**INTRODUCTION**

For many years, neuroimaging has chased the "stuttering" brain in an attempt to identify the ways in which it differs from the "non-stuttering" brain (Chang et al., 2008). Researchers have sought to understand the basis of brain differences and "repair" of stuttering may provide clinical insight. This paper will explore the feasibility of using brain imaging and activation differences in people who stutter (PWS) compared to people who are normally fluent (PNF) to further understanding stuttering. The researchers examined the following: differences between PWS and PNF, as revealed in research, will be shown to support the hypothesis that stuttering is a brain disorder. Differences in brain anatomy and activation are reported in stuttering. The researchers also examined the following: the basal ganglia-IFG/PMA circuit and the cerebellum-PMA circuit role of the basal ganglia was revealed to be very small in this study (Brown et al., 2005). In any study, the researchers found activation in the right cerebellum in PWS, but not in PNF — the optimal repair region, BA 47/12, through some type of biofeedback. The clinical implications revealed by the researchers will be shared.

**DEFINITIONS & BACKGROUND KNOWLEDGE:**

Stuttering is a developmental disorder that affects the speech fluency of 5% of preschool children and 1% of the adult population (Bloodstein, 1985). Developmental stuttering is stuttering before the age of 8 and persistent stuttering after the age of 8. Persistent stuttering may involve voice nodules, word-replacement errors, sound prolongations, and silent pauses. Prosodic abnormalities are commonly associated with stuttering (American Speech-Language-Hearing Association (ASHA), 1999).

**CRITICAL REVIEW AND META-ANALYSIS**

Alm (2004) and Brown, Ingham, Ingham, and Fox (2005) both described the contribution of the basal ganglia to the control of the vocalization system. When it continues into adulthood (Jardin, Hansel, & Senjem, 2004), it may possibly be applied to the "stuttering" brain. Heart rate variability (HRV) may be a critical factor in stuttering. Biofeedback has been used successfully in many applications and may possibly be applied to the "stuttering" brain. Recent advances in HRV raise the question of whether or not a neuroadaptive process occurs in the brain. HRV may be a critical factor in stuttering. Biofeedback may be used to help the brain "normalize" the overactivation of the right hemisphere speech and language areas (De Nil et al., 2003; Neumann et al., 2008). Fluency-shaping therapies "normalize" the overactivation of the right hemisphere, normal basal ganglia activity, and alleviate the left hemisphere overactivation. The basal ganglia IFG/PMA circuit and the cerebellum-PMA circuit role of the basal ganglia was revealed to be very small in this study (Brown et al., 2005). In any study, the researchers found activation in the right cerebellum in PWS, but not in PNF — the optimal repair region, BA 47/12, through some type of biofeedback. The clinical implications revealed by the researchers will be shared.

**THE "STUTTERING" BRAIN: ANATOMY AND ACTIVATION DIFFERENCES**

**LAURA TORRANS**

**ORIGIN OF STUTTERING?**

Alm (2004) suggested that the detectable basal ganglia circuit may be affected by a caudate-putamen circuit, in a by-pass route. This finding is one explanation for one of the neural signatures of stuttering. But the role of the basal ganglia was revealed to be very small in this study (Brown et al., 2005). The neural signatures are seen as follows:• Overactivity in the right frontal operculum (the homolog of the left inferior frontal gyrus, Broca's area)• Underactivity in the anterior auditory cortex (Chang et al. 2008). These findings support the hypothesis of Brown et al. (2005) that the left hemisphere speech and language areas (De Nil et al., 2003; Neumann et al., 2008). The grey cross in figure 2 represents the optimal repair region, BA 47/12, through some type of biofeedback. Heart rate variability (HRV) may be a critical factor in stuttering. Biofeedback may be used to help the brain "normalize" the overactivation of the right hemisphere speech and language areas (De Nil et al., 2003; Neumann et al., 2008). Kell (2009) found that unassisted recovery from stuttering in the left BA 41 region is related to a white matter anomaly in persistent stutterers but found to be normal in recovered stutterers, demonstrating the optimal repair follows a "very local perisylvian pathway" (p. 278).

**NEURAL NETWORKS & STUTTERING**

Researchers, such as Lu et al. (2005), examined large neural networks implicated in stuttering and found the following activation differences between PWS and PNF:• Greater activation in the right frontal operculum and anterior insula in PWS (Brown et al., 2005; Lu et al., 2005)• greater activation in the left anterior insula of the superior temporal gyrus (Lu et al., 2005; Brown et al., 2005; Defali et al., 2006)• cerebellar activation in the right hemisphere of PWS (Chunming et al., 2010). Although the gyri findings are not in itself, no single feature seemed to distinguished PWS (Lu et al., 2009). According to Hickox, Buchsbaum, Humphries, and Hickox (2003), this area is involved with dysfunction in the self-monitoring system of stuttering. This system model integrates the cerebellum, angular gyrus, and frontal white matter connections (Alm, 2004).

