Keeping Track of Your Inner Voice: An Exploration of Speech-Monitoring Deficits in Schizophrenia

by

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We accept this dissertation as conforming to the required standard

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ABSTRACT

During the last 20 years, a body of research has emerged suggesting that deficits in the self-monitoring of willed intention to act may be responsible for the expression of positive symptoms in schizophrenia (Frith, 1992). Empirical evidence supporting this theory indicates that schizophrenics with positive symptoms are impaired on motor and speech based tasks that involve monitoring of internal cognitive mechanisms and behavior plans, but are less impaired when monitoring external sensory feedback. The current project extends this research by comparing the performance of two groups of schizophrenics (hallucinators, n=16; and nonhallucinators, n=15) with a group of non-psychotic psychiatric patients (n = 15) on measures of speech monitoring of internal and overt speech. On two measures of internal speech monitoring (silent reading and identification of speech errors in a white noise environment), the schizophrenics were found to be impaired relative to controls; however, the schizophrenics were also impaired on a task of self-monitoring when they had access to external feedback. Analysis of the subgroups data (hallucinators vs. nonhallucinators) indicated very similar performances across tests and no significant differences were identified, with the exception of the silent reading test in which the hallucinators did perform significantly worse.

These results indicate that the speech-monitoring deficit in schizophrenia is not limited to the internal speech plan, but can also involve a failure to monitor overt speech, contrary to previous report. Furthermore, speech-monitoring deficits are not limited to schizophrenics who experience hallucinations.

An additional experiment involving delayed auditory feedback (DAF) was also conducted to replicate a previous finding in the literature that schizophrenics were more dysfluent in DAF. On the DAF task, the combined schizophrenic group were found to be more dysfluent than controls, and there were no differences between the two schizophrenic subgroups. Further correlational analysis revealed a strong relationship between the level of dysfluency in DAF and self-monitoring impairment. While the results of the experiment were similar to those found by previous authors (Goldberg,

Gold, Coppola, & Weinberger, 1997), the correlational analysis allows for an explanation of dysfluency in DAF based on self-monitoring.

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Introduction

Neuropsychology of Schizophrenia

In the past twenty years, there has been dramatically increased interest in the neuropsychology of schizophrenia. Research in this area has branched in many directions. Some researchers have attempted to identify specific cognitive deficits in schizophrenic patients on neuropsychological tests. Other research has been dedicated to localizing specific brain regions with structural or functional abnormalities through the use of brain imaging or PET scan technology. Further lines of research attempt to explain the broad variety of complex symptomotology in terms of cognitive models in the hope of identifying a parsimonious explanation for this complex disorder.

The body of research examining performance on neuropsychological tests has found that, in general, the majority of individuals with schizophrenia have marked cognitive deficits in several different cognitive domains. A meta-analysis of this research failed to distinguish a specific pattern of strengths and weaknesses in schizophrenia, but rather identified global impairments across domains of neurocognitive function including verbal and nonverbal memory, visual and auditory attention, spatial ability, motor ability, language, executive function and even general intellectual function (Heinrichs & Zakzanis, 1998).

Theories about the localization of brain structures affected by schizophrenia have implicated numerous regions including the left hemisphere, the right hemisphere, the frontal lobes, and subcortical areas of the brain. The left hemisphere theory references the fact that schizophrenia is most commonly associated with language and thought disorders, and argues that the disorder should most logically stem from some deficit in areas of the brain associated with language functioning (Flor-Henry, 1969). The right hemisphere theory identifies the fact that patients with schizophrenia display many symptoms that are similar to those seen in right brain injury including flattened affect, loss of prosody, and loss of volition (Cutting, 1994). A great deal of evidence has emerged from functional and structural brain imaging studies implicating the frontal lobe and its numerous connective pathways in the disorder (Weinberger, 1994). And finally, another large body of research has implicated subcortical connections between the basal ganglia and the neocortex, pointing out similarities between the motor symptoms of schizophrenia and those of Parkinson's disease and Huntington's disease (Pantelis & Nelson, 1994).

Part of the inherent difficulty in attempting to isolate the neuropathology of schizophrenia to circumscribed regions of the brain in this way, is that schizophrenia itself encompasses a extremely diverse range of symptomotology that is not consistent from one patient to the next. Green (1998) points out that "after visiting a treatment unit for symptomatic schizophrenic patients, one can get the impression that the only thing the patients have in common is a chart diagnosis" and that "it is natural to wonder if all patients with a diagnosis of schizophrenia are suffering from the same disorder" (p. 83). He also points out that Bleuler, in some of his original descriptions of the disorder, refers to it as the "Group of Schizophrenias." In order to see the broad variety of symptom expression in schizophrenia one only needs to look as far as the DSM-IV-TR. The first criteria, which identifies characteristic symptoms of the disorder, calls for the expression of two or more of the following symptoms: 1) delusions, 2) hallucinations, 3) disorganized speech (e.g. frequent derailment or incoherence), 4) grossly disorganized or catatonic behaviour, and 5) negative symptoms, (i.e. affective flattening, alogia, or avolition). These heterogeneous groups of symptoms would represent a broad range even if they were themselves distinct, but in fact, each of these symptoms are actually classifications that encompass a broad variety of symptom expression. For example, delusions and hallucinations may take many forms, which look very different and likely subsume different underlying pathology. With this much diversity in the symptomotology itself, it is not altogether surprising that there is so much variability in terms of cognitive profiles and brain regions that are implicated in the disorder.

In his book, the Cognitive Psychology of Schizophrenia (1992), Frith pointed out that most of the early experiments in schizophrenia research focused on examining large groups of schizophrenic patients with very heterogeneous symptomotology. He proposed that research might be more fruitful if it follows a model similar to that developed in cognitive psychology, examining much smaller groups with more homogenous symptom clusters. This is especially important in schizophrenia, as there is clearly evidence to support different subtypes within the disorder. While this task is simply stated, it is complicated by the fact that there is little agreement on how to subtype patients, and several different subtyping schemas have been developed over the years. The DSM-IV-TR divides patients into subtypes including Paranoid, Catatonic, Disorganized, Undifferentiated and Residual Types. While this classification system is still used throughout the psychological and psychiatric community, there has been very little interest in this classification scheme in the experimental neuropsychological or psychiatric literature. The DSM-IV classification scheme has also been proven to suffer from poor discriminant validity (Frith, 1992). Other systems that are far more prevalent in the literature include Crow's positive and negative symptom distinction (Crow, 1980), and Liddle's three category typology (Liddle, 1987). Liddle's typology separates patients into three categories including 1) 'reality distortion' which includes patients with hallucinations and delusions, 2) 'disorganized features' which includes incoherence of speech and behaviour, and 3) 'psychomotor poverty' which includes poverty of speech, flattening of affect, and psychomotor retardation. These classification systems have proven very useful, and the recent trend in literature has been to examine specific samples of patients by using these categories. In keeping with this trend, the current project was designed to examine cognitive abilities in schizophrenics who exhibit specific positive symptoms. For this reason, the literature review will focus on the research that primarily deals with positive symptoms or to use Liddle's typology – those patients with reality distortion symptoms.

Models of Hallucination

Over the years, several models have been constructed to explain why patients with schizophrenia experience hallucinations. Slade's theory (Slade, 1976; 1994) states that there are four factors necessary for an individual to experience hallucinations. First, the person likely has predisposing factors to develop hallucinations such as a genetic predisposition, some type of neurological vulnerability, or an extremely high responsiveness to suggestion; all of which have been found to exist to some extent in schizophrenia (Bentall, 1990). Second, the individual must be faced with a psychologically stressful event or high arousal state, which would precipitate the experience. Third, there must exist proper environmental factors, which will facilitate the likelihood of experiencing the hallucination. Finally, the experience of hallucinating must be in some way rewarding or associated with relief, which leads to positive reinforcement and increases the likelihood of generating hallucinations in the future. While the theory does account for a great deal of data regarding the occurrence of hallucinations in schizophrenia, it does not provide a specific neurological or cognitive account of the mechanism or mechanisms responsible. Instead, it depends on a theory of reinforcement, which seems somewhat tenuous considering there is a great deal of evidence that schizophrenics are horrified by their own hallucinations and do not seem to find them particularly reinforcing.

Another theory for hallucinations (Collicott & Hemsley, 1981) suggests that schizophrenics who experience hallucinations (hallucinators) have a primary deficit in their perceptual system responsible for the experience. According to this hypothesis, a deficit in perception causes hallucinators to misperceive normal external stimuli as voices. This may be due to actual perceptual deficits or "high levels of spontaneous noise" in the perceptual system that disrupts processing.

This attribution of hallucinations to a deficit early in the perceptual system has generally fallen out of favor due to several lines of evidence. From a theoretical basis, Frith (1992) made two interesting points. First, he noted "if hallucinations really are misperceptions, then it is striking that patients only misperceive noise as voices (since they hear voices when no voices are present), and never misperceive voices as noise." He also pointed to research from his own laboratory on bias errors in hearing. He argued that if there is a perceptual deficit and patients misinterpret environmental noise, then the patients should more frequently misperceive noises that sound similar to words, compared to noises that do not sound similar to words. To test this theory he conducted an experiment (Frith, 1992) in which the schizophrenic participants had to decide whether or not stimuli presented in white noise were or were not words. The stimuli included words, sounds that were "word-like" but not actual words, and random phoneme strings. Hallucinators did not show any indication of a selective bias for hearing sounds as words, which is contrary to the theory that they misperceive sounds as voices.

In their study, Collicutt and Hemsley (1981) also found evidence against the signal detection theory in a physiological study. They tested hallucinating schizophrenics and normal controls on an auditory threshold task, and discovered that there were no differences between the groups. Their primary conclusion was that "hallucinating schizophrenics are not characterized by sensory systems with increased levels of spontaneous noise." In response to these data, they suggested that hallucinations might arise as "the inappropriate response of the perceptual system to internally generated activity." In other words, since hallucinators do not appear to have faults in their auditory perceptual system which would sufficiently explain the development of hallucinations; it may be that hallucinations arise from deficits in cognitive processes that are internal, such as a deficit in the speech production process. In this manner, some fault in cognitive processing, unrelated to the basic perceptual processes of external stimuli, generates an experience or condition, such that the hallucinator experiences perception in the absence of actual stimuli. This concept captures precisely a trend in the understanding of hallucinations that has been the focus of a the vast majority of research since that time aimed at understanding hallucinations as internally generated neurocognitive phenomena. Hoffman and Rapaport (1994) indicate four additional lines of empirical evidence supporting the notion that verbal hallucinations are intimately related to cognition and internal speech products as opposed to misattributions of external sensory information. First, there is evidence that hallucinations, like ordinary inner speech (inner speech can be thought of as formulated speech products which are not articulated, or organized verbal thought), seem to be accompanied by subtle activation of vocal musculature that is electromyographically detectable (Gould, 1948; Inouye & Shimizu, 1970). Based on this, they indicated that hallucinations are likely associated with the same mechanisms as speech. Second, there is evidence that the presence of hallucinations can actually disrupt discourse planning (Hoffman, 1986), which suggests that there is an intimate relationship between the language planning system and hallucinations. Third, there is further evidence from positron emission technology (PET) studies indicating that chronic schizophrenics with auditory hallucinations show increased activation in speech centers of the brain during hallucinations (Cleghorn et. al, 1990). Finally, there is the observation that the content of hallucinated voices tends to be repetitive and stereotypic over time (Chaturvedi & Sinha, 1990; Hoffman, 1986, Kinsbourne, 1990) as if stored information is being persistently reproduced.

The concept that hallucinations arise from mechanisms related to cognitive or metacognitive processes as opposed to noise in the sensory system is now extremely popular, but there are still several different hypotheses about their genesis. Some evidence has arisen indicating that hallucinating schizophrenics may have a problem with suggestibility or skewed bias in their perceptual system. It has been hypothesized that this suggestibility causes the hallucinators to believe they are hearing things when they actually are not. Evidence for theories of this nature have been explored in studies in which schizophrenic patients seemed to identify stimuli in a noise situation that was not truly there. For instance, Mintz and Alpert (1972) suggested to schizophrenic patients that they were about to hear the song "White Christmas" embedded in white noise. After playing the white noise, which did not actually contain any music, hallucinating participants were far more likely than control subjects to admit that they heard the music. Similarly, Slade and Bentall (1985) asked patients to identify the target word "who" in a white noise background. Again, hallucinating schizophrenics gave significantly more false positives responses than control groups.

To explain these data, Bentall (1990) proposed a related theory that hallucinations result from a deficit in "reality discrimination" which he defines as a metacognitive skill that enables a person to discriminate between events that are real and those that are imaginary. Bentall argues that there is a metacognitive process through which individuals weigh experience to decide whether information has been perceived from the outside world or has been self-generated. In schizophrenia, it is proposed that there is a criterion shift that occurs such that internally generated material is believed to be externally generated far more frequently. This may account for the "suggestibility" data cited above in that individuals may have generated the information (i.e., White

Christmas) themselves, but believed that it was real. Bentall (1990) also cites studies of deficits in source memory in which patients with schizophrenia had significant difficulty recognizing their own productions from a random list of statements after a delay of one week as evidence of difficulty with reality discrimination (Heilbrun, 1980).

As an alternative mechanism for the generation of hallucinations, Hoffman suggests that hallucinations arise as noise in the discourse planning process as opposed to noise in the perceptual processes. Specifically, he proposes that there is pathologically stored linguistic information in long term memory (also termed "parasitic verbal memory") that disrupts language production processes and interjects content in the form of "verbal messages that are consciously experienced as repeated alien unintended auditory images" (Hoffman, 1986; Hoffman & Rapaport, 1994). To test this theory, Hoffman and Rapaport conducted an experiment (1994) to see if hallucinatory themes would arise when patients were asked to shadow speech in a noise filled condition. (Shadowing refers to the process of tracking ongoing speech and repeating what is heard as closely as possible). They hypothesized that when hallucinating schizophrenics attempted to shadow, their ability to track speech would be impaired in comparison to non-hallucinating groups, but also that the speech they produced might include information related to their own personal hallucinatory content. The results of their content analyses were inconclusive; however, there were specific cases in which patients clearly seemed to incorporate their own hallucinatory themes subconsciously in their speech productions during the shadowing task. Despite the fact that their hypothesis was not conclusively demonstrated, they discovered that hallucinating patients were much worse in their tracking accuracy overall than either control subjects or non-hallucinating participants. They interpreted these data as further evidence for the discourse planning hypothesis, and suggested that the alternative perceptual defect model or a failure to distinguish signal from noise would have predicted a nonspecific deficit of distractibility in both groups of schizophrenics contrary to the results that were actually found. Despite their suggestion, the rationale for this argument is not clearly stated. It seems that noise in sensory systems, limited to hallucinators, could just as easily explain their data as the discourse planning model.

Some of the most interesting theories regarding the positive symptoms of schizophrenia come from the work of Feinberg (Feinberg, 1978; Feinberg & Guazzelli, 1999) and Frith (Frith, 1987; Frith, 1992; Frith & Done 1988; Frith & Done 1989). These theorists have proposed that positive symptoms can be explained in terms of a failure in the system by which we monitor our own behaviour. While Feinberg and Frith conceptualize their framework in a slightly different way, their contributions are very similar.

In Feinberg's original article on the subject (1978), he theorized that the process of thinking and the experience of conscious thought may be governed by the same type of systems that function in the motor system. Specifically, he believed that there may be a system similar to that known as "corollary discharge" or "efference copy" in the motor system, that occurs during the process of thought generation and allows us to recognize our thoughts as our own. For the moment, it is necessary to explain the concept of corollary discharge before returning to the potential applications of the theory to higher thought.

Corollary Discharge

Corollary discharge has most frequently been explained with the simple but elegant example observed in the differences in perceptual experience that occur during active versus passive movement of the eye. When an individual voluntarily moves his/her eye in the direction of a stimulus (say left), the effect on the retina is a dramatic shift of the external environment in the rightward direction. Despite this change in the retinal image, the individual does not perceive a shift in the environment, but rather experiences the smooth transition of an environment that remains stable. However, if an individual were to push his/her eye with use of some external source not involving the ocular musculature (i.e., his/her finger), the individual would perceive the environment as having jumped to the right. This suggests that there is a distinct difference between the processes of movement that are generated/guided by willed intention and processes of movement that are caused by external sources. This difference allows us to identify our movements as self-generated, and likewise to recognize other sensory stimuli as arising from external causes.

The original roots of the concept of corollary discharge stem from work on the study of motor systems in animals in the early 1950's. Independently, Sperry (1950) and Von Holst and Mittelstaedt (Von Holst & Mittelstadt, 1950; Von Holst 1954) while working with the visual systems of different types of animals (fish and insects respectively), postulated that motor efferents from the brain to effector muscles must be accompanied by additional feedback information that relays information about intended movements for the purpose of postural and visual stability. The mechanisms that each group proposed at the time were slightly different.

Sperry proposed "a corollary discharge of motor patterns into the sensorium may play an important adjuster role in the visual perception of movement along with nonretinal kinesthetic and postural influences from the periphery." He further explained "any excitation pattern (overt movement) that normally results in a movement that will cause a displacement of the visual image on the retina may have a corollary discharge into the visual centers to compensate for the retinal displacement." This implies an anticipatory adjustment in the visual centers specific for each movement with regard to its direction and speed.

Von Holst's conceptualization, which is slightly different, suggests that a motor efferent for every action leaves an "image of itself" or an "efference copy" somewhere in the central nervous system. When the afferent sensory experience is returned, it also sends an "image" to higher centers in the brain. When this image is correctly matched to the efferent copy, there is a nullifying effect so that the planned motor movement is not confused with a sensory experience.

These theories were later reconceptualized by Teuber (1966) while describing different motor conditions in the human nervous system. In his analysis, Teuber also highlighted distinctions between voluntary movement and involuntary movement. Teuber stated that "a voluntary movement (e.g. of the eyes) is always characterized by a twofold process: an efferent discharge to the effectors (in the case of eye movements, to the extraocular musculature), and a simultaneous discharge (the corollary discharge) to the appropriate sensory system (here, the visual system) which forewarns them, so to speak, of the impending change" (Teuber, 1966). In contrast, involuntary movements are not accompanied by efferent discharge and are hence attributed to external causes. For further information on the origins of corollary discharge the reader is directed to Evarts review article (1971), which includes a comprehensive review of these theories.

The examples provided thus far involve primarily the visual system, but the process of corollary discharge could also be applied to other simple motor actions. Information regarding intention to generate any motor behaviour including information such as speed and trajectory, is necessary to establish equilibrium, maintain balance, and facilitate visually guided movements such as picking up an object. For example, when we move our arms, we are able to maintain our balance because there are analogous feed-forward mechanisms, which send information about the intention to move to other centers in the brain and allow us to compensate and shift appropriately to counterbalance the movement. Without this type of continuous internal feedback, we would have significant difficulty with any movements. Likewise, it has been argued that feed-forward models of corollary discharge explain why self-inflicted tactile stimulus is perceived differently than externally generated tactile stimulus as evident, for example, by the phenomenon that people cannot tickle themselves (Weiskrantz, Elliot, & Darlington, 1971).

Models for positive symptoms involving "willed intention and corollary discharge"

Returning to the original topic, Feinberg (1978) proposed that the processes of thinking and the experience of thought that occur in the "highest level of brain activity" likely operate according to the same basic rules that operate in motor movements. That is, just as there are corollary discharges that inform us about our intentions to make muscle movements, there are also corollary discharges that inform us about our own intentions to generate a thought. It is proposed that this system allows us to have the phenomenological experience that our thoughts are our own. To use Feinberg's words "the subjective experience of these discharges should correspond to nothing less than the experience of will or intention" (p.638).

