarily by the same hemisphere site (Bryden 1982). Using this paradigm, investigators have observed that the right hand (a left hemispheric function) performance fell when subjects were asked to perform a verbal task (a left hemispheric function) concurrently (Lomas & Kinwra 1976; Rodney 1980). The performance of the left hand (a right hemispheric function) also fell when subjects were asked to perform a non-verbal (a right hemispheric function) task concurrently; for example, remembering faces or shapes (Piazza 1977 ; Mc Farland & Ashton, 1978).

The evidence suggests that interference produced by the processing of two mutually exclusive tasks by the same hemisphere is a subsystem of the normal pattern of bilateral organization in the brain. A second major aim of the present study was to examine the magnitude of interference in people with stuttering during their performance of two mutually exclusive tasks which are functions of the same hemispheric side. It was hypothesized that the magnitude of interference induced experimentally would be significantly more in people with shuttering relative to matched controls because of lowered bilateral organization. Alternatively the experimentally induced - interference would yield a null effect on the performance of people with stuttering because of the functioning of two hemispheres in isolation.

II. SUBJECTS AND METHODS

Subjects

Twenty people with stuttering (16 males and 4 females; mean age = 17.5 years, SD = 3.4 years; I.Q. 90-100), and 20 age and sex-matched control subjects with no stuttering problems (16 males and 8 females ; mean age = 18 years)

SD = 3.9 years; IQ = 90-100) were selected for experimental purposes. Normal controls and stutterers had the ability to follow instructions (in Hindi language, the script of which is read from left to right and the vocabulary of these sbjects were tested by a 5 item simple questionnaire in which they showed they were able to recognize (a) a color (b) instrument (c) an animal (d) a fruit, and (e) a familiar person.

The diagnosis of stutterer was made by the treating counselors and also examined by the criteria of DSM-IV (APA, 1994). The stutterer subjects participated in the study were obtained from 'Guidance and Counseling' Centre. Department of Psychology, B.H.U. Varanasi. The disorder was more common among family members of the affected child than in the general population stuttering occurs as a response to conflicts, fears, and certain stressful situations.

All subjects were communicable and were communicable and were right handed as measured by a 22-item hand preference inventory (Mandal, Pandey, Singh & Asthana, 1992). The preference for an activity was indicated by a three-point response continuum (i.e. left, both, right). The laterality quotient (LQ), the magnitude of right-hand bias (LQ = right - left/right + left; Bryden 1982), was slightly higher for the control subjects (LQ=0.55). Relative to those with stuttering (LQ=0.35; range = -1.00 to +1.00).

III. PROCEDURE

Two experiments were conducted to examine : (1) Bilateral transfer of motoric skills; and (2) dual-task interference during motor performance.

The bilateral transfer of motor skill was assessed using an electronic version of the mirror-drawing apparatus originally developed by Starch (1910). The above author observed that skill acquired in one hand may be carried over to the other during the performance of this task as a function of interhemispheric transfer. Later studies have found the method useful as a way of measuring interhemispheric transfer (Mandal, et al. 1992; Biswas, et al, 1996; see also Woodworth & Schlosberg 1971). The mirror-drawing apparatus had a mounted, five-pointed star pattern (with an angle of 30º between each point, a pattern length of 52 cm, and width between its outer and inner boundaries of 0.4 cm), the image of which was reflected through a mirror placed vertically over it. A metal

pointer, connected to an automatic counter, was used to trace the star pattern. The counter recorded the errors committed by touching the boundaries with the metal pointer.

The subjects were asked to trace the star pattern with the metal pointer by looking at the image in the mirror. A horizontal screen obstructed the direct vision of the subject to the star pattern. The subjects were asked to trace the star pattern in any direction, clockwise or anticlockwise, 25 times; five trials with their preferred hand (pre), followed by 15 trials with their non-preferred had (interpolated) and then five trials with their preferred hand (post). They were given a period of 1 min for each trial. An error was registered in cases where the stylus touched the outer or inner boundary of the star pattern during tracing. The index of transfer of training between hands was obtained in terms of errors committed.

Dual-task interference was examined in the second experiment. The experiment was conducted in three steps. In the first (the control condition), the subjects were required to perform finger tapping task. They were instructed to tap as fast as possible within a period of 1 min. An automatic counter connected with the apparatus registered the speed (frequency) of tapping. The performance y each hand was examined. In the second step (experimental condition I), a verbal interference (input) task was introduced together with the finger-tapping task. Subjects were required to listen a story (with instructions to recall the story at a later period) during the motor performance test (finger-tapping). The difference in performance for each hand (i.e. left and right) between the control and experimental conditions was the index of verbal interference. Subjects were required to recall the story after their tapping performance, although these data were not utilized for later analyses. In the third step (experimental condition 2), a non-verbal interference task was introduced together the finger-tapping task. Subjects were required to listen musical rhymes (with instructions to recite these at a later period) during their manual performance (finger-tapping). The difference in performance for each hand (i.e. left and right) was the index of non-verbal interference. As in experimental condition 1, the subjects were required to recite the musical rhymes, although such data were not utilized for later analyses.