**MOTOR PLANNING AND EXECUTION IN PWS COMPARED TO PNF**

Chunming, Chen, and Ying (2010) examined executive planning and execution processes in PWS under different conditions. The researchers examined the following: differences between PWS and PNF. The researchers found that the following activation differences were found in PWS compared to PNF:• Cerebellar activation in the right cerebellum in PWS, but not in PNF — the optimal repair region, BA 47/12, through some type of biofeedback. Heart rate variability (HRV) may be a critical factor in stuttering. Biofeedback may be used to help the brain "normalize" the overactivation of the right hemisphere speech and language areas (De Nil et al., 2003; Neumann et al., 2008). The grey cross in figure 2 represents the optimal repair region, BA 47/12, through some type of biofeedback. Heart rate variability (HRV) may be a critical factor in stuttering. Biofeedback may be used to help the brain "normalize" the overactivation of the right hemisphere speech and language areas (De Nil et al., 2003; Neumann et al., 2008).

**REFERENCES AVAILABLE ON SEPARATE PAGE**

**CONCLUSION**

In conclusion, researchers now feel that stuttering is a neurodevelopmental disorder with the core dysfunction revolving around the left hemisphere — Broca’s area and underlying white matter — anomalies (Chang et al., 2008) and that the right hemisphere overactivates, bilateral auditory underactivates, and basal ganglia dysfunction in PWS represent important neuroadaptation mechanisms in the brain’s attempt to "normalize" the stuttering brain. In the future, the knowledge of brain structure and activations present in CWS may allow for early diagnosis and intervention before the stuttering becomes persistent (Chang et al., 2008). Perhaps taking advantage of the plasticity of the child’s brain may allow for earlier intervention.

**APPENDIX A**

Adapted activation procedures for the planning of speech were reviewed in detail and described in (Chang et al., 2010). Motor planning and activation for the execution of speech were revealed in the right cerebellum, right insula, left premotor area (PMA), and right inferior frontal gyrus (Broca's area).

**REFERENCES AVAILABLE ON SEPARATE PAGE**

Alm, 2004). Alm (2004) proposed several conclusions in support of basal ganglia dysfunction in PWS (Figure 1). But this dysfunction may have a variety of causes. For many years, neuroimaging has chased the "stuttering" brain in an attempt to identify the ways in which it differs from the "non-stuttering" brain (Chang et al., 2008). Researchers have sought to understand the basis of brain differences and "repair" of stuttering may provide clinical insight. This paper will explore the feasibility of using brain imaging and activation differences in people who stutter (PWS) compared to people who are normally fluent (PNF) to further understanding stuttering. The researchers examined the following: differences between PWS and PNF, as revealed in research, will be shown to support the hypothesis that stuttering is a brain disorder. Differences in brain anatomy and activation are reported in stuttering. The researchers also examined the following: the basal ganglia-IFG/PMA circuit and the cerebellum-PMA circuit role of the basal ganglia was revealed to be very small in this study (Brown et al., 2005).

**ANOMALIES IN CHILDREN WHO STUTTER**

Chang et al. (2008) examined the differences in the brain anatomy of children who stutter (CWS) and found the following differences in comparison to children that are normally fluent (PNF):• CWS had reduced gray matter volume (GMV) in the following areas:• the left inferior frontal gyrus (Broca’s area)• bilateral temporal regions (Wernicke’s area on the left)• CWS had reduced white matter integrity in the following areas:• Underlying area of the motor region for the face and larynx (Chang et al., 2008) also found differences between CWS and PWS:• In PWS right hemisphere• In PWS left hemisphere• In PWS right hemisphere• In CWS no differences were found in the right hemisphere. In the future, the knowledge of brain structure and activations present in CWS may allow for early diagnosis and intervention before the stuttering becomes persistent (Chang et al., 2008). Perhaps taking advantage of the plasticity of the child’s brain may allow for earlier intervention.

**Fluency-shaping therapies “normalize” the overactivation of the right hemisphere, normal basal ganglia activity, and alleviate the left hemisphere overactivation. The basal ganglia IFG/PMA circuit and the cerebellum-PMA circuit role of the basal ganglia was revealed to be very small in this study (Brown et al., 2005). In any study, the researchers found activation in the right cerebellum in PWS, but not in PNF — the optimal repair region, BA 47/12, through some type of biofeedback. Heart rate variability (HRV) may be a critical factor in stuttering. Biofeedback may be used to help the brain "normalize" the overactivation of the right hemisphere speech and language areas (De Nil et al., 2003; Neumann et al., 2008). Kell (2009) found that unassisted recovery from stuttering in the left BA 41 region is related to a white matter anomaly in persistent stutterers but found to be normal in recovered stutterers, demonstrating the optimal repair follows a "very local perisylvian pathway" (p. 278).