When discussing issues related to thoughts and consciousness it is very difficult to conceive of how this would operate. The concepts are much more abstract, and there is little, if any, opportunity in the realm of normal experience to explore the differences between internally generated thought and externally generated thought. However, Feinberg (1978) does point to some anecdotal evidence of interest. In the original brain stimulation work of Penfield (1974), in which conscious patients were subjected to direct stimulation of their motor cortices, the experiences of the patients prompted them to report statements such as "You caused my arm to move." Similarly, stimulation of regions in the temporal lobe was said to trigger memories that prompted the patients to report "You caused me to think that". Note that this suggests a very different subjective experience than would be expressed by statements such as "I am now thinking of ______." This may be the only scientific data ever acquired in which the possibility of externally generated thought exists, and the patients appeared to acknowledge the difference. It is the direct equivalent of passive movement of the eye (from the previous section), in the context of actual conscious thought (memory).

This stated, Feinberg extended his proposal in an attempt to explain some of the experiences that are reported by patients who suffer from positive symptoms of schizophrenia. Similar to the models described above, Feinberg's theory remains in line with the evidence that hallucinations are internally generated. According to this theory, hallucinations are merely self-generated thoughts that are either not accompanied by corollary discharges or the corollary discharges are not interpreted correctly.

A decade after Feinberg's original hypothesis, Frith and Done (Frith & Done, 1987; Frith & Done, 1988; Frith, 1992) developed a cognitive model of schizophrenia that is rooted in the concepts originally put forth by Feinberg. The essential difference between the models of Frith and Feinberg is that Feinberg's hypothesis speaks of corollary discharge as a neurophysiological process; while Frith's model (Frith & Done, 1988; Frith & Done, 1989; Frith, 1992) speaks in terms of cognitive neuropsychology and refers to a number of cognitive modules. Frith refers to a process termed "self-monitoring" conducted by a cognitive module identified as "the internal monitor" which is responsible for monitoring behaviour. According to Frith's thesis, there is a deficit in the monitoring of the output of action patterns within the brain. Frith further indicates, as did Feinberg, that an important function of the internal monitor is to distinguish the difference between internally guided/generated movement and movement caused by other sources. When the system fails, internally generated behaviours, including thoughts, are not recognized as arising internally and can thus be attributed to external forces. Based on this theory, schizophrenic patients experience silent self-talk in the same way that normal individuals do, except they do not have the phenomenological experience that the talk is self-generated. An interesting aspect of this theory, is that its premise can explain far more schizophrenic symptomotology than can be explained by other models of hallucination. Specifically, it has been used to explain a number of delusional beliefs that are commonly found in schizophrenia including delusions of control, thought insertion, and thought broadcasting.

For example, consider the example of delusions of control. Patients who suffer from delusions of control believe that actions they are performing are not of their own will, but are instead the will of others. This phenomenon is often described as "alien influence" or "alien control". If one considers the argument above, some deficit in the corollary discharge systems, or a failure to monitor the willed intention of action plans, could produce a situation in which the patients no longer have the sense of responsibility for the generation of their actions that they should. To use Frith's words " We proposed ... that it is information about self generated acts that fails to reach the monitor. As a consequence, the patient experiences himself carrying out acts without awareness of a willed intention to perform such acts" (Frith & Done, 1988, p. 439). In other words, when an action is generated but not accompanied by the usual feed-forward mechanisms that allow us to have the experience of intendedness, or if those mechanisms cannot be accessed, the result is the perception that the act is externally generated. This experience would be very similar to that described by Penfield's patients.

Similarly, the same deficit can explain the symptom of thought insertion. In delusions of thought insertion, schizophrenics report that they experience thoughts in their own mind that are not of their own volition, but have been placed there by others. Frith and Done (1988) reason that "only if each thought is specifically labeled as my own does the possibility arise of having a thought that is not my own", and suggest that if something went wrong with the labeling system then the patient might experience the thought as alien.

Experimental Support for Self-Monitoring Deficits

One of the inherent difficulties in this theory involves testability. While it is fine to hypothesize that patients with schizophrenia suffer from a self-monitoring deficit that is related to concepts of corollary discharge in the brain, it is another thing to prove the existence of concepts such as the "self-monitoring of thought". In an attempt to support their theories, Frith and Done (1988) point to studies examining physiological differences between schizophrenic patients and normal control subjects. Specifically, it has been found that schizophrenics present an atypical EEG response under certain experimental conditions. When normal individuals are presented with randomly occurring tones, the tones elicit a large response in EEG recordings (Shafer & Marcus, 1973). However, if the subject initiates the tone by pressing a button, the evoked response is much smaller in amplitude. As the delay between the button press and the onset of the tone if increased, the amplitude of the evoked potential increases proportionally to the length of the delay. When studies of this nature were conducted with schizophrenic patients, they showed atypical response patterns (Frith & Done, 1988; Braff, Callaway, & Naylor, 1977). Specifically, they demonstrated a "paradoxical delay effect" such that the patients demonstrated a decrease in amplitude when the delays were increased from 250-500 ms. Frith has interpreted this data as further evidence of a self-monitoring deficit. It appears that when the schizophrenic patients produce the tone through their own motor actions, their brain function does not monitor the action normally, and/or prepare the mind for the upcoming event, or if it does, it does so at a much delayed rate.

A similar example of self-monitoring of motor sensation has been identified by examining the ability of schizophrenic subjects to make distinctions between self-generated tactile stimulation and externally generated tactile stimulation (Blakemore, Smith, Steel, Johnstone, & Frith, 2000). In this experiment, participants were asked to describe the intensity level of a tactile sensation (being touched in the palm by a piece of foam) in two conditions. In the first condition, an experimenter controlled the application of the sensation and in the second condition, the participants themselves controlled the application of the sensation by depressing a lever. Two groups of patients including a control group, and a group of patients with affective disorders noted significant distinctions between the conditions, and reported the sensations to be more "intense", "tickly", and "pleasant" when the stimulus was generated by the examiner as opposed to when it was self-generated. This finding is attributed to a sensory attenuation that arises from having the feed-forward knowledge that you are about to induce stimulation on yourself. This is similar to the notion that you cannot tickle yourself, as mentioned above. In contrast to the responses of these participants, a schizophrenic group with auditory hallucinations and/or symptoms of passivity did not note any differences in their subjective reports to indicate this expected attenuation. These data were interpreted as support for the self-monitoring deficit in schizophrenia.

In another line of evidence, Frith and Done (1988) point to a variety of experiments that have attempted to explore issues related to the central monitoring of error correction in the motor system. Their theory is that "if schizophrenic patients have something wrong with their internal monitoring system, they should have difficulty in correcting errors using this system." The rationale for using paradigms of this nature arises from early work on models of motor planning and error correction (Rabbitt, 1966; Rabbitt, 1967; Angel and Higgins, 1969; Higgins & Angel, 1970; Angel 1976). In a series of experiments, these researchers explored the notion that people can make very quick error corrections by utilizing central monitoring of their own actions. They suggest that this error correction is conducted by a self-monitoring process because participants can make the self-corrections with faster response time than would be deemed possible if they were utilizing the sensory feedback that resulted from their actions. Two types of experiments were conducted in these studies, both of which involve the elicitation of very fast motor responses and error detection.

In Rabbitt's experimental design, participants were tested on continuous performance tests in which they had to respond to digits that were flashed on a computer screen. In one study (Rabbitt, 1966), the participants were presented with digits from 1-8. If the numbers 1-4 appeared the screen, the participants had to respond by pressing a button with their left index finger; and when the numbers 5-8 appeared on the screen they had to respond by pressing a button with their right index finger. If the participants made an error, they were requested to correct their responses by pressing the correct button as soon as they realized their error. They were never provided with any external feedback regarding the correctness of their responses. The results of this experiment revealed: 1) that the participants were able to identify and correct motor errors in the absence of external feedback, and 2) that the time latencies recorded for error correction were faster than time latencies for standard stimulus response. Based on this evidence, Rabbitt argued that " internal monitoring of (the subject's) own responses allowed them to correct errors more quickly than they could respond to any external signal from the display." (Rabbitt, 1966). The fact that the time latencies were faster for error correction than basic stimulus response is important, because it makes a distinction between the possibility that the self correction was governed by a "central monitoring" system as opposed to a monitoring system that is based on external feedback.

Using a different paradigm, the work of Angel and Higgins (Angel & Higgins, 1969; Higgins & Angel, 1970; Angel, 1976) provided additional evidence for central monitoring. This procedure, which was originally developed by Gibbs (1965), involves the use of a computer and requires participants to monitor very rapid directional movements that are made with a joystick. In these experiments, the subjects were placed in front of an oscilloscope (or a computer monitor in the later studies), and provided with a controller. On the screen, they were presented with two markers. The first marker was a target, which could appear in one of three places on the computer screen: a center starting position, a left position, or a right position. The second marker was a cursor that the participants could control with the joystick. The goal of the experiment was to attempt to move the cursor from the center position, toward the target, which would appear in either the right or the left position. The cursor and the target were centered between each trial. In the early phases of the experiment, the participants would simply move the joystick in the direction of the target and the cursor would move in the same direction as the participants' movement (when they moved the controller left the cursor moved left). However, during the later stages of the experiment, the polarity of the joystick was reversed (such that if the joystick is moved to the left the cursor moved to the right). This reverse of polarity was done without warning. This change in polarity was utilized to increase the number of trails in which errors were committed, such that error correction could be studied. The polarity was reversed several times during the course of the experiment.

The results obtained from these studies revealed that the participants' error correction times were much faster than their initial response times to move to a target. This was initially proposed to be sufficient to prove the concept of central monitoring (Angel & Higgins 1969; Higgins and Angel, 1970). However, Angel (1976) made an astute distinction in later work that strengthened the argument considerably. The fallacy in the early works came from the fact that the comparisons being made were between choice reaction times and simple reaction times. When the participants were making the initial decisions, they were making an immediate stimulus response, but there were two possible directions at the onset of the trial. Once they moved the cursor in the wrong direction, they were provided with immediate feedback from the computer, and then only had one direction to choose from in order to correct the mistake. Angel notes that this is not a fair comparison as it is perfectly logical for the participants to respond faster in a simple reaction time condition (move the other direction), than in a choice condition (move one of two possible directions). In order to correct for this flaw, he added a condition to the experiment in which an opaque cover was placed on the screen that blocked the central portion. With this cover in place, the participants could see the target stimuli on the two sides of the screen, but could not see which direction the cursor moved when they moved the joystick. In this experiment, the trials immediately following a polarity switch were eliminated because it would be impossible for the participants to know the polarity had changed. As with the previous experiment, the participants had to keep in mind which response set (normal or reversed polarity) was is place and respond accordingly. Since no feedback was provided, the participants were required to consider their actions (and the results of their actions) as opposed to any visual feedback in order to make any corrections. If they believed that they had made an error then they corrected it. In this condition, even in the absence of feedback, the participants successfully identified a number of errors without feedback and their corrective moves were still much faster than initial responses.

With the availability of experimental paradigms such as these, the next obvious step for researchers in the area of schizophrenia was to examine the performance of schizophrenic patients on monitoring tasks. Due to the relevance of this research to the current study, these experiments will be described in detail.

It was proposed that if patients with schizophrenia had difficulty with self-monitoring, then they should also have difficulty with these types of motor self-monitoring tasks. This is precisely the line of research that was pursued by Malenka and his colleagues in two separate experiments (Malanka, Angel, Hampton, & Berger, 1982; Malenka, Angel, Theimann, Weitz, & Berger, 1986). In these experiments, the researchers used exactly the same methodology described above in the work of Angel, on three separate groups of patients. Specifically, the participants had to move the cursor with a joystick, to a target that appeared on either the right or the left side of a computer monitor. An opaque screen covered the center of the monitor so the participants could not see initially if the joystick was oriented in normal or reversed polarity until the cursor reached the edge of the screen. The patients had to make an initial decision to attempt to move the cursor to the target, but could change their decision if they felt that they were moving the wrong direction up to the point where the cursor became visible. Several polarity switches occurred during the experiment to increase the number of initial errors and error correction potential, and the first few trials immediately after a polarity switch were removed from the data (because the participants could not possibly know the correct response). The patients included a normal group comprised of medical students and hospital staff, a separate control group comprised of patients who were involved with an alcoholic treatment program, and a group of schizophrenics. The schizophrenic group was heterogeneous consisting of nine chronic patients (2 paranoid, 6 undifferentiated, and 1 residual), two subchronic patients (2 paranoid), one acute patient (undifferentiated), and two schizoaffective patients (1 chronic, 1 acute).

The experiment examined the movements of the patients and each response was scored as 1) correct, not reversed, 2) correct, but reversed (a false reversal), 3) incorrect not reversed (uncorrected error), or 4) incorrect, but reversed (corrected error). From these data the researchers examined two composite scores 1) the probability that a false move would be reversed, and 2) the probability that an initially correct move would be reversed. The results of the experiment revealed that the schizophrenic group was significantly worse than both control groups at correcting responses that were initially incorrect. In fact, the schizophrenic group reversed only 38% of their false moves whereas the normal controls and the alcoholics reversed 70% and 75 % of their false moves, respectively. The schizophrenic group also had a tendency to reverse correct moves far more frequently than both control groups. The authors considered the possibility that the schizophrenics may simply be reversing moves more frequently, however, they also examined the actual ratios of reversed moves to total moves, and found no significant differences between the groups. In sum, these results were interpreted as positive evidence that schizophrenics have an impaired ability to monitor ongoing behaviour by means of internal, self-generated cues.

In a follow up article (Malenka, Angel, Theimann, Weitz, & Berger, 1986), this study was extended by examining another group of schizophrenic patients, and included a new control group of patients with major psychiatric illness other than schizophrenia. The authors admitted that one of the potential limitations of the original study was that it compared patients with psychotic illness to participants who were either healthy (and well educated) or alcoholic (without additional comorbid psychopathology). They felt that considering the numerous psychological and physiological differences that exist between schizophrenic patients and their original control group, the examination of other patients with psychiatric disorders would be a more realistic comparison. The schizophrenic population in this study was again a heterogeneous population, consisting of nine patients, including seven chronic patients (three paranoid, three undifferentiated, one residual) and two subchronic patients (one undifferentiated, one disorganized).

The results of this study were consistent with that of the previous study; the schizophrenics performed significantly worse than both the control group and the depressed group. The mean reversal rate for initial errors was 81% in the normal control group, 82% in the depressed group, but only 53% in the schizophrenic group. In addition, it was reported that only two schizophrenic patients were able to reverse more than 70% of their errors.

In an attempt to examine the differences between schizophrenic subjects on and off neuroleptic medication, the authors pooled the data from the two experiments to create a large enough group to split the samples. The analysis compared 10 patients who were on neuroleptic medication with 11 who had been drug free for a minimum of two weeks. The only significant difference between the two groups involved the probability of making a reversal, as the "medicated schizophrenic subjects exhibited a tendency to reverse fewer moves than nonmedicated schizophrenic subjects." The authors concluded that from their data that "medication status did not contribute significantly to the results, as statistical reanalysis with the medicated schizophrenic subjects deleted had no effect on the reported difference between the groups." The authors also attempted to identify any potential differences between patients of different symptom severity as determined by their scores on the Brief Psychiatric Rating Scale (BPRS), but found no significant correlations between the total BPRS score or the severity of positive symptoms and any test variable.

Shortly after Frith and Done (1988) proposed their theory about the relationship between self-monitoring deficits and schizophrenic symptomotology, they developed an experiment using a more user-friendly paradigm in the form of a video game that was adapted from the procedure used by Angel and Malenka (Angel, 1976, Malenka, Angel, Hampton, & Berger, 1982; Malenka, Angel, Theimann, Weitz, & Berger, 1986). In their design, the patients sat in front of a computer screen, which displayed two men with guns on different corners of the screen. One man was located on the top left corner, and the other was located in the bottom right corner of the screen. During the game, a bird would appear opposite one of the men, and the patients would have to move a joystick either to the right or the left in order to make the appropriate man fire his weapon. Once the joystick was moved, a bullet would make its way across the screen toward the bird reaching it in 2800ms. If the participant were to push the joystick in the wrong direction, the incorrect man would fire his weapon and the bullet would move across the screen. If the participant made this error but corrected it within the 2800s trajectory, he/she could reverse directions and the correct man would fire his weapon. To make the test slightly more difficult, the polarity of the joystick was periodically reversed, so that moving the joystick to the left would cause the man on the right to fire, in contrast to the normal condition in which moving left would cause the man on the left to fire. If the bullet was allowed to complete is course without the participant changing direction, the message "you pulled the wrong trigger" would flash on the screen before the next trial.

In the second phase of the experiment, an opaque screen covered the center portion of the computer screen. This screen prevented the participants from seeing the trajectory of the bullet for 2000ms after it was fired, but visual feedback was provided for the final 800s after the bullet past the screen and before it reached the bird. The data collected from this experiment included the number of incorrect responses, the proportion of errors that were corrected within 2800ms, the proportion of errors that were corrected within 2000ms, and the number of false corrections that were made.

In line with the cognitive psychology model, and in line with their own theory, Frith and Done (1988) were much more specific about their patient selection in this study. Their groups consisted of: 1) a group of 10 patients with the diagnosis of schizophrenia who demonstrated symptoms of alien experience; 2) a comparison group of 4 patients with schizophrenia who did not experience any such symptoms; 3) a control group of 9 patients diagnosed with affective disorders; and 4) a control group of 6 participants with no psychiatric history. They also emphasized the importance of working with patients who were medication free at the time of testing.

The results of the first experiment in which the participants were provided with complete visual feedback revealed no significant differences as expected; however, during the second task significant differences were found between the participants with alien experiences and all three comparison/control groups. Specifically, it was found that the patients' with alien control symptoms were significantly less likely to correct their errors using self-monitoring of motor actions (before they received visual feedback). However, analysis of the patients' individual performances indicated that the patients with alien control symptoms were better able to identify their errors during the last 800s when they received visual feedback, than when they had to rely on their own self-monitoring to guess the correctness of their initial response. This last observation is important because it rules out the potential criticism that the patients were unable to remain vigilant, or that they were unmotivated to perform the task.

This experiment provided further evidence for the nature of self-monitoring deficits in patients with schizophrenia. In addition, as intended by Frith, it identified the fact that patients with symptoms of alien control are more likely to demonstrate the self-monitoring deficits, and may in fact be the only group of schizophrenics who suffer such problems. However, there is a serious limitation in the study in that the group of schizophrenic patients without alien control symptoms included only four participants. Furthermore, all of the groups in this study suffer from relatively small population numbers.

While examining this literature, Kopp and Rist (1994) pointed out that the paradigm used in both the Malenka et. al. (1982; 1986) studies and the Frith and Done (1988) study contains a potential confound. In all three of these studies (and the original studies by Angel, 1976), there is a cognitive component that may be beyond simple error monitoring. Specifically, when the participants are presented with the stimuli, they are instructed verbally (in the best controlled study) that there are going to be changes in the polarity of the joystick controller. However, the participants must still remember and hold this information in mind while they are completing the task. Therefore, in addition to being a stimulus response motor task, the task has the additional cognitive component of tracking the response rule that currently applies. To address this criticism, Frith and Done (1989) argued that the patients were able to keep track of the movements that were correct for each trial successfully. They support this argument by pointing out the large number of initial correct moves that the participants made. If the schizophrenics were able to make a large number of correct initial moves, then they must have been able to track the polarity switches reasonably well. Despite this rebuttal, it appears that there is still more cognition required by this paradigm than meets the eye.