IV. RESULT

The data for experiments I (bilateral transfer) and II (dual task interference) were analyzed separately.

Table .1 shows the amount of bilateral transfer in terms of the errors committed

Subjects	First five trials		Last five trials		Bilateral transfer	
	Preferred hand (pre)	Non-preferred hand (interpolated)	Non-preferred hand (interpolated)	Preferred hand (pre)	Between hand transfer	Within hand transfer
Individuals with SD Controls	38.51±11.02 24.47±8.66	44.24±9.16 28.37±7.91	40.90±8.80 16.52±6.79	35.84±11.13 11.09±4.46	8.28% 52.76%	11.08% 41.5%

These data were analyzed with a Groups: Subjects with stuttering and controls) x 2 (Trials: first five and last five) mixed factorial analysis of variance (ANOVA) with repeated measures in the 'Trial' factor. The individuals with stuttering committed significantly more errors relative to the control subjects. ($F1, 38=152.53$, $P<0.001$). Subjects committed more errors during the first five trials in comparison to the last five trials ($F1, 38=50.23$, $p<0.001$). The interaction of Group x Trial was also significant ($F1, 38=28.64$ $P<0.001$). Central subjects had made a significantly smaller number of errors during the last five trials than in the first five trials ($P<0.01$). The difference was non-significant for people with ID (Turkey HSD=$P>0.05$).

Errors committed during the first five trials with the preferred (right) hand and the first five trials with the non-preferred (left) hand were analyzed with a Group x Trial mixed factorial design with repeated measures in the 'Trial' factor. Group ($F1, 38=114.02$, $P<0.001$) and Trial ($F1, 38=16.24$, $P<0.001$) factors were significant. People with stuttering made more errors in comparison with controls. Errors were committed more with the preferred hand than with the non-preferred hand. The interaction of Group X Trial was also significant ($F1, 38=26.50$, $P<0.001$). People with stuttering committed significantly fewer errors with their non-preferred (left) hand as compared to their preferred (right) hand ($P<0.01$). The difference was non-significant for controls.

The magnitude of bilateral transfer in terms of accuracy (error) was calculated for each subject with the formula (first five trials - last five trials / first five trials x 100; wood worth & Schlosberg 1971). Any negative value obtained with this formula was treated as a 'zero transfer. Group difference was examined with the percentage of bilateral transfer as the dependent measure. People with ID had significantly less transfer of motor skill relative to the control subjects ($F1, 38 =245.95$, $P<0.001$). Therefore, these findings substantiate a hypothesis of the failure to establish normal dominance in people. With stuttering. Although the magnitude of transfer was significantly less in people with stuttering problem, the effect was neutralized as a result of the hand preference

factor. Unlike control subjects, the preferred hand (right) was not the hand that produced a relatively better transfer effect in these subjects.

Subjects	Verbal interference		Non-verbal interference	
	Left hand	Right hand	Left hand	Right hand
Individuals with SD	34.28±19.31	46.56±17.57	32.40±11.23	32.76±12.33
Controls	26.40±14.54	35.13±11.89	23.83±12.69	21.33±12.17

Table 2 shows the interference (Neau±50) in tapping speed following verbal and non-verbal interference. The magnitude of interference in dual-task performance in terms of speed of taping was calculated for each subject with the formula: without interference with interference / without interference x 100. Any negative value obtained by this formula was treated as 'Zero' interference, Group difference was examined with a 2 (Group) x 2 (Interference conditions: Verbal and non-verbal) x 2 (Hands: left and right) mixed factorial design with the magnitude of interference as the dependent measure. 'Interference condition' and 'Hand' were the within subject factors. The findings indicated a significant main effect for all factors. People with stuttering problem were significantly more prone to interference relative to the controls ($F1, 38=13.60$, $P<0.005$). Interference was more evident in verbal tasks than non-verbal ones ($F1, 38=11.69$, $P<0.005$). Performance with the right hand was more prone to interference relative to performance with the left hand ($F1, 38=23.92$, $P<0.001$). The two way interaction of Group x Condition ($F1, 38=18.10$, $P<0.001$) was significant. The three way interaction of Group x condition x hand was also significant ($F1, 30=13.69$, $P<0.002$). The significant three way interaction of Group x condition x Hand indicated that people with stuttering were more prone to interference by the nature of the task. Verbal task induced significantly more interference in comparison to non-verbal ones ($P<0.01$). In general, these findings substantiate the hypothesis that people with stuttering problem have poorer bilateral organization. Although the magnitude of interference was significantly greater for people with stuttering, the effect was more pronounced during the performance of right hand tasks.