In order to examine the possible distinctions set up by this observation, Kopp and Rist (1994) devised a similar paradigm that eliminated the demand for memory on the procedure. In their experiment, the participants were again placed in front of a computer and given a joystick to make responses. Their stimulus was an arrowhead that appeared on either the right or left hand side of the screen. The object of the task was to point the joystick in the direction indicated by the arrowhead. To create the anticipatory errors, half of the trials included an additional cue. When the participants saw this additional cue on the screen, they were trained to move the joystick in the direction opposite that indicated by the arrowhead. Using this paradigm, no differences between the groups were identified in error correction. (The groups included a heterogeneous group of 27 schizophrenics, an alcoholic group, and a normal volunteer group). The schizophrenic group corrected 50.2% of their errors, the controls 61.8% and the alcoholic group only 48.8%. Despite the apparent lack of replication found in this study, the authors proposed that the difference in results could be explained by a theory within Frith's original conceptualization (Frith & Done, 1987, Frith & Done, 1988). In their proposal, Frith and Done explain that there is a difference between stimulus elicited action and willed action (concepts credited to Goldberg, 1985). It was further argued that patients with positive symptoms of schizophrenia had difficulty monitoring their willed intentions to act (as described above). If Goldberg's conceptualization is correct and motor systems are operated by distinct neural pathways, then it is possible that these two tasks express this distinction. To quote Kopp and Rist directly "the concepts of stimulus driven and memory-driven action may correspond to the concepts of stimulus intention and willed intention. Frith confined the purported deficit in monitoring to functions of willed intentions. Reduced error corrections in schizophrenic patients may be absent in stimulus driven joystick tasks, but are present in memory driven joystick tasks" (Kopp & Rist, 1994, p 20).

Further work examining the differences among schizophrenic patients was conducted by Mlakar, Jensterle, and Frith (1994). This experiment addressed issues of central monitoring by examining the patients' ability to draw geometric figures without visual feedback in two different experiments. In addition, the groups of schizophrenic patients that were used were much larger. The groups examined included 1) 25 schizophrenic patients who were currently experiencing Schneiderian first rank symptoms, 2) 14 Patients who were not currently experiencing first rank symptoms, but who were at one time, 3) a control group of 16 patients with psychiatric illness other than schizophrenia, and 4) a normal control group of 10 individuals.

The first experiment involved drawing two simple geometric figures on a computer screen using either a joystick or a keyboard. Each drawing could be completed by making a sequence of four possible moves correctly (either by making four direction choices with the joystick, or pressing four direction keys). Before the experiment was started, the participants were allowed to practice drawing the figures on the computer screen. The experiment was conducted using four conditions that varied in the amount of external feedback that the participant had to guide their behaviour. In all four conditions the computer screen was turned off, so that the participants could not see what they were drawing (and hence did not know whether or not they were correct). In Condition A the participants could view a model drawing of the stimulus while they were making their drawing, and were required to use they joystick. Condition B was the same as A, except that the participant was required to use the keyboard as opposed to the joystick. The two controllers were utilized because it was felt that the use of the joystick allowed for additional proprioceptive information about the act of drawing. The use of the keyboard was conducted by pressing one of four direction keys, which does not provide nearly as much information about position. In conditions C and D, the participants were no longer able to see the stimulus card, and had to generate their drawings from memory. The differences between these two conditions, again, involved the use of the joystick in C and the use of the keyboard in D.

During this experiment, all participants were able to complete the procedure while the computer screen was on and visual feedback was available. However, when the computer screen was turned off, both schizophrenic groups performed significantly worse than both control groups. In addition, it was found that the group with Schneiderian symptoms performed significantly worse than the other schizophrenic group. The Schneiderian symptom group was also the only group to display a decline in performance that was directly related to the amount of central monitoring required. That is, while the schizophrenic group without Schneiderian symptoms committed errors that were randomly dispersed among the conditions, those with Schneiderian symptoms had significantly more difficulty as the level of central monitoring that was required increased. These data were interpreted as evidence that patients with Schneiderian symptoms had a specific deficit in central monitoring, while those patients without the symptoms suffered from a more general cognitive deficit that hindered their performance on any tests of this nature.

In the second experiment of this study, the researchers had the same groups of patients generate their own drawings using either the joystick or the keyboard. The only requirements were that the participants make geometric drawings consisting of five or six horizontal or vertical lines. Again the computer screen was turned off, so the patients could not see what they were drawing. When the participants were done, the computer stored their drawing and generated three foils by rotating the design into three different configurations (either rotated 90 degrees or 180 degrees). The participants were then asked to select the drawing that they had completed from the four possible choices. Only those patients with the Schneiderian symptoms had difficulty performing the task. This again suggested that patients who are currently experiencing Schneiderian symptoms are more impaired on tasks of central monitoring.

In an effort to explore the potential relationships between these apparent self-monitoring tasks and neurocognitive measures, Stirling, Hellewell, & Quraishi, (1998) conducted additional work, utilizing and expanding upon the procedures used by Mlakar et. al. (1994). In this study, the authors examined four different self-monitoring tasks including: and odd/even task, a spontaneous drawing task without feedback, an instructed drawing task without feedback, and an instructed drawing task with feedback. The first task involved the presentation of random digits on a screen in a predictable order (odd followed by even). The participants were required to press one of two keys marked "odd" or "even" depending on the type of number that was presented. To develop anticipatory errors, the presentation order was occasionally switched such that two consecutive odd or even numbers would occur confusing the participants temporarily. The spontaneous drawing was a direct replication of the Mlakar et. al. (1994) procedure except the drawings were generated using a pencil and paper, and the foils were generated with carbon paper (as opposed to the original computerized version).

Likewise, the instructed drawing conditions involved drawing figures (of a model drawing), either with or without feedback, and choosing which drawing was self-generated. The neuropsychological test measures that they utilized for comparison included a continuous performance test (CPT), the Visual Recognition Memory Test (VRMT), the Stroop Color-Word interference test, the Trails Making Test, and the Quick Test.

The overall results of the experiments indicated that the schizophrenic patients: 1) were slower to correct errors and made more errors on the odd even task; 2) performed significantly worse on a number of neuropsychological tests including the CPT, the VRMT, the Stroop interference test, and the Trail Making Test; and 3) failed to recognize their own self-generated drawing significantly more often, when compared to a control group of hospital staff. Furthermore, analysis of correlations between performance on the self-monitoring tasks and symptom ratings (SAPS-Schedule for the Assessment of Positive Symptoms) revealed a "strong relationship between the presence of these symptoms of alien control and poor performance on self-monitoring tasks."

An additional aspect of this study was the use of covariance to determine whether the deficits in self-monitoring were attributable to general cognitive ability or neuropsychological impairment. The results of the covariance analyses indicated that the differences in the drawing tasks remained significant when the effects of IQ, CPT performance, and VRMT were considered, but that the group differences for the odd-even paradigms were no longer significant. The finding that the odd-even paradigm was no longer significant was interpreted as evidence that the error correction times found between schizophrenics and the control groups, may have been the result of impairments in vigilance that are commonly found in schizophrenia. Despite the fact that the odd-even task was found not to be robust to covariance, the study's results regarding the drawing task remained compelling because it is one of the first studies to specifically identify correlations between self-monitoring performance and positive symptoms that is most likely not attributable to general cognitive ability or other neuropsychological deficit.

While most of studies of self-monitoring in schizophrenia have supported the self-monitoring hypothesis, not all authors have been effusive about the model. While using a different type of visual-motor paradigm to explore self-monitoring, one group (Fourneret, Franck, Slachevsky, & Jeannerod, 2001) found results which they felt were contrary to Frith's thesis. Their task involved a visuo-motor adaptation task in which the goal of the participant was to draw a line from one target to another target immediately above it on a computer screen with the use of a stylus pen and graphics tablet. During the experiment the participants were prevented from seeing their drawing hand and were required to watch the video screen where the targets and the resulting line that they are drawing was displayed. Once the task was understood, the participants' view of the first two thirds of their line connecting the targets was blocked with an opaque screen. As the experiment began, the settings of the graphics pad and display were altered with a directional bias of 15 degrees. Thus, if the participant continued to draw a straight vertical line, the resulting line that was displayed on the screen would deviate 15 degrees to the right and miss the target. In order to complete the task, the participants would have to compensate for the bias and make their actual hand movements draw a line with a corrected 15 degree bias to the left instead of drawing a straight line. The study examined the number of trials that it took participants to correctly draw a straight line, but also involved a debriefing session in which the participants were asked to explain their experience to determine if they could explicitly state that they had adapted their motor movements. The study examined three groups of patients including schizophrenics with Schneiderian symptoms, schizophrenics without Schneiderian symptoms, and a control group. The results of the first phase of the experiment indicated that there were no differences between the groups on the visual adaptation task. With regard to the conscious monitoring of action, despite the fact that all participants were able to perform the task, only nine of the 19 schizophrenic patients (7 with and 2 without Schneiderian symptoms) were able to explicitly report the error correction strategy to the examiners. The authors indicated that their results weakened the assumption of a failure of the central monitoring because the Schneiderian symptom group was not significantly different than the control group; and more importantly that they were able to self-monitor their motor behavior well enough to explicitly state that they had made an adjustment. While this study may weaken the argument to some degree, the fact remains that the participants did receive visual feedback regarding their errors and were likely compensating consciously based on this visual feedback.

Models of Speech Production and Self-Monitoring of Speech

While all of the studies reported thus far have focused specifically on self-monitoring of motor tasks such as drawing and joystick responses, there have been a few studies examining the central monitoring of speech. There is a relatively broad literature available on the speech of schizophrenics, but this review will attempt to maintain a focus on the applications of speech research to issues of central monitoring. Before discussing the literature on speech in schizophrenia, it is necessary to digress once more and examine current models of speech production and current thinking about the monitoring of speech.

Several models have been proposed to explain speech production and speech monitoring, of which the currently predominating model is that developed by Levelt (1983; 1989). This model has been used in the bulk of literature reviewed for the current topic (even with relation to schizophrenia) and hence will be used here for the sake of continuity. Levelt's theory fractionates the speech production process into several different modules that are felt to represent unique essential functions of the system. The first module described by Levelt is the *conceptualizer*. The conceptualizer is viewed as the module in which an individual's initial intentions of speech originate, and is the primary location of conceptual message construction. In addition to the formulation of ideas and concepts that an individual wants to express, there are thought to be monitoring systems within the conceptualizer, which help the speaker to organize their concepts efficiently. For example, in the process of speech, one needs to consider the global intentions with respect to what one intends to express, to organize the information for expression, and to monitor what has already been said. All of these processes are subsumed by this module. The product of the conceptualizer is said to be a *preverbal message*, which contains information about the message that the person desires to say at the current time.

The output of the conceptualizer, is the input to Levelt's second module, the *formulator*. This module contains two processes, the grammatical encoder, and the phonological encoder. The functions of these two processes are to organize the intended message into correct grammatical and phonological units associated with speech. In this way the basic concepts that emerged from the conceptualizer are transformed into an organized speech product which obeys grammatical and phonological rules. The output of this module is described as a *phonetic plan* or *internal speech.* According to the theory, the information is passed in two directions from this point. First, internal speech can be an end product, which is available for examination by the individual. Second, if the person intends to speak aloud, the information from the internal speech/phonetic plan needs to be transformed into speech. This process is said to be a function of the *articulator.* Specifically, the articulator is thought to interpret internal speech and organize a motor plan incorporating the articulatory musculature (respiratory, laryngeal, and supralaryngeal musculature) in order to generate *overt speech.*

Regardless of which end product is generated, there are other essential components to the model that involve comprehension and monitoring of the speech that has been generated. In order to complete the system, Levelt (1989) considers one final module described as the speech comprehension system. As his model is predominantly meant to describe speech production, this system is not described in as much detail. It is said to subserve two functions including *parsing* and *self-monitoring.* Parsing is described as a "cover term for the sum total of procedures available to a language user for understanding spoken language." The parser is said to be capable of deriving the conceptual message from speech, as well as analyzing the linguistic aspects of the speech string including: the ability to correctly place phonemes, the ability to place referents in the correct place, and the ability to establish syntactic and prosodic features, and other vocal qualities. It is also noted that the parsing mechanisms have access to the same sources of information as the formulating mechanisms, such that speech can be analyzed under the same rules through which it is developed.

Once information has been parsed within the speech comprehension system, the speaker may self-monitor their language output. This self-monitoring process is the most relevant to the current research. Levelt states the monitor performs two primary functions. The first is a matching function, which compares parsed aspects of internal speech and overt speech with the intentions, and the message sent to the formulator. The second function is to check the speech according to the criteria and standards of speech production. The first process is said to involve checking whether what the individual says corresponds to what was intended, while the second comparison is involved with the detection of speech errors, syntactic flaws, and the maintenance of standards for rate, loudness, and other prosodic aspects of speech.

Based on this model, Levelt has allowed for three different types of monitoring of speech production. The first already described, involves monitoring within the conceptualizer to decide what ideas should be expressed, and eliminate generated thoughts that would not be appropriate at the current time. The second is an internal loop, which occurs when internal speech or the phonetic plan is passed directly through to the speech comprehension system. The third is an external loop, in which overt speech is experienced through audition, and then examined by the speech comprehension system. Empirical evidence for the existence of these latter two monitoring systems (the internal and external loops) is available from research in speech error correction, which analyze errors in two ways. The first analysis involves the examination of error detection latencies, and the second involves the types of error correction.

In a groundbreaking study, Lackner and Tuller (1979) developed an experiment in which participants were provided with phonetically challenging material, and asked to monitor their own errors. In order to examine their self-monitoring ability, the participants were asked to press a button every time they detected an error in their speech. Error correction was analyzed in two different conditions. The first condition allowed normal auditory feedback, and the second condition involved masking all feedback of overt speech by placing earphones on the participants and playing white noise. The results of this study indicated that the participants were less able to detect certain types of errors in the noise-masked condition than in the normal feedback condition. While there is little argument against the notion of the external processing loop, this finding does support its existence as a distinct ability. The fact that there were certain errors that the participants were able to detect in a normal feedback condition, that they were unable to detect in the noise masked condition, suggests that there must be an independent ability to monitor external speech.

Evidence for the existence of internal monitoring comes from work that has attempted to prove individuals can edit generated information before it is overtly spoken. In one such study (Motley, Camden & Baars, 1982), it was theorized that during the speech production process, it is possible to detect an error at the stage of internal speech before it is articulated, and attempt a correction before the word is actually spoken. This correction may be accomplished either by correcting the word, or preventing the word from being spoken. To test the hypothesis, the authors designed a protocol that increased the chances that a person would make produce spoonerisms in their speech. Spoonerisms are defined as unintentional interchanges of the sounds, usually of initial sounds, in two or more words. For example, if a person were attempting to articulate "funny bone" but interchanging the sounds, they might accidentally produce "bunny fone (phone)". During the experiments the participants are exposed to a number of interference words which they are supposed to read silently followed by a target word which they are required to say aloud. The authors state that with this procedure they can get participants to generate spoonerism approximately 30% of the time. In order to test the prearcticulatory editing hypothesis, the authors developed stimuli that would generate spoonerisms consisting of taboo words (e.g., "tool kits" = "cool tits"). The stimuli were also developed such that the taboo word could appear in either the first or the second position in the word pair. It was reasoned that if the participants were able to monitor their internal speech at a point prior to articulation (the phonetic plan), they would attempt to prevent themselves from saying the taboo word more often then they would prevent themselves from generating a neutral spoonerism. They also hypothesized that the participants would be more likely to prevent the spoonerism if the taboo word was in the second position in the pair as opposed to the first word in the pair, because they would have more time to prevent the articulation. The results supported the hypotheses. The participants in general prevented themselves from saying the taboo spoonerisms more often in comparison to the neutral spoonerisms, and were also better at preventing articulation of the taboo words if they were in the second position. As a security measure, the experiment also measured galvanic skin responses to ensure that participants were generating (and monitoring) the spoonerisms. It was found that the participants often generated higher skin responses at times when they were able to prevent themselves from actually saying the taboo words. This indicated that they were actually generating and monitoring the taboo spoonerism despite the fact that they did not say them overtly.

Another line of evidence providing support for the existence of the internal monitoring loop comes from error detection latencies. An additional result of the Lackner & Tuller (1979) study described above revealed that when participants were denied auditory feedback, they detected a larger percentage of their own speech errors with latencies between 0-100ms than they did when permitted auditory feedback. These reaction times are much faster than would be expected if information were based strictly on auditory or proprioceptive feedback, which are thought to take much more time (approximately 300-400ms; Woodworth & Schlosberg, 1954). While these data seem to provide evidence for internal speech monitoring, there are two potential types of monitoring that could account for the data. First, error detection could be based on monitoring of the phonetic plan as suggested by Levelt. In addition, Lackner and Tuller suggest that it is possible to identify errors in speech production by monitoring the articulatory musculature as speech attempts are made. There seems to be little argument about the fact that we are capable of monitoring movements of the articulatory musculature to some degree, much in the way that we can detect errors in any other type of movement, but the question remains whether or not we can notice speech errors by monitoring the articulatory musculature. Lackner and Tuller (1979) argue that it is possible. When they examined their data, they discovered that participants in the noise masked condition, were much less accurate at detecting errors that required small positional changes, than recognizing errors that involved more gross positional changes.

Based on these data, it seems that motor monitoring can play a role in speech monitoring. However, the data in this area are not conclusive. In a more recent study (Postma, & Noordanus, 1996), the experimental methodology was extended to include two additional conditions, error detection during mouthed speech, and error detection during silent speech. In this experiment, the participants performed the same error detection in four conditions (silent speech, mouthed speech, noise masked, and normal feedback). It was reasoned that if speech monitoring included monitoring of articulatory musculature, there would be a significant difference between those errors that were detected in any condition that involved motor use. Specifically, there should be some errors detected during silent speech, a greater number of errors detected during the mouthed speech and noise masked conditions which involve utilizing motor musculature, and greater error detection still in the condition of normal auditory feedback. However, these results were not found. The only significant difference in error detection rates was between the normal feedback condition and all three internal or 'silent' speech conditions. Based on this result the authors argued that "speech monitoring entails only three loops: conceptual, inner, and auditory, rather than four or more." They do qualify their hypothesis by noting that "it is also possible that certain elements are monitored in a more automatic unconscious fashion, precipitating more or less automatic self repairs. This type of speech monitoring may be involved in motor execution." Because these data are conflicting, it is not entirely clear how many types of self-monitoring are available, however it is generally agreed upon that there are at least three types of monitoring that occur during the speech process.

Self-Monitoring of Speech in Schizophrenics

While there is an extensive literature on the speech of schizophrenics, there is a much smaller quantity of work that that has actually examined the nature of self-monitoring and error correction and how these abilities might relate to models of Frith (1992) and Feinberg (1978). Two such studies have been conducted by Ivan Leudar and his colleagues (Leudar, Thomas & Johnston, 1992; Leudar, Thomas, & Johnston, 1994).

In the first study, Leudar, Thomas, and Johnston (1992) performed a complex analysis of the self-repairs that schizophrenic patients make in their free flowing speech. Their procedure involved having the patients watch the examiner manipulate small tokens in front on them. The objective for the patient was to pretend they were on a telephone with someone else who had the same display in front of them, and to tell that person exactly what the examiner was doing with the tokens. For example, the examiner might put a small, square, black token on top of a red, circular token, and the patient would have to describe what had occurred. The researchers examined the language profiles of the patients by counting the frequency of message inadequacies; the frequency of repairs and the adequacy of attempted repairs. They reasoned that if models such as that proposed by Frith and Done (1988) or Hoffman (1986) were accurate, then patients should generate many message inadequacies because they would be unable to monitor their internal speech. They also anticipated that the patients would be able to identify their errors once they had been spoken, and would make error corrections, but that these error corrections might also be defective because of the patient's internal monitoring difficulty. These were exactly the results that they found. In general, the schizophrenic group made far more inadequate messages than the control group, but they attempted to fix just as many (proportionally) as did the controls. This was taken as evidence that the patients did have difficulty monitoring their internal speech generation mechanisms; but were able to monitor external speech products (through auditory channels), recognize that errors were made, and attempt to correct the errors. What was more intriguing was the fact that patients who did not experience hallucinations were able to make speech repairs adequately, but those patients who did experience hallucinations produced significantly more inadequate repairs. This was interpreted as evidence for Hoffman's theory that verbal hallucinations and discourse disturbance are related. Leudar et. al. (1994) stated that Frith and Done's (1988, 1989) model does not clearly specify whether or not schizophrenics should have differences between the monitoring of internal and external experiences, however, it does seem based on this review of the literature that there is clear evidence of their intention. In the majority of the self-monitoring literature reviewed above, schizophrenic patients with Schneiderian symptoms or hallucinations (depending on the study) were able to perform much better if they were allowed to examine their own external productions.

In a follow-up study, this same group performed a technically sophisticated exploration of repairs in schizophrenic patients that examined the precise timing of error corrections to determine whether or not there were quantitative differences in the types of error corrections made (Leudar et. al., 1994). Using the same paradigm (the reporter test), the researchers examined the resulting speech products to discover the timing of error corrections made by the participants in relation to the spoken utterance, and well as the exact latency of the correction in relation to the error occurrence. Specifically, they counted the number of times a word was interrupted before it was completed, the number of times an interruption was made immediately after a word was completed, and the number of times speech flow interruptions occurred later in their speech. In addition, they calculated timing of each correction in milliseconds to determine whether or not external (acoustic) information could have been utilized in the correction process. The logic is the same as that seen in the motor error correction literature listed above. If the participants produce interruptions and attempt to make speech corrections before the amount of time that would be necessary for acoustic information to arrive, then it is assumed that the error correction must have been achieved through internal monitoring of phonetic plans.

The first type of error correction calculated was the proportion of immediate, within word repairs. These corrections occurred when the participant actually started a word, but then halted their speech output and prevented completion of the word. The average duration of time between the onset of the word with the error and the corrective stop was 257ms. This was reported to be a short enough time to assume that their detection could not have occurred through monitoring of acoustic analysis because it is simply too fast. The reaction time taken to make the pause itself was stated to be at least 250ms. Analysis of the interruptions revealed that these types of corrections were made significantly more frequently in the control group than in three groups of participants with schizophrenia. When the effects of working memory and attentional deficits were included as covariates, the results were still significant.

The second type of error correction analyzed involved repairs that were made immediately after words that contained errors. The timing data collected on these errors indicated that the average duration of time for correction following word onset was 400ms. Therefore, it was thought that these corrections were initiated after acoustic information had been acquired. The results indicated that this type of speech error was much more frequent in the schizophrenic patients than the controls. Comparisons of the schizophrenic subgroups did not reveal any significant differences.

In sum, these results seem to support the models of Frith (1992). Schizophrenics with verbal hallucinations should have a deficit in prearticulatory error detection and speech editing, if they have difficulty with self-monitoring. The results indicate that schizophrenic subjects did indeed produce fewer speech repairs that required monitoring of phonetic plans relative to controls, but had less difficulty using external feedback and made a greater number of error corrections once they were able to process this information.

In general, this study is very compelling. It had a relatively large sample size (30 patients with schizophrenia), and utilized an appropriate control group (orthopedic hospital inpatients), but it is the only one of its kind published at the current time. It also has the disadvantage that it examined the repairs of patients in the process of free speech. While it an excellent paradigm for the study they conducted, it is well established that patients with schizophrenia demonstrate a broad variety of problems in their free speech. It is possible that studies examining the patients' ability to speak in situations of altered feedback would provide a cleaner picture of self-monitoring of speech than is allowed by the examination of free speech.

There are two lines of research that have examined self-monitoring with the use of altered feedback. The first type examined self-monitoring with the use of voice distortion, and the second examined the ability of patients to cope with the experience of delayed auditory feedback. In the area of voice distortion, a series of recent experiments (Cahill, Silbersweig, & Frith, 1996; Johns et. al., 2000, 2001) have analyzed the ability of schizophrenic patients to distinguish their own spoken words from the same words spoken by another individual when the voices were subjected to varying levels of distortion. During these experiments, the participants were asked to say a series of words while wearing headphones that eliminated their ability to hear their own voice. After 500ms they heard either their own voice saying the word just spoken, or the voice of a same sex research assistant (who was seated behind a one-way mirror) who read the exact same word attempting to mimic to participant as closely as possible. To make the task somewhat more difficult the participants' voices were presented 1) without alteration, 2) with a moderate amount of distortion (lowered by three semitones), or 3) with severe distortion (lowered by six semitones). After hearing the words played through the headphones, the participants were required to make a decision as to whether the voice was their own (Self), the voice of another (Other), or indicate that there were unsure (Unsure). The studies differed in terms of the patient populations examined. Johns et al. (2001) examined the differences between a group of schizophrenics with a history of hallucinations, a second group of schizophrenic without a history of hallucinations, and a normal control group. The results of their experiment revealed that both patient groups made significantly more misidentification errors than the control group, and detailed analysis demonstrated that this only occurred when the voices were distorted. While both schizophrenic groups had difficulty with the task, individual analysis of the self-misidentification errors (attributing their own voice to another) indicated that the hallucinating group performed significantly worse than the other two groups. These data were viewed as consistent with the self-monitoring deficit but a number of exceptions were noted. First, it was emphasized that the non-hallucinators also had difficulty with the task. Of note, the non-hallucinators they examined were not entirely free of positive symptomotology and had some delusions. For this reason it was argued that self-monitoring deficits certainly may not be limited to hallucinators, but are expressed in patients with positive symptomotology. Similarly, Cahill et. al. (1996) identified deficits in of verbal self-monitoring in patients with delusions but without history of hallucinations. Other studies using this paradigm have discovered that the manifestation of self-monitoring deficits may be specific to the symptom expression as well. When compared with patients currently experiencing symptoms, patients in remission were less impaired on this test of verbal monitoring (Johns et. al., 2000).

The other line of research that has involved manipulating auditory feedback has utilized a manipulation known as delayed auditory feedback (DAF). DAF involves a procedure in which individuals are required to speak while wearing headphones that block normal auditory feedback and play the participants' own speech back to them at a delayed rate (such as 200 ms after it is actually spoken). The use of DAF conditions has been a topic of interest since Lee (1950) discovered the dramatic impact that it has on speech fluency in normal individuals. When placed in DAF most individuals will demonstrate significant dysfluency in their speech, as they try to readjust their speech with the auditory feedback to produce fluent speech. The level of dysfluency that results has also been found to change depending on the length of the delay. For instance, very short delays such as 90ms or less produce a small amount of dysfluency, but longer delays of 200-300ms produce a much greater amount of dysfluency. As delays are lengthened beyond a critical level, the level of dysfluency again diminishes as it extends well beyond normal feedback time (e.g., greater than 600ms). One interesting (and relevant) finding in this literature is the observation that some populations of individuals (e.g., stutterers) actually improve in DAF conditions and speak more fluently than they do with normal auditory feedback.

In a recent study, Goldberg, Gold, Coppola, & Weinberger (1997) reasoned that schizophrenics would show less dysfluency than normals under DAF conditions. The logic behind this hypothesis is that Frith's model actually refers to a disconnection between willed intention and the systems that monitor actions. If there is a true disconnection between the willed actions systems and the systems that monitor speech production internally, then schizophrenic patients should essentially always live in a world of delayed auditory feedback. In other words, if the patients are completely incapable of monitoring internal speech, and are always required to monitor auditory feedback, then their 'experience' of generated speech is always delayed more than it is for nonschizophrenics. They further reasoned that if Frith's model were true, schizophrenics should not show the usual dysfluency when placed in a DAF situation. To date four studies have examined schizophrenic patients under conditions of DAF, but only the Goldberg et. al. study (1997) has made specific reference to this line of research. The other three studies were conducted in the 60's and 70's and were designed to examine issues such as the effect of personality variables on speech performance during DAF.

Although, the three older articles examined the effects of DAF on schizophrenic populations for reasons other than those discussed here, the data presented in those experiments tended not to support the disconnection model. Specifically, Sutton, Roehrig & Kramer (1963) reported that DAF actually affected the schizophrenic group more than male controls, but not more than female controls, while Watson (1974) and Spear (1963) reported that there were no differences between normals and schizophrenic groups. Goldberg et al. (1997) argue convincingly that the results of the older studies were inconclusive. This is primarily because the populations of schizophrenic patients that were used were extremely heterogeneous (especially considering the dramatic changes in the classification of schizophrenia since the 50's and 60's when these studies were conducted). In their own work (Goldberg et. al., 1997), three groups of participants were tested under the DAF conditions; the groups included 10 schizophrenics with hallucinations or delusions, 5 schizophrenics without delusions or hallucinations, and 19 normal control participants. The results of their experiment were exactly the opposite of those anticipated by the authors. The schizophrenic patients with hallucinations were affected most dramatically by the DAF condition, and performed significantly worse than the controls. The schizophrenics without hallucinations or delusions held an intermediate position. It is noteworthy that these results mirror the results of the self-monitoring studies very closely, with hallucinating schizophrenics performing worse than schizophrenics without hallucinations. The authors failed to account for this finding, and merely concluded that the Frith model must be incorrect if the patients did not respond in the predicted fashion.

Close examination of the reasoning that underlies the conclusions Goldberg et. al. (1997) drew from their study reveals an apparent flaw. The flaw implicit in their reasoning arises from their repeated assumption that the Frith model calls for a "disconnection" between the systems that are responsible for willed intention and the system that monitors ongoing actions or action plans. While Frith and Done (1988; 1989) do argue that the mechanism for hallucinations arises from a deficit in self-monitoring of willed intention, it is never explicitly stated that there is a true disconnection in the same sense as conduction aphasia might be seen as disconnection between two brain areas. In fact, none of the literature supports a complete disconnection between willed intention and self-monitoring of actions; it is rather reported that patients are less efficient at self-monitoring. For instance, Leudar et. al (1992) indicate that their results imply the internal monitoring of phonetic plans is not altogether absent, but is less effective in schizophrenia than in controls. Likewise, Stirling et. al. (1998) report significant differences on measures of self-monitoring between groups, but never report that the patients are completely unable to monitor their own errors. In fact, even when one examines the symptoms of schizophrenia, it appears that the patients only fail to monitor some of their actions. For example, hallucinating schizophrenics state that they hear voices, but are still able to recognize their own communications when necessary. They clearly are capable of monitoring some of their actions, but appear to be less efficient, and lose track of or misattribute some of the information. Based on this reasoning, there is room for reinterpretation of the data put forth by Goldberg et. al. (1997). As noted above, the Goldberg et. al. (1997) data follow a trend such that schizophrenics demonstrate a greater level of dysfluency in DAF conditions than non schizophrenics, and hallucinators demonstrate more dysfluency than non-hallucinators. If the hallucinators have a self-monitoring deficit and are unable to monitor their internal speech, then they may in fact become more dependent on their external speech products to track their speech than normals. For this reason, it may be expected that they would perform worse under conditions in which the external feedback that they are relying on is disrupted.

The goal of the current study is to further explore potential deficits of self-monitoring in schizophrenia by examining the patients' ability to monitor their own speech productions. If the models and mechanisms proposed by Frith and Feinberg are correct, then a number of predictions can be made about how patients with schizophrenia should perform on various speech tasks. For a moment, reconsider the speech model proposed by Levelt. Levelt states that there are three types of monitoring that exist in the speech process. The first is the monitoring of thoughts in the conceptualizer and the appropriate selection of ideas; the second involves monitoring of internal speech; and the third involves monitoring of auditory information. If schizophrenic patients have self-monitoring deficits at every internal level then it would be predicted that the patients have at least two deficits in their speech productions. The first deficit (failure to monitor the conceptualizer) should result in difficulty organizing the content of speech, and saying what is intended. It has been noted by Chapman (1966) that patients with schizophrenia often find their own statements poorly matched to that which they intended to say. Furthermore, there is extensive evidence of disorganized speech in schizophrenia, although this is not specific to patients who suffer from hallucinations. These deficits seem to indicate that some schizophrenics do have difficulty with monitoring at the level of the conceptualizer. While this is an interesting line of research, it is beyond the scope of the current project and mentioned here only to state the fact that it is consistent the model.

The second and third types of monitoring that are proposed in the speech production process are monitoring of internal speech and the monitoring of the overt speech product that is heard following articulation. If schizophrenic patients have difficulty with central-monitoring but not with monitoring of external sensation, as argued by Frith, then they should demonstrate an inability to identify errors in their own internal speech, but retain the ability to identify completed speech errors. In their work, Leudar et. al. (1992;1994) demonstrated that schizophrenics have a number of anomalies in their self-repair of free speech, and argue that they demonstrate deficits of monitoring the speech plan. While their evidence is convincing, their conclusions are based on the precise timing of error corrections, which may be more generally related to deficits in speed of processing which are common in schizophrenic populations. In order to build on their work, the goal of the current project is to examine speech-monitoring performance utilizing a paradigm that can allow for a distinction between internal and external speech monitoring, without reliance on notions of correction time. In order to accomplish this goal, three different tasks were developed.

Experiments and Hypotheses

Experiment 1- Silent Reading

The first task assessed the ability to monitor auditory aspects of intended speech by having the participants attend to the sounds of words as they read silently. The objective of the task was to read a paragraph and cross out all the syllables that make an [i] sound. The purpose of this task was to identify whether the patient groups would be differentially able to monitor their own internal speech and correctly identify the target syllables. Based on Frith's model the hypothesis was made that:

1) Schizophrenics should be worse than control groups at the internal monitoring of such auditory 'imagery';

Furthermore, the argument extends that:

2) Patients with hallucinations and/or symptoms of alien control/passivity should be more impaired than patients without these prominent positive symptoms.

Experiment 2 – Tongue Twister Test

A second experiment was designed based on the previous work (i.e., Lackner & Tuller, 1979; Postma & Noordanus, 1996) that attempted to examine self-monitoring in the speech of normal subjects by examining speech error detection with the manipulation of feedback. Specifically, the goal of the experiment was to examine the error detection rates of schizophrenic patients and controls in a condition of normal auditory feedback, and in a noise masked condition in which they were unable to hear their overt speech products.

Based on the Frith model the following predictions can be made about the performances of schizophrenics in this study.

1) In a normal auditory feedback condition, there should be no differences in error detection rates between schizophrenic patients and normal controls.

2) In a noise-masked condition, there should be a significant difference between the error detection rates of schizophrenic patients and normal control groups, with schizophrenics performing more poorly.

3) Patients with hallucinations and/or symptoms of alien control should be more impaired than patients without these prominent positive symptoms.

The first prediction stems from the fact that schizophrenics are thought to perform as well as normal participants in situations in which they have access to external acoustic information. If this is true then they should demonstrate no more difficulty than the control group in terms of the total quantity of errors corrected. While other studies have examined the latencies of these detections in detail, the purpose of the current study is to examine the quantity of corrections made. The only available published data of this type indicate that in free speech schizophrenics produce just as many error corrections as controls (Leudar et. al, 1992). The current study uses a slightly different methodology by examining error detection rates versus error corrections.

In the noise-masked condition, the participants are unable to hear their overt responses, and hence are forced to rely on methods of internal monitoring in order to detect errors. In this condition, it was anticipated that the schizophrenics would perform much worse on the error detection task than the control group because they should have more difficulty monitoring their speech output without auditory feedback. Previous studies have examined error correction data and the precise timing that occurs during error correction, but to date no one has examined error detection rates, which may provide a better separation between pre-articulatory and post-articulatory monitoring systems than can be provided by the timing experiments. The potential advantage of this paradigm lies in the fact that there is a true separation between monitoring of internal and overt speech. While the previous studies assumed that there were differences in the types of monitoring due to time elapsed, the participants always had access to overt speech. With the use of the white noise condition, the participants have no access to overt speech, which should enable a clearer distinction between processes. No studies to date have examined the effects of error detection in a white noise situation with a schizophrenic population.

It is important to note the possibility that there is more than one type of monitoring subsumed in the noise-masked experiment. As noted above, Lackner and Tuller (1979) found evidence that people can monitor their articulatory muscles for errors as well as their internal speech. This finding was, however, contested by another experiment that failed to find a difference between mouthed speech, which includes articulatory motion, and silent speech which does not (Postma & Noordanus, 1996). If there are two types of monitoring that are occurring at this level, then the differences between the control group and the schizophrenic group should be even greater, as the controls have two systems that they can potentially monitor more efficiently. While it may be interesting to explore the differences between all four conditions (silent, noise masked, mouthed, and normal) with schizophrenic participants, the current study will be limited to the noise masked and the normal feedback condition. It is felt that the other conditions would be too difficult to analyze with a schizophrenic population, because the data would depend entirely upon the introspection of the patients. With the two conditions incorporated in the current study, the error detection rates can be compared with the actual output in order to determine the percentage of errors that are correctly detected.

The third prediction as in the experiment above arises from the fact that the bulk of the research in the area of self-monitoring has focused on patients with positive symptoms and correlations have been identified between deficits of self-monitoring and positive symptomotology.

Experiment 3 – Altered Feedback

While the first two experiments were designed to examine the nature of internal speech monitoring in schizophrenics, an additional experiment was included to examine more carefully the effects of altering external feedback in schizophrenia. As noted above, Goldberg et. al. (1997) argue that Frith's model calls for a "disconnection" between willed intention and action monitoring systems, such that schizophrenic patients should always live in a world of DAF, and hence should be unaffected by a DAF situation. As this argument is debatable, it remains plausible that Frith's model calls for a deficit in central monitoring or an inefficient central monitor as opposed to a true disconnection, and a new model for performance on DAF is proposed. If patients have some difficulty monitoring their internal speech, but successfully monitor it to some degree, then they should be slower to detect errors, and should be more reliant on the external feedback system to correct their errors. Based on this hypothesis, they should not only demonstrate more difficulty/dysfluency during a DAF condition, but they should also demonstrate more difficulty/dysfluency if any type of alteration is made to the acoustic information available for processing. In order to test this hypothesis two experiments were conducted. First, attempts were made to replicate the work of Goldberg et. al. (1997) and to determine if schizophrenics experience greater dysfluency than controls in a DAF condition. It was anticipated that the patients would show the same type of performance. Specifically, the hallucinating group was expected to experience the greatest amount of difficulty and produce more dysfluency in their speech than the control or non-hallucinating groups.

A second condition was also utilized as part of this experiment in order to test the hypothesis that the patients experience dysfluency because they are more reliant on external feedback. In this condition, the participants were asked to perform the same task as in a DAF condition, but instead of DAF, they heard a tape of another speaker that they had to ignore. It is hypothesized that control subjects would demonstrate no differences in their fluency, and be able to continue speaking easily, while the hallucinating schizophrenic group would have more difficulty coping with the distraction.

Experiment 4 – Motor Self-Monitoring

As a final experiment in this study, attempts were made to replicate some previous work in the area of motor self-monitoring so that any results obtained from the studies listed above could be considered in direct comparison to the results of previous work in this area. The measure selected was a drawing task similar to those originally described by Mlakar et. al. (1994) and replicated by Stirling and his colleagues on two additional occasions (1998, 2001). The task involved the recognition of self-produced drawings from a series of foil drawings (rotated images of the original drawing), under three different conditions. In the first two conditions, the participants were prevented from viewing their hands or the self-produced drawings during construction. These tasks differed in that the participants either copied a model drawing (Condition A), or generated their own drawing (Condition B). During a third condition, the participants were able to see their hand and their drawings during construction. It was anticipated that the results would be similar to those discovered previously and that the schizophrenic participants with positive symptoms would have greater difficulty as the demands of self-monitoring increased. Specifically, they should have little difficulty with Condition C, greater difficulty with Condition A, and greater difficulty still with Condition B since they have no initial model to view.