V. DISCUSSION

The results of experiment I demonstrate that people with stuttering : (I) were significantly more inaccurate in the mirror drawing task and (2) had significantly less bilateral transfer of motor skills in comparison with control subjects.

In the mirror-drawing task, the subjects had to learn a new form of hand-eye coordination because what they saw in the mirror as 'up' was actually 'down' and vice versa (stevens, 1951). In the process of reversing their responses to cues, the motor learning was habit-interfered in the beginning, followed by an ability, with practice, to make kinesthetic appropriation with issue cue. The amount of neural overflow has been found maximum for contra lateral limbs, as documented in electromyography studies (Davis 1942; Hicks et al 1983), and therefore, the motor learning by kinesthetic appropriation in one hand is supposed to be carried over to the other (Mandal,,, et al, 1992). One advantage of the mirror drawing task is that transfer effect may be tested independently of the basal level of performance. In doing so, the motorist performance is considered as a constant measure and the motoric transfer as the dependent measure (Mandal, et al, 1992). The present findings indicate that people with stuttering problem are significantly inferior on the constant measure (basal level of performance) or the dependent measure (bilateral transfer). The finding of poor motor skill in people with stuttering are of less significance to the artists because of the evidence that these subjects exhibit poor hand-eye coordination and learn much more slowly than control subjects (Kalpan & Sadock, 1995).

The anatomical locus of the interhemispheric transfer is the corpus collosum (Hoptman & Davidson 1994). In callosectomized patients, bilateral transfer of skill has been found to be nearly lost (Lehman & Lampe 1970; Hicks et al, 1983).

Previous studies have shown either a left or mixed (atypical) hand-preference pattern in people with stuttering. Performance measures have also indicated non-right-handedness in these subjects. (Mandal, et al; 1998). In the present study, a within-group comparison revealed that people with stuttering were significantly more efficient (as indicated by less error) with their left hand than with their right. The difference in hand performance was non-significant for control subjects. Therefore, the link between stuttering and non right handedness is partially supported by this finding. It was observed that people with stuttering hand less difficulty (as indicated by the occurrences of reverse correction) with their left hand mirror drawing, suggesting a better response strategy (hand-eye coordination) for the hand.

The present findings allow us to accept a hypothesis of 'failure to establish normal pattern of dominance' rather than 'lowered bilateral organization' in people with stuttering. It has been seen that during oral reading, stuttering and no stuttering (normal controls) subjects showed clear differences in lateralization of cortical regions involved in speech production. As expected, the no stuttering speakers showed a pattern of largely unilateral left hemisphere activation, including Boca's area, and primary sensory motor and temporal

cortex. A similar activation pattern was observed in the stuttering subjects, but this time clearly lateralized to the right hemisphere.

Much neurological evidence suggests that the right hemisphere may be dominant for production and perception of affective speech prosody [reviewed in hymer et al, 2002]. Production and perception of vocal fundamental frequency therefore seems meditated, at least in part, by the right frontal operculum / anterior insular. Van Borsel, et al (2003) found an absence of activations bilaterally in auditory areas in stutterers on an overt speech task for which controls demonstrated strong activations bilaterally. In De Nil et al, (2000) for the contrast of oral reading minus silent reading, non stutterers showed only left auditory activations (BA22), whereas stutterers showed of non-stutterers minus stutterers had significant signal in left auditory association cortex. Neumann et al (2003) reported that bilateral BA22 was more active in people who stuttered less severely than it was in those with more severe stuttering (based on clinical assessment), demonstrating that auditory activations seem to correlate negatively with stuttering severity.

A close inspection of the data reveals that the transfer effect was evident in most trials. More precisely, only one out of the 20 people who stutter had 'zero' transfer. The present authors believe that the magnitude of transfer would have been much higher had they (I) been given more interpolated trials with their non-preferred hand or (2) been allowed to use their left hand as the experimental hand on which the transfer effect was calibrated. Although these subjects were all self classified right handers, it is argued that such preference may be confounded with a social desirability factor. Put together, the findings suggest that non-right-handedness is a feature associated with failure of normal dominance of lateralization pattern. A less asymmetrical pattern of cerebral organization has been associated with left-handedness (Bryden, 1982) Lefthanders have, on average, a large corpus callosum than right handers, and this has been related to the notion that they have a more bihemispheric and less asymuvetrical representation of cognitive functions than right handers (Witelson, 1985)
In the present study, it has been found that non-right handedness (deviation from the normal pattern of handedness) is significantly more common in people who stutter. This belief was based on evidence at the time of an association between left-handedness and developmental disabilities (Bryngelson 1931; 1935; Dearborn, 1933; Quinam, 1921; Travis and Lindsley, 1933) and the fact that there appeared to be a positive correlation between forced handedness changes and an abnormally high incidence of developing those disorders (Ballard, 1912; Bryngelson, 1935). Bryngelson (1940) reported that of 152 male stutterers, 34% were "ambidextrous" and 61% had been forcibly shifted from left to right handedness whereas the same figures for fluent speakers were 4% and 5% respectively).