Methods

Participants

The 48 participants recruited for the study were divided into three groups. The first group (Hallucinators) included 16 participants (11 males, 5 females) who had a DSM-IV-TR diagnosis of schizophrenia and a history of either hallucinations or prominent symptoms of alien control. The second group (Non-hallucinators) consisted of 15 participants (12 males, 3 females) with a DSM-IV-TR diagnoses of schizophrenia who never had a history of hallucinations or alien control symptoms. These patients were identified as potential participants through the psychiatrists and psychologist in the Schizophrenia Service Program at the Eric Martin Pavilion, a provincial psychiatric facility. Symptom profiles were then verified with use of the Positive and Negative Symptom Scale (PANSS; Kay, Fiszbein, & Opler, 1987), and a brief clinical interview conducted before testing. Analysis of the PANSS ratings scales revealed the expected significant differences between the groups on positive symptoms ($t = 3.537$, $p = .001$), such the hallucinator group had far more positive symptoms. There were no significant differences between the groups on the PANSS Negative Symptom scale ($t = -.550$, $p =$ n.s.), the PANSS General Symptom Scale ($t = .740$, $p =$ n.s.), or the PANSS Total Score (t = .920, $p =$ n.s.).

All Schizophrenic patients were taking antipsychotic medication at the time of testing. Twelve of the patients were recruited from the inpatient units (7 hallucinators, 5 non-hallucinators), and the remaining participants were recruited from outpatient services (9 hallucinators, 10 non-hallucinators). Two additional patients with schizophrenia were dropped from the study after recruitment because they were unsuitable for the research study. One participant was unable to read at a sufficient level to participate, and another was too cognitively disorganized to handle the demands of the experiment, so testing was discontinued.

As a control comparison group, 15 patients (7 males, 8 females) never diagnosed with schizophrenia or psychotic illness were recruited. These participants were either receiving treatment on an inpatient unit for affective disorders (without psychotic features), or participating in an outpatient life skills group.

The patients recruited are representative of the populations that were available for the study and were not specifically matched on a case-by-case basis. For this reason, there were some differences between the groups on demographic variables. Specifically, there were differences in gender between the groups with a greater male/female ratio in the schizophrenic groups than in the control group. There were also differences in the ages of the groups with the controls being the oldest ($M = 36.87$; $SD = 8.07$), followed by the hallucinating group ($M = 30.87$; $SD = 10.75$), and the non-hallucinators ($M = 27$; $SD = 6.30$). These differences were statistically significant $F(2, 43) = 4.982, p = .011$.

In addition to demographic data, all participants were given a brief screen of intelligence (WAIS-R, two subtest estimate of intelligence; Silverstein, 1982) a measure of divided attention (Brief Test of Attention; Schretlen, 1989), and a measure of selective attention (modified version of the Dichotic Listening for Words test described by Spreen & Strauss, 1998). There were no significant differences between the groups for intelligence, $F\,(2,43) = 2.785, p = .073$, or selective attention, $F\,(2,42) = 2.584, p = .087$. However, there were differences identified between the groups in divided attention, $F\,(2,43) = 3.978, p = .026$, such that the hallucinator group was significantly more impaired than the control group (*LSD*, $p = .023$). There differences between other groups were not significant. Given the voluminous literature on attention deficits in schizophrenia this finding was anticipated, and will be given consideration while reviewing the results of the experimental paradigms.

Also of note, all of the participants spoke English as their primary language and none had an accent that would have affected their performance on any of the language measures.

Materials and Procedure

Experiment 1 –Silent Reading

The first experiment was designed to measure the degree to which the participants could monitor their own inner speech while reading. The participants were given a brief story entitled "The Biography of Victoria" and asked to cancel every syllable that contained an [i] sound (See Appendix A for the actual story with target syllables highlighted). Directions read to participants stated, "Now I would like you to read this little story about the history of Victoria, *SILENTLY*. As you read, I would like you to put a line through any letter or group of letters that make a long 'e' sound like you hear in the word 'cheese'. Remember you are not supposed to mark all of the 'e's' on the page – only the ones that make an [i] sound. Also remember that not only the letter 'e' can make that sound. You will come across other letters such as the letter 'y' in 'Biography' which will also make a long 'e' sound (examiner crosses off the 'y' in biography on the participant's response form to demonstrate). Please be careful and try to get as many as you can." There were a total of 82 targets. There was no time limit on the task.

Experiment 2 – The Tongue Twister Test

The second experiment was designed to examine the error detection rates of the participants in two conditions: a normal auditory feedback condition and a white noise masked condition. In order to create a situation in which sufficient errors would be generated to study error detection, the participants were asked to recite a series 20 phonetically challenging statements (tongue twisters, see appendix B) five times each in both conditions. During the normal feedback condition, the participants were simply asked to say the tongue twisters (TT) as quickly as possible and then to immediately provide feedback as to whether they believed that they had read the statement correctly or whether they believed that they had made an error during their recitation. In order to prepare the participants for the protocol two different practice phases were presented before the experiment began.

During the first learning phase, the participants were given a set of headphones and asked to listen to a digital recording of the experimenter attempting to say a number of TTs. Half of the recorded statements were spoken fluently and involved no errors; and half of the stimuli included different examples of potential errors including slips of the tongue, spoonerisms, and stutters. The participants listened to the tape while following a transcript of the tongue twisters, and provided "yes" or "no" answers to indicate whether or not the speaker had said the statement correctly. Their responses were recorded by the examiner. Any participants who made errors on this portion of the experiment were asked to listen to selected tongue twisters again to ensure that they understood the directions and to teach them what should have been considered an error. Very few participants actually needed this further training, and all participants were able to correctly identify all of the errors on the tape before proceeding to the next stage.

The second training phase involved the participants practicing the experimental protocol on five practice TTs. For each TT, the participants were required to recite a series of TTs presented on a piece of paper as fast as possible, and then immediately indicate whether or not they believed that they produced the phrase correctly. For instance, a given trial should sound like "rubber baby buggy bumpers, pause, Yes". This response would indicate that the participant felt that they had correctly repeated the TT. Each TT was repeated five times in succession and correct/incorrect evaluations were provided following each trial. The participants typically kept track of how many times they had said the statements themselves, but reminders were provided by the experimenter, as needed, to either move on to the next TT or to repeat a TT if they had not completed a series of five. Any completed extra trails spontaneously performed by the participants were incorporated in the data. The participants performed the practice TTs and were provided with immediate feedback regarding their performance.

Initially, it was proposed that the reading pace of the participants be metered with the assistance of a visual metronome in an attempt to standardize reading speed. Pilot work using the metronome proved to be too distracting and disruptive for the participants, and did not allow sufficiently for individual differences in reading speed and verbal fluency. Since the use of the metronome was not feasible, the practice period was also utilized to attempt to regulate the rate of speech. Participants were encouraged to read the statements as quickly as possible, and prompted to read faster if they were be perceived to be reading too cautiously. Additional examples were provided as necessary.

Once the participants had completed the two training phases the experimental trials were initiated. As noted above, the experiment included conditions of normal auditory feedback, and a white noise condition. The normal feedback condition involved a protocol exactly as described above in the practice session. The participants read a series of TTs from a transcript five times each, and indicated following each trial whether or not they believed that they had said the TT correctly. A small desktop microphone was placed in front of the participants, and the entire experiment was recorded on digital audio using a standard PC with Sonic Foundry Inc. SoundForge XP for Windows (Version 4.5f) software.

In order the generate the white noise condition, a Kay™ Facilitator 3500 was set to generate white noise and fed through an amplifier to ensure that it would reach a sufficient volume. Headphones were attached to the amplifier and the volume was set to an established level that generated approximately 100db's of noise. This was the level of volume utilized by Postma and Noordanus (1996) and Lackner and Tuller (1979) in their previous work in this area. The volume was measured with a Radio Shack 33-2050 Sound Level Meter. All participants agreed that the white noise was of sufficient volume to preclude hearing their own speech. A few participants did indicate that they were able to hear their responses to a very mild degree (probably through bone conduction), but even this feedback was extremely muffled by the white noise. The participants were exposed to this level of white noise for approximately 10 minutes during the experiment.

In order to counterbalance the experiment for experience with the TTs the conditions were separated with an ABBA design. All participants began in the normal auditory feedback condition and completed the first set of 10 TTs. They then placed their headphones on, repeated the first 10 TTs in the white noise condition, and then immediately continued with the second 10 TT's in the white noise environment. The experiment was then completed by having the participants remove their headphones and repeat the second set of 10 TTs in the normal feedback condition.

Experiment 3- Alteration of Feedback

The third experiment in the study explored the participants' ability to cope with delayed auditory feedback. During this experiment the participants were asked to perform a series of tasks under three experimental conditions. The experimental conditions included: a normal feedback condition, a delayed auditory feedback condition, and a distracter condition. The tasks included: reading a brief story transcribed from the Gray Oral Reading Test- 3rd Edition (Weiderholt & Bryant, 1992), reciting months of the year, reciting days of the week, and counting forward by twos to 30. Digital tape recordings were made of the speech products for all the trials using the same equipment noted above. These tasks were chosen to replicate the procedure reported by Goldberg et. al. (1997).

During the normal feedback condition the participants were given a sheet a paper with the instructions to 1) Count to 30 by twos. 2) Recite the days of the week, 3) Recite the months of the year, and 4) Read this paragraph (after which the paragraph was transcribed).

Once the first task was completed, the participants were handed a set of headphones and asked to repeat the procedure a second time. Before the participants placed the headphones on their head, an audiotape of a book on tape was begun. The participants then put the headphones on, prepared for a few seconds to cope with the distraction, and the proceeded to read though the protocol a second time.

Immediately following the distracter task, the headphone input was switched from the audiotape to the Kay Facilitator ™ 3500, which was set for a Delayed Auditory

Feedback of 180ms. The delay of 180ms was selected because in the previous experiment of this type (Goldberg et. al., 1997) the raw data indicated of the delays that they used (90ms, 180ms, 270ms, 360ms), a delay setting of 180ms produced the largest amount of dysfluency across groups. For both the distracter and the DAF procedure, the input from the respective electronic devices were fed though an amplifier, which was set for a relatively loud listening volume (70db). This volume is the same as that stated in the previous study (Goldberg et. al, 1997).

Experiment 4 – Motor Self-Monitoring

In order to compare the experiments above to similar work previously done in this area with self-monitoring. A task of motor self-monitoring was attempted utilizing a computerized task developed by John Stirling based on the work described in two previous publications in this area (Stirling, Hellewell, & Quraishi, 1998; Stirling, Hellewell, & Ndlovu, 2001). The task involves three different conditions, which are thought to vary in the degree to which self-monitoring is involved. In condition A, participants were asked to examine a simple geometric drawing that is flashed on the screen for several seconds. Once they have examined the model drawing, they are asked to draw a picture of the model using a computer stylus and drawing pad. To reduce the amount of visual feedback that the patients receive, a hand screen was placed in front of them to block their vision of their hand as they drew. The participants were able to watch the computer as they attempted to make their drawing, which displayed a small cursor (crosshairs) to indicate where they were drawing on the screen. As they drew, the crosshairs moved to register their movement, but there was no evidence of a trace or drawing. Once the participants had completed their drawing, the computer presented them with six drawings. One of the six drawings was identical to their drawing and the other five were foils computer generated by rotating the participants' drawing 90, 180, or 270 degrees, or by making a mirror image representation of the drawing. Only one drawing was correct. The participants were then asked to identify their own drawing from the six possible choices. Condition A is thought to put a very high demand on self-monitoring because they participants are unable to see their hands, or their drawings as they draw, and must monitor their behavior internally.

Condition B was similar to condition A except that instead of copying a model drawing, the participants were asked to create their own unique drawing with a few simple lines. The participants were instructed to keep their drawings relatively simple, and were told not to make any figures that were identifiable, orientation specific icons such as letters or specific pictures (i.e. a stick figure, or a face). Once the participants had created a drawing, the paradigm was the same the first condition. They were requested to choose their own drawing from six possible drawings. This condition also requires a high demand on self-monitoring because the participants are still unable to see their hand, or their drawing. In theory, this condition should also require a greater degree of monitoring than the first condition because the participants are not drawing to a visible model, but rather drawing from their own creation which they have never actually seen.

Condition C required the least amount of monitoring and is designed as a control for the experiment. In this condition, the participants were requested to again make unique drawings using the stylus and pad, but they were able to see their hand as they drew, and they were able to see the actual drawings displayed on the monitor. Once they had completed their drawing, they simply had to identify the exact same drawing from the six possible foils. This condition presumably minimizes dependence on self-monitoring, as it only requires the participants to perceptually identify their own previously observed drawings.

Results

Experiment 1 – Self Monitoring of Inner Speech (Silent Reading)

The dependent measure for the silent reading test was the number of correctly identified targets from the story (Appendix A) that are pronounced with an [i] sound. In total, there were 82 potential syllables that could be marked in the story if the typed numbers (e.g., 1858) were included in the tally. Analysis of the scored data revealed that a large number of participants elected to cancel the entire number (i.e., ~~1858~~), failing to identify the fact that the numbers may have included more than one symbol that make the target sound (eighteen, and fifty). For this reason, numbers written in numeral form on the transcription were counted as one target regardless of the number of syllables that are pronounced with the target sound. This reduced the total number of targets to 79. Further, analysis of the data revealed two additional anomalies, which could have contributed to misleading results. The first anomaly occurred because a few participants failed to mark any syllables/symbols from the numeric stimuli like the examples noted above. The second occurred because two participants failed to realize that the test transcript had a second page of data. In order to account for these potential anomalies the dependent variable calculated for this test was the percent of targets identified based on the number of targets that were evaluated, as opposed to the raw score, which was initially proposed.

A-priori power analyses were performed to determine the strength of the statistic to find significant results based on the sample size that were utilized in the experiment. Since this was the first experiment to utilize this paradigm, several studies from the self-monitoring literature were evaluated to estimate the effect size of the self-monitoring deficit in the population of schizophrenics. While effect sizes were not specifically reported in the literature, examination of three different studies (Stirling, Hellewell, & Quraishi, 1998; Stirling, Hellewell, & Ndlovu, 2001; Mlakar, Jensterle, & Frith, 1994) revealed effect sizes (calculated based on means and standard deviations) that were extremely large (ranging from $f = .52$ through $f = .72$ from ANOVA). At the onset of the experiment it was anticipated that ANOVA for the three groups would be the most appropriate statistic for this experiment. Based on these findings, Cohen's large effect size convention of .40 was utilized for the power analysis (Cohen, 1988). While this is actually felt to be a conservative estimate of power, power analysis indicated that based on an effect size of .40 and a sample size of 45, the statistic would have sufficient power to detect the effect (Power = .83).

Preliminary screening of the grouped data was conducted to test for normality of the data and homogeneity of variance. This exploration of the data revealed the presence of a single outlier in the control group whose performance was significantly lower than the rest of that group (See Figure 1). The data for the control group were also found to demonstrate significant kurtosis as a result. Examination of the outlier revealed an individual who also happened to have the lowest intelligence score of the control group. It was decided that his data were relevant to the study as his score was likely a normal variant in the population given the typical correlation between reading and intelligence. As the data were found to deviate from the normal distribution and since there is no explicit reason to believe that these data would be normally distributed, it was decided that nonparametric statistics would be most appropriate to handle the data. Since the statistical analysis was changed following data collection, additional power analyses were conducted (after the experiment had been conducted) to ensure that the new statistics would have sufficient power.

In order to conduct power analysis for the Mann Whitney U test, it has been recommended that power be estimated based on the results of power analysis for the t-test statistic (Buchner, Erdfelder, & Faul, 1997). The studies reported above were reanalyzed in order to estimate effect size with particular attention to differences between subgroups where possible. Two of the studies (Stirling, Hellewell, & Quraishi, 1998; Stirling, Hellewell, & Ndlovu, 2001) reported only comparisons between controls and a heterogeneous group of schizophrenics. Calculation of effect sizes for t-tests based on the data provided in their studies indicated effects of self-monitoring between the groups consistently greater than $d = .85$. Specifically, estimates for two experiments reported by Stirling, Hellewell, & Quariashi (1998) revealed effect sizes (for their sample) of $d = .86$, and $d = .93$ with sample sizes of 35 schizophrenics and 24 control participants. In their follow-up study (Stirling, Hellewell & Ndlovu, 2001), their sample effect sizes were even larger on similar measures (sample effect sizes $d = 1.34$, and $d = 1.42$ were calculated based on sample sizes of 40 schizophrenics and 36 nonpatient controls).

One study (Mlakar, Jensterle, & Frith, 1994) offered sufficient data to examine effects between schizophrenics with Schneiderian symptoms (n =25), schizophrenics without those symptoms (n =14) and normal controls (n =10) across two tests of self-monitoring. Examination of their data revealed effect sizes between schizophrenics with Schneiderian symptoms and controls of $d = 1.69$ and $d = 1.96$ across the two experiments. Effect sizes for comparison between the schizophrenic group without symptoms and normal controls were also very large at d =1.06 and d = .85. Finally, comparison between the two schizophrenic groups revealed smaller effects of d= .45 and d= .86.

Based on review of this data a number of decisions were made regarding estimating effect size for the current study in power analysis. First, it was clear from the analyses of the data above that effect sizes (d) in the literature examining differences between controls and schizophrenics were consistently greater than .85 and frequently greater than 1. For this reason an estimated effect size of d = .85 was utilized for analysis comparing the combined group of schizophrenics to controls, and for analyses comparing the nonhallucinators to controls. For comparisons between patients with Schneiderian symptoms and controls, it is extremely likely that the effect size is much larger so for the purposes of these comparisons an estimated effect size of 1 was utilized. Finally, the effects between the two schizophrenic groups were found to be slightly smaller so the effect size of d = .60 was utilized.

The results of power analyses based on these estimates of the effect size were as follows: 1) Comparisons between the combined schizophrenic group (n =30) and the control group (n =15) with the Mann Whitney U Statistic have power of .88; 2) Comparisons between the hallucinator group (n =15) and the control group (n =15) have power of .86; 3) Comparisons between the nonhallucinator group (n=15) and the control group have power of .75; and finally, 4) power to compare the two groups of schizophrenics was calculated at .50.

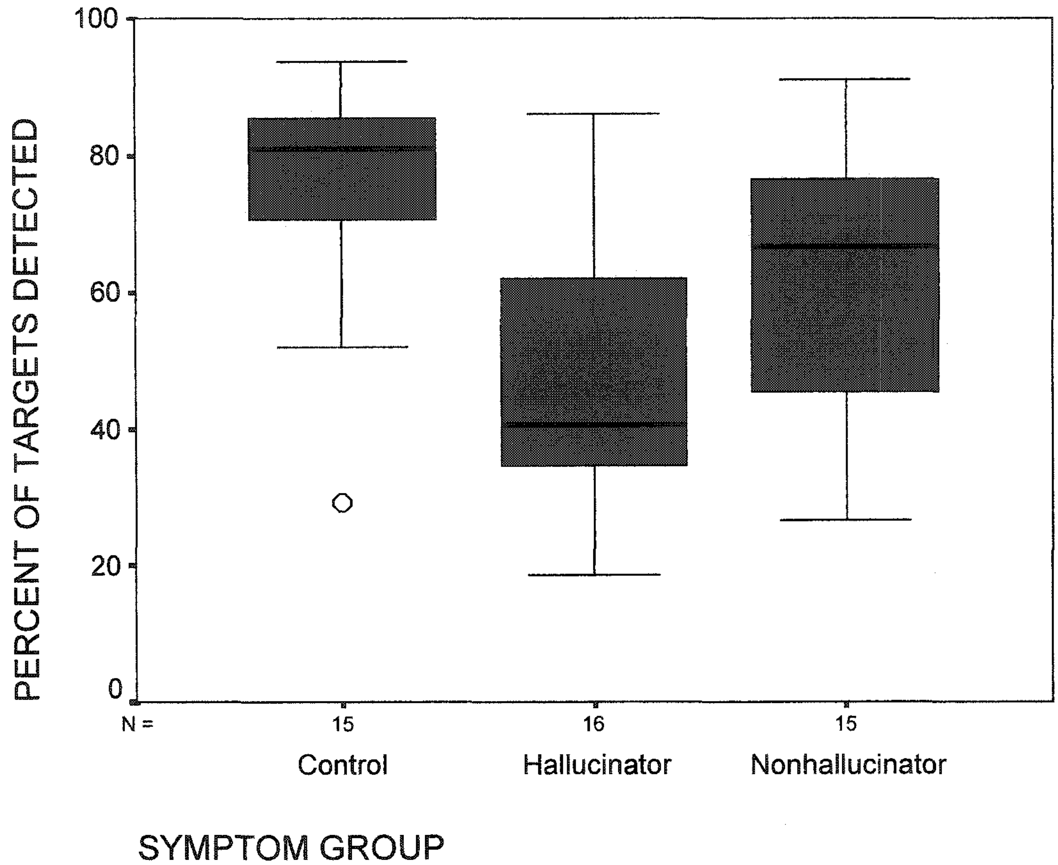
Of these analysis all comparisons were felt to have sufficient power to identify the anticipated effects with the exception of the comparison between the two schizophrenic groups which was lower than ideal. As the comparison between the two groups is a secondary goal of the project, the analyses were conducted despite the power problem and the results of those particular analyses were considered with caution.

Review of the descriptive data indicated the expected results such that the control group had the best performance (Median = 81.01; Interquartile range= 15.41) on the measure followed by the nonhallucinators (Median = 66.67; Interquartile range = 34.17) and hallucinators (Median = 40.66; Interquartile Range 29.96) respectively. When the schizophrenic groups were combined the median score was 53.16 with and interquartile range of 36.70.

Based on the original hypotheses, four a-priori planned comparison tests were conducted utilizing the Mann-Whitney U test. The results of all analyses were consistent with the initial predictions. Specifically, the results of the first test indicated a significant difference between the control group and the combined group of schizophrenics (one tailed $U\,(1,45) = 102.50$, $p < .001$, $d = 1.44$[1]). Further analysis examining the schizophrenic groups separately indicated that the performances of both the hallucinator group and the nonhallucinator group were significantly worse than the control group (control vs. hallucinator, one tailed $U\,(1,30) = 40.50$, $p < .001$, $d = 2.4$; control vs. nonhallucinator, one tailed $U\,(1,29) = 62$, $p = .018$, $d = .78$). Finally, the difference between the hallucinator and nonhallucinator groups was also significant $U\,(1,30) = 73$, $p = .033$, one-tailed, $d = 1.09$) with the hallucinator group performing significantly worse.

1 A nonparametric equivalent of Cohen's d was calculated by substituting median for mean, and IQR/1.35 for Standard Deviation. No other measure of effect size for nonparametric statistics were identified in the literature.

Figure 1. Distribution of Performance on the Silent Reading Test across Groups.



The graph above is a boxplot, which is interpreted as follows:

The whiskers represent the entire range of scores excluding outliers.

The area marked in red (the box) indicates the area within which 50% of the scores are located with the upper boundary representing the score at the 75%ile, and the lower boundary representing the 25th %ile.

The bold line within the box represents the median score of the distribution.

Circles beyond the whiskers are outliers of their respective distribution

(Outliers are defined as scores that are located at a distance 1.5 to 3 times the interquartile range of the distribution as measured from the end of the box.)

Stars beyond the areas demarcated by the whiskers are extreme scores.

(Extreme scores are score located at a point beyond 3 times the interquartile range as measured from the edge of the box.)

In order to examine the relationship between the participants' performances on the silent reading test and their performances on neuropsychological tests, Spearman nonparametric correlation analyses were completed. The Spearman rho statistic involves ranking each of the participants' performances on each measure from smallest to largest and calculating a Pearson correlation of the ranks (Seigel & Castellan, 1988). The results of these analyses indicated that performance on the biography test was highly correlated with all of the neuropsychological measures administered. Specifically significant positive correlations were found between the two-subtest measure of IQ ($\rho = .657$, $p < .000$), divided attention as measured with the BTA ($\rho = .659$, $p < .000$), and selective attention with the modified dichotic listening test ($\rho = .580$, $p < .000$). This indicates that many of the differences identified between the participants with this measure could be attributable to differences in general cognitive ability and attention.

Additional analyses were also conducted examining the same correlations without the controls to ensure that the correlations were not merely an artifact of the stronger performance of the control group on all tasks. The results of these correlations were still very significant (IQ, $\rho = .579$, $p < .001$; BTA, $\rho = .639$, $p < .000$; Dichotic, $\rho = .481$, $p < .007$).

Experiment 2- The Tongue Twister Test

The raw data collected in the tongue twister paradigm proved to be relatively complex. Specifically, there was a great deal of variability in response speed, speech fluency, and gross ability to handle the tongue twister stimuli. For instance, some individuals who were very strong readers and fluent speakers identified minor pauses as errors, while other individuals failed to identify rather gross errors such as misreading a word. For this reason, a scoring system was established to determine whether a given trial was scored as an error or not (See Appendix C). The goal of the scoring system was to provide a consistent rating that would best capture whether or not participants made self-monitoring errors of their own *intended* speech. To meet this goal, several rules were developed to account for frequently occurring situations in which the participants either consistently misread the stimuli, or consistently mispronounced words in the tongue twisters. Other special qualifiers were added to handle instances of pauses. All of the data were scored on two separate occasions by a single rater (JS) to verify scoring and establish intra-rater reliability, and a subset of the data was scored by a research assistant trained on the scoring system to establish inter-rater reliability. The inter-rater reliability was found to be acceptable (95.24 % agreement; Cohen's Kappa = .89), while the intra-rater reliability was found to be higher (99% agreement). During the development of the scoring protocol and initial data analysis, it was determined that two of the stimuli were too difficult to analyze and were removed from the data. The data eliminated included all responses to tongue twister #5: "The sixth sheik's sixth sheep's sick" and tongue twister #14 "Many an anemone sees an enemy anemone". Tongue twister #5 was eliminated at the time of scoring because it was simply too difficult to differentiate the syllables on the digital recordings sufficiently to generate a reliable score. Tongue twister #6 was eliminated because the majority of the participants were so inconsistent with the word "anemone" that it also became impossible to reliably score.

Once the data had been scored, comparisons were made between the participants' recorded self-ratings and the scored ratings to assess self-monitoring ability. Possible combinations of scores included: correct detection of an error, correct detection that no error was committed, failure to detect an error, and false positive report that an error was made when none could be audibly detected. The dependent measure collected for analysis included a combined "failure to monitor" score which included both errors of omission (missed errors) and false positives (indication of error when none was audibly detectable). As noted above, participants occasionally did not complete all five trials of some tongue twisters and generated more than five on others because communication between the examiner and participants was limited during the white noise phase. Since all of the data were included in scoring, the number of trials varied from participant to participant. In order to utilize all of the data, the self-monitoring score was calculated as a percentage of self-monitoring errors. One participant (a nonhallucinator) was lost to this portion of the study because he was extremely uncomfortable in the white noise condition and did not wish to continue.

Preliminary analysis of the data revealed the presence of several outliers and departures from normality. Specifically, in the normal feedback condition two outliers in the nonhallucinator group were identified who had a much higher error percentage than the remainder of their group in that condition. In addition, in the white noise condition there were two hallucinators and one nonhallucinator who were each significant outliers compared to the rest of their respective groups with performances that were significantly worse (higher error percentages). The distributions of the participant's scores for the normal feedback and white noise conditions are depicted in Figures 2 and 3 below. Median and Interquartile range are also reported in Tables 1 and 2.

In order to handle these departures from normality, nonparametric statistics were utilized to examine the data.

As with the previous study, power analysis for this experiment was initially conducted for the use of parametric statistics. Based on the work in self-monitoring it was anticipated that the schizophrenics would perform significantly worse than controls in the white noise condition. While the studies of Leudar and colleagues (Leuder, Thomas & Johnston, 1992; Leudar, Thomas & Johnston, 1994) are most similar in topic, their results and experimental procedure were so completely different that they were inappropriate for comparison of effect size. The most appropriate studies for the anticipated effect are actually the same series of studies that were described in the silent reading experiment above. Power for ANOVA with a sample size of 45 was calculated to be .83. Since the actual experiment was conducted with nonparametric statistics, power was reanalyzed for each set of statistics. This information will be discussed separately for each set of analyses.

Figure 2. Distribution of Self-Monitoring Errors (Percentage) in the Normal Feedback Condition.

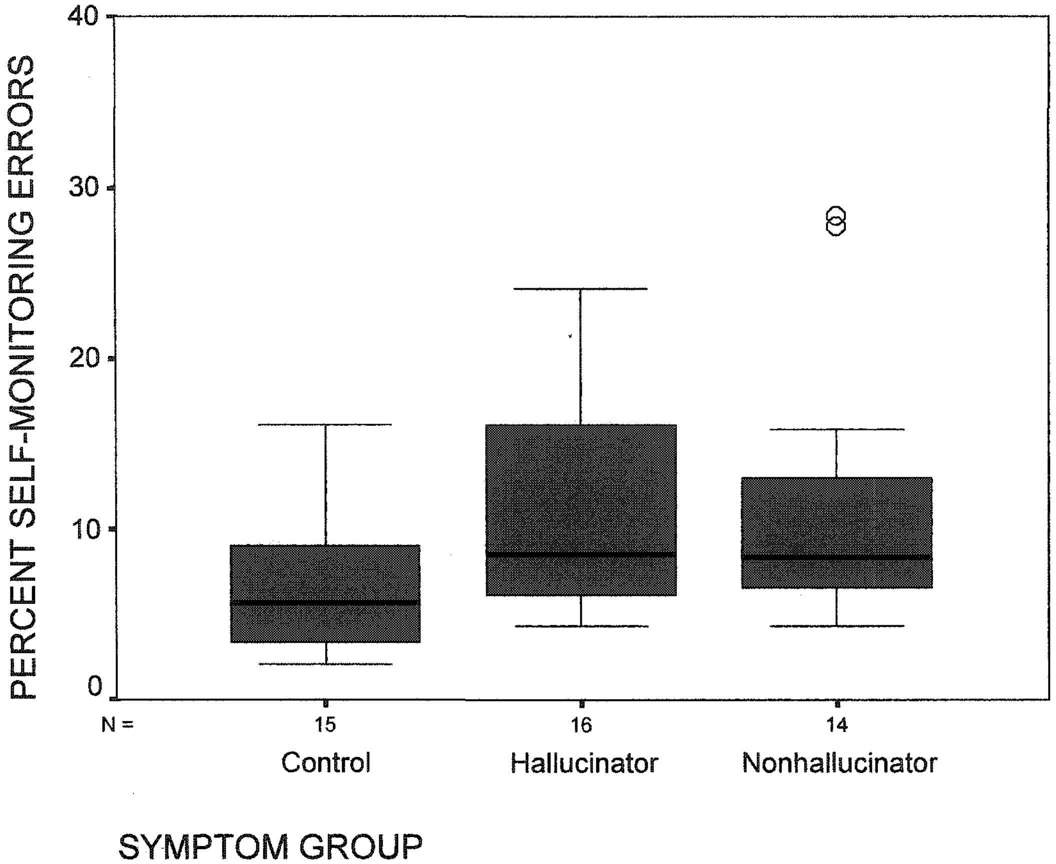


Table 1

Median and Interquartile Ranges for Self-Monitoring in the Normal Feedback Condition.

Group	Median	Interquartile Range
Control	5.68	5.70
Hallucinator	8.52	10.30
Nonhallucinator	8.37	7.20
Schizophrenics (Combined)	8.50	9.35

Figure 3. Distribution of Self-Monitoring Errors (Percentage) in the White Noise Condition

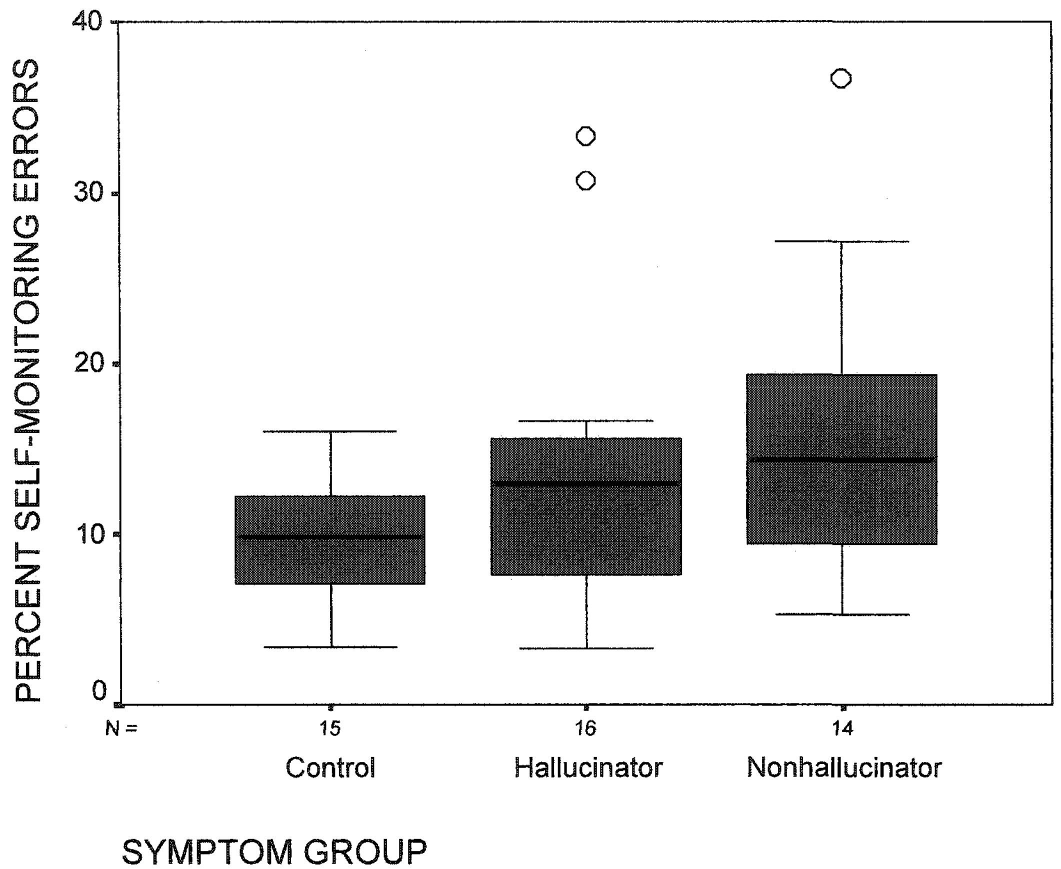


Table 2

Median and Interquartile Ranges for Self-Monitoring in the White Noise Condition.

Group	Median	Interquartile Range
Control	9.88	5.83
Hallucinator	12.97	9.07
Nonhallucinator	14.34	10.06
Schizophrenics (Combined)	13.31	7.36

The data were first examined with the Wilcoxon signed ranks test to determine if there was a significant effect of condition (normal vs. white noise) in each of the groups. The finding of decreased error detection in a white noise environment has previous been found to have a very large effect size (Lackner & Tuller, 1979; estimate $d > 1$), and the Wilcoxon signed ranks statistic was believed to have sufficient power to detect this extremely large effect. When the data of all participants combined ($N = 45$) were examined, the effect was significant (Wilcoxon $Z = -3.562$, $p < .001$, one tailed) indicating that the sample as a whole was affected by the white noise and demonstrated more difficulty with self-monitoring in that condition. Similarly, when the groups were examined separately, both the control group and the nonhallucinator group were found to perform significantly worse at self-monitoring during the white noise condition as opposed to the normal feedback condition (Control group, one tailed Wilcoxon $Z = -1.977$, $p = .024$; Nonhallucinator group, one tailed Wilcoxon $Z = -2.542$, $p = .005$). In contrast, and contrary to expectation, the performance of the hallucinator group was not found to differ significantly in the two different conditions, although the results were approaching significance (one tailed Wilcoxon $Z = -1.590$, $p = .056$).

In order to compare the performances of the groups relative to each other, planned comparisons were completed utilizing the Mann-Whitney U test across both conditions. The results of these comparisons are presented in Table 3.

Table 3

Results of Planned Comparisons for the Tongue Twister Test

Comparison (N)	Condition	Mann-Whitney U	One-tailed significance	Effect size (*d*)[1]
Control (15) vs.	Normal	*U*= 125	.009*	.51
Schizophrenics (30)	White Noise	*U*= 140	.021*	.70
Control (15) vs.	Normal	*U*= 68.5	.021*	.48
Hallucinators (16)	White Noise	*U*= 86	.090 ns	.56
Control (15) vs.	Normal	*U*= 57	.018 *	.57
Nonhallucinators (14)	White Noise	*U*= 54	.013 *	.76
Hallucinators (16) vs.	Normal	*U*= 110	.951 ns**	.02
Nonhallucinators (14)	White Noise	*U*= 93.5	.448 ns**	.19

*significant at the.05 level

** two-tailed test of significance

[1] A nonparametric equivalent of Cohen's d was calculated by substituting median for mean, and IQR/1.35 for Standard Deviation.

When the analyses of the groups were considered separately, several results were consistent with the original hypotheses, but many were contrary to expectation. First, it was hypothesized that the schizophrenic group would have more difficulty with self-monitoring than the control group in the white noise condition. While this hypothesis was confirmed, the schizophrenics (combined group) were also found to be significantly worse at self-monitoring in the normal feedback condition. This latter finding is contrary to the initial hypothesis, as it was proposed that the schizophrenics would not demonstrate the deficits when provided with external feedback. Hence, the data indicate that the combined schizophrenic group had a more global deficit of self-monitoring evident across all conditions as opposed to a condition specific deficit.

When the group data were analyzed separately, the results differed slightly across comparisons with regard to significance. First, when the hallucinator group was compared to the control group, a significant difference was found in the normal feedback condition. As noted above, this finding was contrary to expectation because it was not anticipated that the schizophrenics would be impaired when they had access to their own auditory feedback. It is however, consistent with the performance on the combined schizophrenic group described above. Second, the difference between the hallucinator group and the control group in the white noise condition failed to reach significance. As noted in the data above, while the median performance of the hallucinator group did worsen in the white noise condition, the differences in performance were not of sufficient nature to demonstrate a significant effect of condition. As a result, when the performance of the control group diminished in the white noise condition, the gap between the groups closed in the white noise condition and was no longer significant.

Group comparison between the nonhallucinators and the control group was similar to the initial comparison with the combined groups. Specifically, analysis indicated that the nonhallucinators were impaired relative to the control group during both the normal feedback and the white noise conditions. Finally, comparison between the nonhallucinator group and the hallucinator group revealed no significant differences between the groups in either the normal feedback or the white noise condition.