The results of experiment - 2 revealed that : (I) people who stutter were more prone to interference by the (dual) task demand characteristics than control subjects ; and (2) the interference was more specific to their right hand performance for both the verbal and non-verbal task conditions. The finding that people who stutter were significantly more prone to interference relative to control subjects confirmed of the findings of experiment I, in which people who stutter were found to be significantly deficient in the bilateral transfer of motor skills. Poor bilateral integration or reduced interhemispheric coordination was accounted explained the latter findings. A similar explanation holds good for the findings of experiment 2 because of the magnitude of response facilitation (transfer of skill) between the hemispheres is directly proportional to the magnitude of response inhibition (dual task interference) within a hemisphere as a function of the bilateral organization of the brain. In other words, increased response inhibition reflects lateralized hypo function of the brain that results in decreased bilateral transfer in people who stutter.

Apart from a theory of bilateral integration of motor functions, other theories which explain dual-task interference include : capacity sharing (i.e. distribution of resources to two tasks, resulting in impairment in the outcome of one or both tasks ; Navon & Gopher 1979 ; Wickens 1980) ; bottleneck or task switching (when two tasks demand access to one mechanism, a bottleneck results, followed by impairment of functions) ; and cross-talking (when two tasks involve similar content of information, the outcome channel is degraded ; Kinsbourne 1981 ; Navon & Miller 1987 ; for a review of these studies, see Pashler 1994). In the present study capacity sharing theory has been implemented on these groups. The present results also suggest that interference is significantly greater for the right hand performance relative to the left in people who stutter. This is not unlikely because these subjects were all right-handed, as measured by the HPI, but such interference was not found to be task dependent. In control subjects, verbal task interference was more critical for the performance of the right hand than the left (a left hemisphere inhibition), whereas non-verbal task interference (although to a lesser degree) was more critical for the performance of the left hand than the right (a right hemisphere inhibition; The pattern of lateralization was not clear for people who stutter, and a generalized right hand interference may be explained only in terms of non-right-handedness.

Webster (1996) has reported evidence from manual performance that is also consistent with the hypothesis that people who stutter have more labile or weaker attention bias. He had stutterers and non stutterer's performance a 2:1 rhythmic finger tapping task, which involved tapping twice with one hand for each tap of the other hand under non speeded and unpacked conditions.

Peters (1987) has earlier formed that right handers had a tendency to tap more regularly and more quickly with their right hand "leading (tapping twice for each tap of the left hand) as compared to when their left hand was leading. Since the motoric demands of the task were relatively simple, Peters (1987) proposed that asymmetry he observed in right handers reflected a performance for attending to the right hand. Webster (19906) replicated the findings of Peter (1987) in fluent right-handers, but found that stutterers as a group had no asymmetry on the task. Webster argued that lack of an asymmetry on the task could reflect a more labile or less consistent directional bias in people who stutter than in fluent speakers. Forster and Webster (1991) found that, in stutterer no reliable asymmetry was observed. People who stutter may be similar in this regard to left handers who, according to Annett's Right-Shift model, lack the gene which gives rise to the directional asymmetry found in right handers. The stutterers responded like the non stutterers, though more slowly, providing support for the current contentions that the neuromotor system of stutterers is less robust than that of non stutterers and more affected by the demands of speech production. (Brutten and Trotter, 2002).

The phenomenon of non-right handedness also explains why people who stutter performed better with their left-handed mirror-drawing (experiment I). Because of decreased habit interference, the left-hand performance became better in terms of errors committed or time taken to learn a new form of hand-eye coordination. This explanation holds good for the outcome of the interference experiment.

The present results substantiate the view of failure to establish a normal pattern of lateral dominance in people who stutter proposed by the early cerebral insult theorists (Lenneberg 1969; Berman 1971; Delacato, 1974; for a review, see Pipe 1988). This is because neither the transfer nor the interference experiments in the present study indicated that hands contra lateral to cerebral hemispheres function in isolation for people who stutter. Therefore, the present authors presume that atypical lateralization is a function of reduced bilateral organization in people, who stutterers. Within the limits of the present findings, it may be concluded that reduced bilateral organization, as indicated by reduced transfer of motor skill from a non-preferred hand left handed response inhibition during dual-task performance, is a characteristics feature of right handed subjects with stuttering problem and an I.Q. in the 90-100 range.

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