Before advancing, one final comment should be made with regard to the use of directional hypothesis testing. As noted in the table above, the α level selected for the study was based on a one-tailed directional hypothesis across measures. This criterion was selected because prior to data analysis it was specifically believed that all of the schizophrenic groups (including subgroups) would perform significantly worse than the control group across the self-monitoring tasks. Furthermore, it was initially argued that the hallucinators would perform worse than the nonhallucinator group so this was also planned as a one-tailed analysis. When the raw data and preliminary analyses were reviewed comparing the two schizophrenics groups it became obvious that the use of one-tailed analysis for these groups was unwarranted since the nonhallucinator group actually performed worse. For this reason, two-tailed analysis was used for comparison between the two schizophrenic groups.

Finally, it is conceded that the initial hypotheses only called for differences on the white noise task and not on the normal feedback task. Hence, when examining the data it is perhaps more appropriate to examine the normal feedback data with two-tailed analysis. These statistics were not initially presented because it was felt that it would be inappropriate to treat this subset of data with a lesser criterion when no significant differences were expected. For the sake of completeness, it is noted that the use of nondirectional two-tailed analysis would not alter interpretation of significance on any of the comparisons above.

The initial analyses reported in Table 3 above were conducted utilizing a combined error score, which consisted of both omission errors (failure to identify an error) and false positive errors (the participant stating that an error had occurred when none was heard by the rater). The false positive condition was a relatively unexpected phenomenon, as it was not initially anticipated that the participants would produce a tongue twister fluently, but state that they had made an error. The situation also poses a unique problem because it is possible that the participants actually perceived an error that was simply imperceptible to the raters from the digital audiotape. For this reason, the analyses were conducted a second time excluding all of the data in which the participants made errors of commission. The results of these analyses are displayed in Table 4 below.

Table 4

Results of Planned Comparisons for the Tongue Twister Test (Omission Errors Only).

Comparison (N)	Condition	Mann-Whitney U	One-tailed significance	Effect size (*d*)[1]
Control (15) vs.	Normal	U= 148.5	.03*	.40
Schizophrenics (30)	White Noise	U= 146.5	.03*	.74
Control (15) vs.	Normal	U= 84	.08 ns	.34
Hallucinators (16)	White Noise	U= 84	.08 ns	.34
Control (15) vs.	Normal	U= 64.5	.038*	.42
Nonhallucinators (14)	White Noise	U= 62.5	.032*	.87
Hallucinators (16) vs.	Normal	U= 108	.886 ns**	.01
Nonhallucinators (14)	White Noise	U= 94	.474 ns**	.40

*significant at the .05 level

** two-tailed test of significance

[1] A nonparametric equivalent of Cohen's *d* was calculated by substituting median for mean, and IQR/1.35 for Standard Deviation.

These results were very similar to those reported above across three of the four comparisons. Specifically, the results for the Control vs. Schizophrenic comparison remained significant in both the normal feedback and white noise conditions; the results for the Control vs. Nonhallucinator group comparison remained significant across conditions; and the Hallucinator vs. Nonhallucinator comparison remained nonsignificant across conditions. However, in the Control vs. Hallucinator comparison the results were not found to be significant for either the white noise or the normal feedback condition, contrary to expectation.

Unlike the analyses including the commission data (Table 3), the analyses reported in Table 4 are sensitive to alterations in directional hypothesis testing. While it is clear that no significant differences can be identified between the hallucinator group and either the nonhallucinator group or the control group, the significant findings in the control vs. schizophrenic comparisons, and the control vs. nonhallucinator comparisons would fail to reach significance if viewed in non-directional comparison. As noted above, it is felt that the use of one-directional test is without question warranted in the white noise condition. Furthermore, analysis of the results across conditions indicates that the performances follow a parallel trend such that the groups' performances both change in a manner that is very similar across the two conditions, and the results are extremely consistent across conditions. For this reason, it seems improper to judge the analyses of the different condition based on different criteria, and the results were interpreted in the manner noted above.

In order to examine the relationship between the participants' performances on the tongue twister tests and their performances on neuropsychological tests, Spearman nonparametric correlation analyses were completed. With regard to general intellectual ability, as assessed with the two-subtest WAIS-R, a strong negative correlation was found between IQ and the percentage of self-monitoring errors on the tongue twister test in the normal feedback condition ($\rho = -.525, p <.000$); however IQ was not significantly correlated with the percentage of errors in the white noise condition ($\rho = -.237, p = .116$). This same pattern was identified when the control group was removed from the analysis ($\rho = -.588, p <.001$ in the normal feedback; $\rho = -.298.$, $p <.109$, in white noise).

When compared to the measures of attention, performance on the tongue twister test in the normal feedback condition was correlated with both divided attention and selective attention ($\rho = -.530$, $p <.000$; $\rho = -.446$, $p = .001$). These correlations also remained significant when the control group was removed from the analyses (BTA, $\rho = -.470$, $p <.009$; Dichotic, $\rho = -.445$, $p = .013$). Performance on the tongue twister test in the white noise condition was found to be related to divided attention ($\rho = -.333$; $p = .025$), but not significantly related to selective attention ($\rho = -.275$, $p = .07$). When the control group was removed from these analyses the opposite pattern emerged such that self-monitoring in white noise was significantly correlated with selective attention but not divided attention (Dichotic, $\rho = -.387, p < .038$; *BTA*, $\rho = -.282, p = .131$).

Experiment 3 – Alteration of Feedback

The data collected for the delayed auditory feedback measure included digital audiotapes of the participants' reading/reciting the protocol as described above. The dependent variable consisted of the change in time that was required for the participants to successfully recite the protocol in the experimental conditions relative to the baseline condition. In order to prepare the data for analysis, a number of edits were made to the raw data tapes. First, any extraneous conversation or preparatory noises that occurred prior to the initial stimulus related utterance, and after the last stimulus related utterance, were deleted from the sound files. Then, any significant delays that occurred between stimuli recitation, or as a result of reading of the directions (participant states "Recite the days of the week") were deleted from the sound files. During review of the data, it was discovered that a few participants made errors that rendered their data inconsistent across the three trials. As this occurred relatively infrequently, and the primary objective of the task was to measure the time differences across conditions for the same material, the data sets were edited to make them consistent. For instance, one individual counted from 1-20 by twos instead of 1-30 by twos during one of their three trials. In order to make all three trials consistent, the recitation of numbers 20-30 for the first two trials were eliminated to make all of the trials consistent.

One participant (a hallucinator) was lost to this portion of the experiment because he was unable to cope with the delayed auditory feedback condition and did not want to participate in that trial.

In order to replicate the Goldberg et. al. (1997) study, the dependent measure of percent change from the baseline condition was utilized in this experiment. Using this methodology, two measures were calculated for each participant. The first measure was the percent change in time (seconds) from the normal feedback condition to the delayed auditory feedback condition, and the second was the percent change in time (seconds) from the normal feedback condition to the distraction condition.

Preliminary analysis of the data revealed the presence of three outliers. In each case the outlier scores were participants from the hallucinator group (1 hallucinator in the DAF condition, 2 hallucinators in the distraction condition) whose scores were affected by the conditions to a greater degree than other group members. The distributions of the data for both the delayed auditory feedback condition and the distraction condition are presented in Figures 4 and 5 below.

As in the prior studies a-priori power analyses were initially conducted for parametric statistics. In order to estimate effect size for the power analysis, the results of the Goldberg et al. (1997) study were examined. Effect size for ANOVA based on this study was extremely large (approximately $f = .87$) even in comparison to the Cohen's convention for a large effect size in ANOVA, which is $f = .40$. Power analysis revealed that use of ANOVA to find this effect had a power of .99.

Due to the use of nonparametric statistics in the final analysis, power analyses were conducted a second time. In order to estimate effect size for the power analysis, the data from the Goldberg et al. (1997) study were examined again. The resulting effect sizes of dysfluency in DAF were found to be greater than 1 for comparisons of the hallucinator group and nonhallucinator group with the control group as well as with each other. Since this study was an exact replication of the previous study, the effect size of 1 was utilized for power analysis. While this effect size is larger than Cohen's convention, the effect sizes reported in the previous study were estimated to be considerably higher (exact numbers were estimated from charts because descriptives were not provided).

With regard to the distracter condition there was no available data to obtain estimates of effect size as this is the first time that an experiment of this nature has been conducted. Given the hypothesis expressed in this document calls for results similar to those in the DAF situation, Cohen's large effect size convention of .80 was utilized for power analysis.

Figure 4. Percent Change in Time between the Baseline and Delayed Auditory Feedback Conditions.

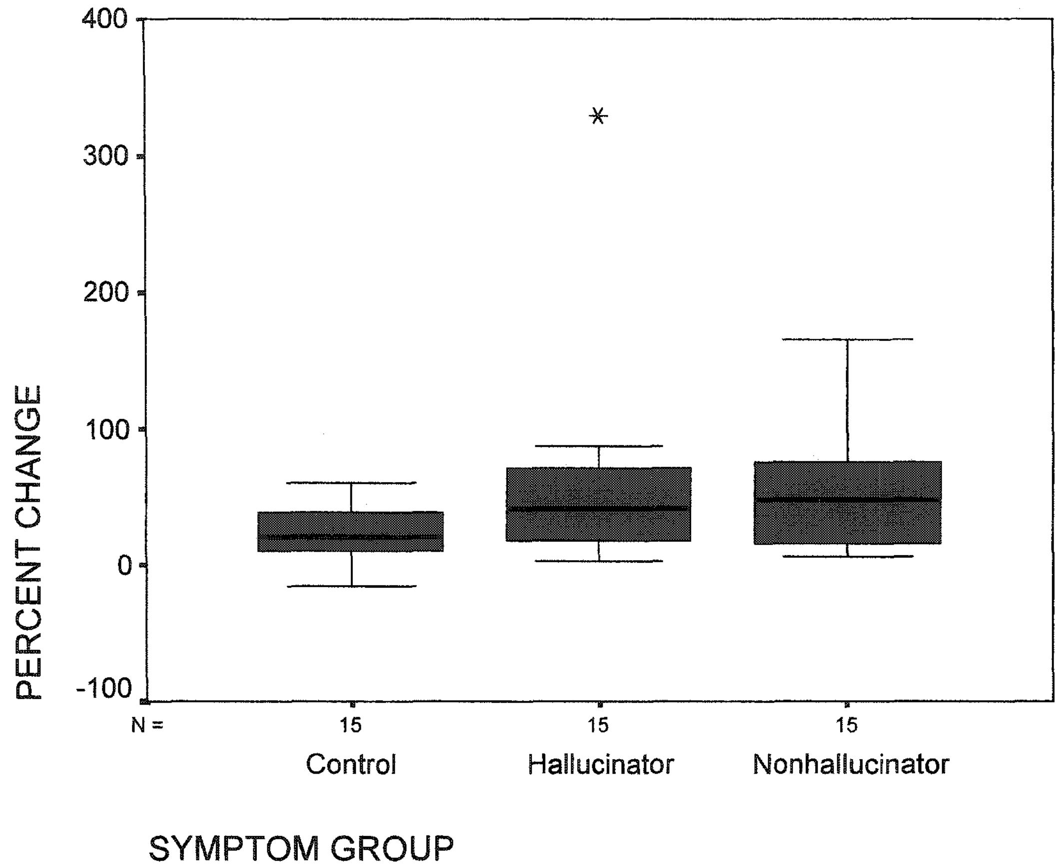
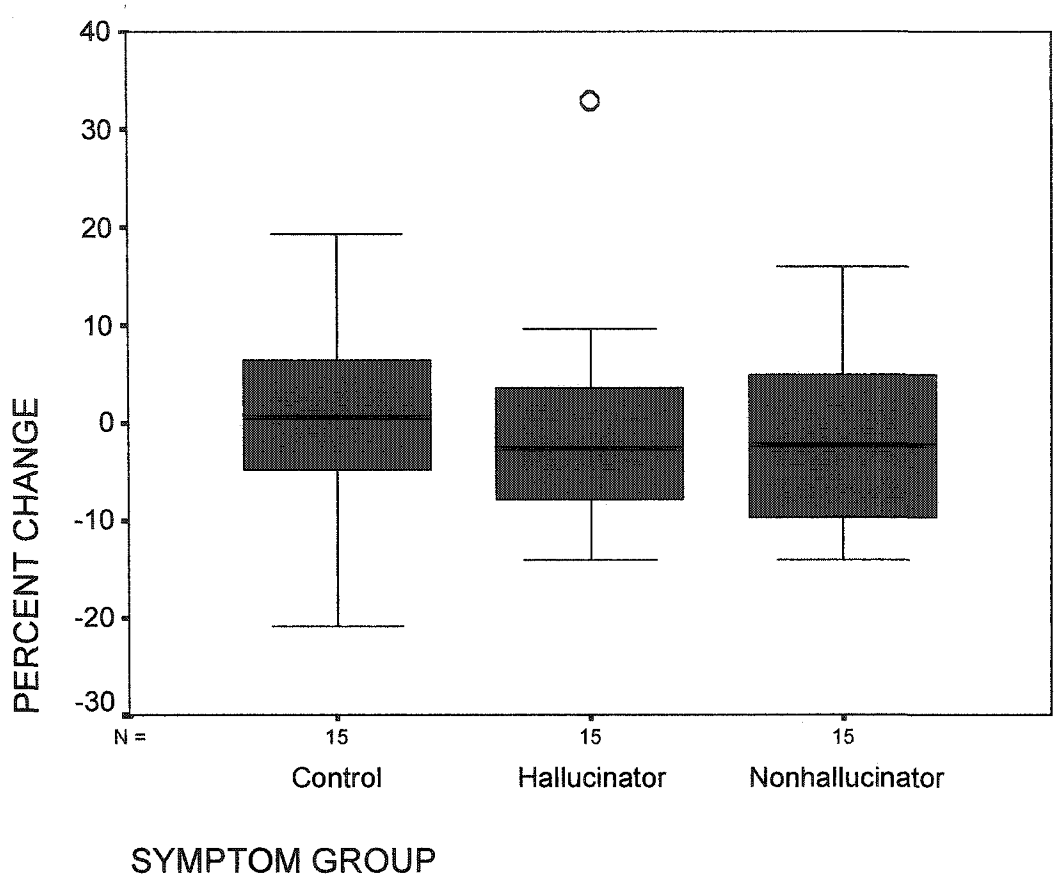


Table 5

Median and Interquartile Ranges of Percent Change in the DAF Condition

Group	Median	Interquartile Range
Control	20.98	37.54
Hallucinator	41.67	54.50
Nonhallucinator	47.61	72.62
Schizophrenics (Combined)	44.74	55.78

Figure 5. Percent Change in Time between the Baseline and Distraction Conditions



*Two outlier points overlap in this figure.

Table 6

Median and Interquartile Ranges of Percent Change in the Distraction Condition

Group	Median	Interquartile Range
Control	.65	13.75
Hallucinator	-2.65	13.16
Nonhallucinator	-2.28	16.87
Schizophrenics (Combined)	-2.47	14.19

Figure 6. Time in Seconds Across Feedback Conditions.

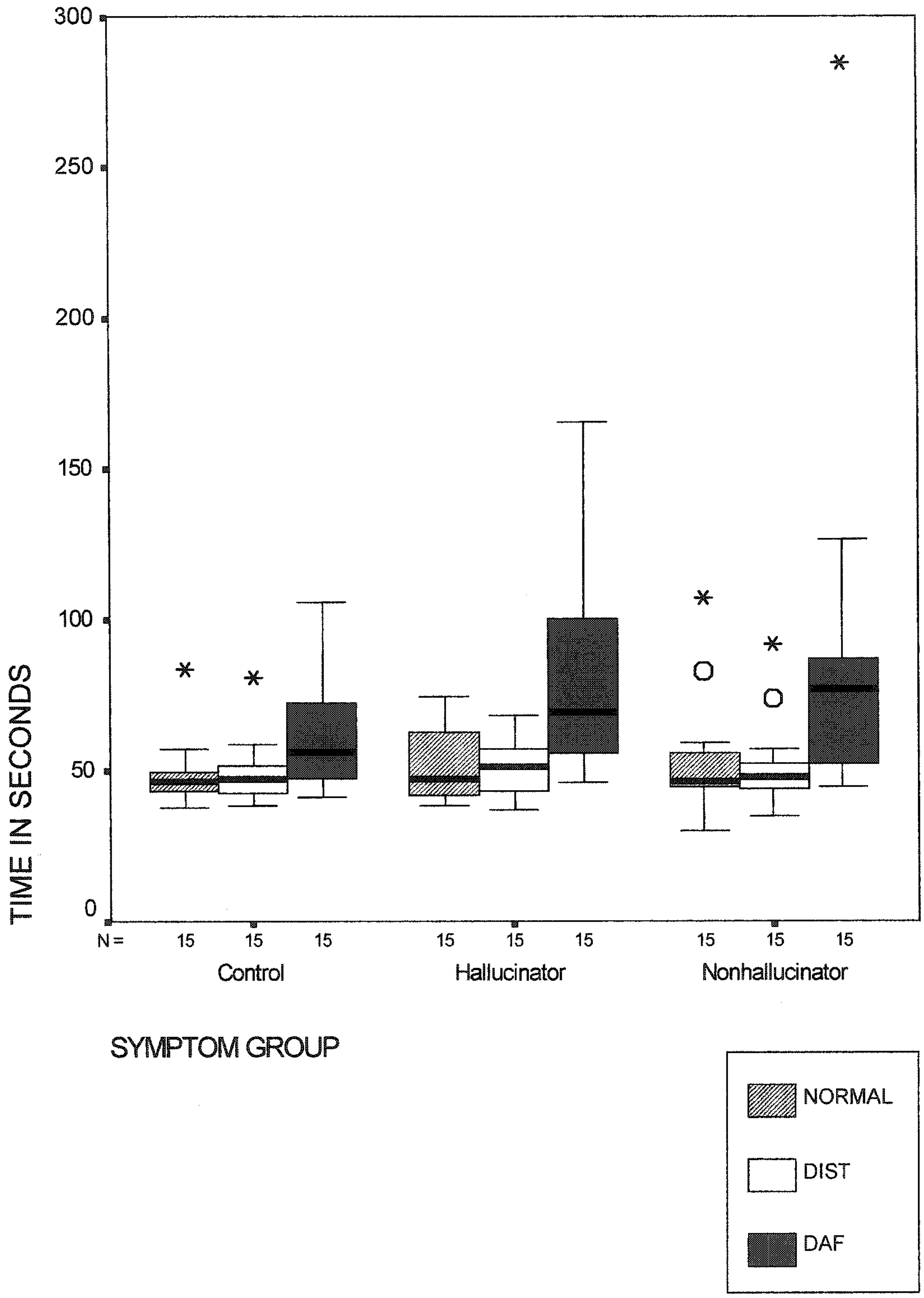


Table 7

Median and Interquartile Ranges Time in Seconds Across Feedback Conditions

Condition	Group	Median	Interquartile Range
Normal Feedback	Control	46.37	6.14
	Hallucinator	47.08	23.19
	Nonhallucinator	46.18	12.96
Distraction	Control	46.77	9.38
	Hallucinator	51.32	15.93
	Nonhallucinator	47.94	10.62
DAF	Control	56.31	30.66
	Hallucinator	69.68	49.17
	Nonhallucinator	76.70	37.79

In order to analyze this data nonparametric analyses were again chosen due to the deviations from normality. As in the tongue twister experiment, the altered feedback data was analyzed with multiple a-priori planned comparisons utilizing the Mann-Whitney U Statistic. Graphical depiction of the raw data is presented in Figure 6 and the results of these analyses are displayed in Table 8 below.

Table 8

Results of Planned Comparisons for the Altered Feedback Conditions

Comparison (N)	Condition	Mann-Whitney U	One-tailed significance	Effect size (*d*)[1]
Control (15) vs.	DAF	*U*= 146	.028*	.68
Schizophrenics (30)	Distraction	*U*= 189	.193 ns	.23
Control (15) vs.	DAF	*U*= 75	.063 ns	.61
Hallucinators (15)	Distraction	*U*= 96	.256 ns	.20
Control (15) vs.	DAF	*U*= 71	.044*	.65
Nonhallucinators (15)	Distraction	*U*= 93	.218 ns	.20
Hallucinators (15) vs.	DAF	*U*= 108	.870 ns**	.13
Nonhallucinators (15)	Distraction	*U*= 111	.967 ns**	.03

*significant at the.05 level

** two-tailed test of significance

[1] A nonparametric equivalent of Cohen's *d* was calculated by substituting median for mean, and IQR/1.35 for Standard Deviation.

As seen in the table above, the analyses revealed several significant findings that were consistent with the previous work by Goldberg et. al. (1997). Specifically, the analyses of the combined schizophrenic group and the nonhallucinator group in isolation were found to differ significantly from the control group. In contrast, the hallucinator group performed in manner contrary to expectation as their performance was not significantly different from the nonhallucinator group or the control group. The final analysis between the two schizophrenic groups was analyzed with a two-tailed test because it was clear from analysis of the descriptive data, that the nonhallucinator group was not performing better than the hallucinator group as predicted. The differences between these groups were not significant. The fact that there were no differences between these groups is consistent with recent data put forth by Johns et. al. (2001) who reported that the self-monitoring deficits were not always confined to hallucinators as previously believed.

Review of the analyses for the distracter condition revealed that there were no differences between groups in any of the analyses which is again contrary the anticipated results. Examination of the raw data also revealed that most of the participants demonstrated very little change across the conditions and in many instances actually performed the task faster in the distraction condition than in the baseline condition.

While these analyses provided interesting insights into the effect of DAF on the respective groups of participants, they do not offer insight into the question as to whether the effect of dysfluency in DAF is related to self-monitoring ability. In order to examine this relationship Spearman nonparametric correlation analyses were run comparing the change in time on DAF to the self-monitoring measures from the tongue twister experiment and the percentage of errors from the silent reading test. Significant correlations were found for self-monitoring errors in the normal feedback condition and DAF % change ($\rho = .508$, two tailed $p < .000$); self-monitoring errors in the white noise condition and DAF % change ($\rho = .365$, two tailed $p = .015$), and negatively correlated with percentage of targets identified from the biography test ($\rho = -.357$, two tailed $p = .016$).

Finally, in order to examine the relationship between fluency in DAF and neuropsychological functioning, nonparametric correlations were conducted comparing the participants' performances across these measures. The results of these analyses indicated significant correlations between measures of fluency in DAF and both divided attention ($\rho = -.439$, $p < .000$) and selective attention ($\rho = -.416$, $p = .005$); however, the correlation between fluency and IQ was not significant ($\rho = .253$, $p = .093$). The same pattern emerged when the analyses were examined without the data from the control group, such that IQ was not significantly correlated with fluency, but both measures of attention were significantly correlated (IQ, $\rho = -.257$, $p = .171$; BTA, $\rho = -.532$, $p = .002$; Dichotic, $\rho = -.480$, $p = .008$).

Experiment 4- Motor Self- Monitoring

Unfortunately, during the administration of the computerized task a number of technical difficulties occurred that resulted in some loss of data. First, data was completely lost for several participants because on several occasions the computer program froze on the very last trial of the test and failed to record any of the data. This was an unforeseeable event as the program operated normally throughout multiple piloting trials and during the majority of the experimental trials. Second, while some of the files remained intact, a similar computer malfunction caused the program to randomly skip through several individual trials, which limited the number of trials (of the 15 trials per condition) that were actually administered. Third, the interface between the computerized tablet and the drawing program occasionally failed, which resulted in the presentation of drawings on the computer screen that were incomplete or altered in some way from movements that were actually drawn on the computer pad. Considering that the participants were unable to see what they drew due to the nature of the task, and the product occasionally failed to look like what they had actually drawn, several trials were contaminated and unusable. This last problem makes interpretation of the data more complicated because some of the "would be valid" trials were actually contaminated. It was impossible to track which of these trials were contaminated at the time of testing because of the trial skipping problem noted above. Since the data in this experiment were so questionable, they will not be reported in this document.

Discussion

Experiment 1- Silent Reading.

Based on the self-monitoring hypothesis, two predictions were made regarding the silent reading test. First, it was hypothesized that the schizophrenics would have more difficulty with the task than the control group due their proposed self-monitoring deficit. Second, it was predicted that the participants with a history of hallucinations should be more impaired than the nonhallucinator group as they have been thought to be more impaired with regard to self-monitoring. The results of the experiment were very consistent with the predicted results on both accounts. First, as predicted, both of the schizophrenic groups performed significantly worse than the control group indicating that the schizophrenics as a group had difficulty with self-monitoring of internal speech. Second, the results indicated that the hallucinator group had the poorest performance of the three groups and that their performance was significantly different from both the control group and the nonhallucinator group. These data are consistent with those from studies such as Leudar & colleagues (1992,1994) that identified deficits of speech monitoring in patients with positive symptoms, and are more generally consistent with the notion of a self-monitoring deficit in schizophrenia as proposed by Frith (1992). With regard to possible limitations of this study, many authors have suggested that deficits on tasks of this nature could result from deficits other than that of self-monitoring, such as attention. As noted previously, the participants were given a few measures of neuropsychological functioning including a very brief measure of intelligence and two measures of attention. While no significant differences were identified between the groups on a selective attention task, the hallucinator group had more difficulty on a measure of divided attention than the control group. Further, nonparametric correlations comparing the results of the silent reading test with intelligence and attention revealed very strong correlations which suggests that differences in overall cognition or attention could have contributed to performance on this measure.

Another possibility that cannot be specifically ruled out is the notion that some difference in reading level accounted for the difference in monitoring of silent speech. The measures of intelligence administered included expressive vocabulary and visual-motor construction but did not specifically assess reading level. While all of the participants were screened for basic reading ability during an interview, and were required to read several stimuli across the experiments administered in the battery, no formal evaluation was conducted and it remains possible that some attribute of the reading process could account for these differences.

Beyond simple reading ability, this task as developed also involves a potentially more complex cognitive ability of grapheme to phoneme translation, and it remains plausible that differences exist in this ability among the groups that could also account for these results. Review of the literature for base rates on grapheme to phoneme translation ability for schizophrenics or normal participants was unfruitful. However, there is evidence that overall reading and spelling ability are typically well preserved in schizophrenics (Dalby & Williams, 1986; Kremen et. al., 1996), so there is no evidence to suggest group differences on this ability.

One additional characteristic of this test in comparison to other measures administered during the experiment was the level of independent effort that was required for the participant. While most of the measures involved significant interaction and engagement with an examiner who was prompting and eliciting responses from the participants, the silent reading experiment required them to perform the task independently following a brief explanation from the examiner. Hence, in addition to self-monitoring ability the measure may have required an added level of sustained effort that may have differed across groups and explained the results.

Experiment 2 – The Tongue Twister Test

The results of the tongue twister test successfully replicated some findings previously established in the literature, but also produced results that were contrary to expectation based on the original hypothesis. First, an initial series of preliminary analyses were designed to examine the effect of the white noise on the sample of participants. The results were generally consistent with those initially demonstrated by Lackner and Tuller (1979). Specifically, when the data from the combined group of participants were analyzed, the results indicated that the participants were significantly less effective at self-monitoring speech errors in the white noise condition than in the normal feedback condition. As in the original study (Lackner & Tuller, 1979), these data provide evidence that there are at least two types of self-monitoring of produced speech. One system involves self-monitoring of an internal speech product/plan, and a second system involves self-monitoring of an overt speech product through analysis of acoustic feedback. The existence of the internal monitoring system is verified by the fact that all participants could successfully detect many of their errors in the absence of external auditory feedback. Furthermore, the fact that the participants had significantly more difficulty with error detection in the absence of auditory feedback substantiates the existence of the second system, which monitors the external acoustic product. As noted above, it must be conceded that the internal monitoring system, as established by this experiment, potentially includes both the internal monitoring of the speech plan, and motor monitoring of proprioceptive feedback of the articulatory musculature. Future analyses of these processes may prove that they are also dissociable, but that research was beyond the scope of the current study.

Interestingly, when the same analyses were examined for each of the groups separately, not all of the results were significant. While the comparison between the control group and the nonhallucinator group revealed significant differences across both conditions (normal feedback and white noise), the comparison between the control group and the hallucinator group did not meet the criterion of significance at the .05 level. This result is particularly surprising because it was anticipated at the outset of the experiment that the hallucinator group would be the group most dramatically affected by the change in condition. Since the data was approaching significance and generally consistent with the data from the other groups, it will be assumed that the effect is also present in the hallucinators, but masked by the variance in the group. Alternative explanations that the participants in the hallucinator group are not affected by white noise, or that they do not benefit from the addition of external auditory feedback are not logical or supported by the data.

The second finding of the experiment was a significant effect of group such that the schizophrenic group (combined) detected significantly fewer of their errors than the control group across both conditions. This finding also remained significant when the data were analyzed without the presence of commission errors (under one-tailed analysis). This result is consistent with the notion that schizophrenics have deficits of speech monitoring. In addition, one of the unique contributions of the tongue twister study in comparison to the previous work concerns the type of speech monitoring involved. In this experiment, participants were given very specific stimulus content (the tongue twisters) that was to be spoken as written. This type of stimulus is very different from that used in previous studies (Leudar, Thomas & Johnston, 1992; Leudar, Thomas,

& Johnston, 1994), which included self-generated free speech descriptions. With respect to Levelt's model, the current study should bypass the very early stages of speech development involving 'the conceptualizer', because the material does not have to be specifically conceptualized and planned. Instead, it merely has to be read. The works of Leudar et. al. (1992,1994) clearly incorporated an additional component of task complexity that involves the generation of content appropriate speech, and the evaluation of the appropriateness of the generated content. The stimuli in the present experiment allowed for careful examination of the ability of participants to monitor the structural component of the internal speech plan with minimal reference to content. Hence, the current study has established the presence of a self-monitoring deficit of speech that exists in the absence of more abstract conceptual speech generation processes.

While the study was successful at identifying speech-monitoring deficits in schizophrenics, the pattern of performance was surprising and inconsistent with the initial hypotheses of the experiment.

Based on the previous literature and Frith's model of self-monitoring, it was hypothesized that the schizophrenics would be impaired relative to controls in the white noise condition, but perform normally when provided with access to external auditory feedback. Contrary to this expectation, the schizophrenics were found to be impaired relative to controls in the baseline condition as well as the white noise condition. This suggests that the schizophrenics may have a more encompassing deficit of speech monitoring than previously believed.

Careful review of the Frith theory, in light of the current findings, suggests that examination of speech-monitoring as conducted here and in previous work, may not actually be an effective mechanism to elucidate differences between self-monitoring of internally guided action, and stimulus driven response. It was hypothesized by Leudar and his colleagues (1992), and further argued in this study, that examining the differences between self-monitoring of inner speech and monitoring of an acoustic speech product would actually make this discrimination. Perhaps, speech-monitoring in general, regardless of the feedback received, should be considered to fall into the rubric of internally guided action. While speech-monitoring in a normal auditory feedback condition clearly allows for increased analysis of an external sensory process, it can not be stated with certainty that it is stimulus driven behavior as outlined by Frith. The difference lies in the fact that speech-monitoring with sensory feedback still requires the cognitive ability to compare the external speech product with the internal speech plan. When evaluating the motor self-monitoring tasks, Kopp and Rist (1994) posited that almost all of the tasks required the extra cognitive ability of memory to keep in mind the current response set. When they conducted an experiment that required true stimulus driven responses the deficits in self-monitoring did not emerge. In other motor-tasks of self-monitoring that have proven significant differences in schizophrenics, participants were required to compare self-created drawings that they had never actually seen to an anticipated result. When they performed a similar task that involved recognition memory, they were unaffected. The current study as well as the work of Leudar required individuals to compare a speech product with a self-generated speech plan. In either case, the participants were never actually given a true stimulus driven test that did not require at least some component of self-monitoring. This may explain the more global nature of the deficit.

While this explanation may explain why schizophrenics would be impaired on both conditions of the current task, what remains enigmatic is the fact that the schizophrenic participants in the Leudar et. al. (1992) study made the same percentage of error corrections as the control participants. Based on the results obtained here, it should be anticipated that in the process of free speech, the schizophrenic participants would make a greater number of speech errors than controls due to deficits of self-monitoring, but that they would correct a smaller percentage of those errors than controls due to their further deficits in error correction (even with external auditory feedback). It is not clear why this pattern did not emerge in their data; however, as noted above, the current experiment differs from the previous experiment with respect to the types and complexity of self-monitoring that are required. In the current experiment, the participants were asked to identify speech errors that typically involved very subtle deviations from the script or intended speech product. In contrast, in the context of the free speech, the types of errors that were made, and in turn corrected, perhaps created greater discordance from the intended speech product since they involved more conceptual material. For instance, while a participant may fail to realize that they have misspoken or stuttered while saying "Tim, the thin twin tinsmith", they may be more apt to realize that they have made the conceptual error "yellow" instead of "red" or "right" vs. "left" while providing a description of objects in front of them. This type of distinction is also referenced by Levelt in his speech production model, as he calls for two separate levels of monitoring, one which compares aspects of the overt speech product with the message that is intended, and a second which checks the speech product according to criteria and standards of speech production (e.g., speech errors, syntactic flaws, loudness, and prosodic aspects of speech). This may be a fruitful area of inquiry for future work.

Following the analysis of the combined group of schizophrenics, separate analyses were conducted comparing the three groups of participants to each other in each condition. Based on the previous literature a number of hypotheses were developed. First, it was anticipated that none of the groups would differ in the normal feedback condition. Second, it was proposed that in the white noise condition, the hallucinator group would perform significantly worse than both the control group and the nonhallucinator group. Finally, based on the theory that self-monitoring is specifically linked to hallucinations, it was anticipated that the nonhallucinator group would not be significantly different from the controls.

The results of the experiments were inconsistent with these hypotheses on several accounts. First, analyses of data regarding the normal feedback condition revealed that both schizophrenic groups were significantly different than the control group on measures of self-monitoring (with the exception of analysis between the hallucinators and controls when commission data was excluded). Second, in the white noise condition, a significant difference was found between the control group and the nonhallucinator group. And finally in the white noise condition the hallucinator group was not found to differ significantly from either the control group or the nonhallucinator group.

The fact that the schizophrenic groups were significantly different from the control group in the normal feedback condition was unexpected. However, as noted in the discussion above, this finding suggests that the schizophrenics have a more global impairment of self-monitoring than previously believed.

With regard to the white noise data, it was anticipated that there would be a significant difference between the hallucinator group and the control group, but this was not found. Despite this failure to achieve statistical significance consistently across measures with the Mann Whitney U test, a reasonable effect size was identified between the hallucinator group and the control group and there was large amount of variability across participants. Hence, while the hallucinator group was not found to be significantly different than the control group on this measure, their performance may still be considered abnormal, and variable across group members.

The fact that the nonhallucinator group was significantly different from the control group across all analyses can be explained by a global deficit in self-monitoring in schizophrenia as detailed above. In fact, this data is consistent with recent work (Johns et. al., 2001) that indicated deficits in self-monitoring were not isolated to patients with positive symptoms as was previously believed. This is also consistent with the finding that there were no differences between the two schizophrenic groups in any of the analyses, again suggesting that the two groups are similar in their performance on self-monitoring tasks. One concession does need to be addressed with regard to the specific symptoms of the participants in this study. While the nonhallucinator group clearly did not have a history of hallucinations or alien control symptoms, they were not entirely free of positive symptomotology, as many of them had some history of delusions in the past. Hence, while it appears that hallucinations are not specifically associated with the self-monitoring deficit, the possibility that some other positive symptom is related to self-monitoring cannot be ruled out.

In total, these results indicate that while schizophrenics may have a deficits of speech-monitoring, the deficit is not selective to those patients with hallucinations as it is also found in nonhallucinators. The finding that speech monitoring is not exclusively linked to hallucinations has further reaching ramifications with regard to the models of Frith and Feinberg. This concept will be revisited and addressed in detail in the general discussion below.

Finally, note should be made with regard to the correlations identified between the measures of neuropsychological functioning and the results of the tongue twister tests. When the percentage of self-monitoring errors in the normal feedback condition was compared to IQ and both measures of attention, the results were very significant. This suggests that those with greater cognitive skills of attention and intelligence were more perceptive of their own speech errors on this test. While this correlation is not terribly surprising, it suggests that the findings of this test could simply be attributable to differences in intelligence and are not specific to self-monitoring. Interestingly, the strength of the correlations all dropped considerably when the measures were compared to the percentage of errors in the white noise condition. Specifically, the correlations between both intelligence and selective attention and the percentage of self-monitoring errors failed to reach significance, and the correlation between self-monitoring and divided attention dropped less dramatically from -.530 to -.446. The same pattern was identified when the data from the schizophrenic group were examined in isolation, except for the facts that the divided attention test failed to reach significance, and the selective attention test remained significant, but was less significant than in the normal feedback condition. This may suggest that the white noise condition had the effect of reducing the efficiency of those participants with stronger intellectual skills and attentional ability.

Experiment 3 – Alteration of Feedback

Previous work on the effect of delayed auditory feedback with patient groups similar to those examined in this study revealed significant differences between groups in dysfluency as measured by percent increase in time when reading in a normal feedback condition and a delayed auditory feedback condition (Goldberg et. al, 1997). The first goal of this experiment was to replicate the findings of that study. While some of the results of the experiment replicated their findings, the results were not consistent across all groups, so each group will be considered separately.

When the data of the combined group of schizophrenics were examined, the results were exactly as anticipated with schizophrenics being significantly more dysfluent than the control group in the delayed auditory feedback condition. While Goldberg and his colleagues have argued that this finding is inconsistent with Frith's self-monitoring theory, it seems plausible that this may not be a valid argument. As described above, their argument stems from the notion that the self-monitoring deficit in schizophrenia is synonymous with a disconnection syndrome such that the patients do not have any access to an internal speech planning system and hence always experience speech as if they were in a delayed auditory feedback environment. Based on this logic the authors argued that the schizophrenics should not be affected by exposure to DAF and should be able to speak fluently in that environment. Alternatively, if the schizophrenics are less efficient at self-monitoring and more reliant on external feedback than it seems more likely that they would in fact be even more affected by DAF. To this point, it is impossible to use the data to distinguish between the hypothesis presented by Goldberg et. al. (1997), and the hypothesis proposed here because both theories rely on the same findings. However, in the Goldberg et. al. (1997) study, no data were actually collected on self-monitoring ability, and the hypothesis that dysfluency in DAF should be inconsistent with deficits of internal self-monitoring was made entirely on theoretical grounds.

Additional data in this study that provide support for relationship between self-monitoring deficits and the effect of increased dysfluency in DAF were identified with correlational analysis. When nonparametric correlations were conducted, it was discovered that there is a strong positive correlation between speech-monitoring and the level of dysfluency in DAF. This analysis suggests that contrary to the Goldberg et. al. (1997) position that patients with self-monitoring deficits should be unaffected by DAF, there is actually an increased likelihood that patients with self-monitoring deficits will experience dysfluency in the DAF environment. This is more consistent with the notion that self-monitoring deficits increase the likelihood of dysfluency, rather than the alternative hypothesis that schizophrenics should be unaffected by the DAF environment.

When the groups of participants were divided and comparisons were examined separately, a surprising pattern of results emerged that were consistent with those in the tongue twister experiment. First, the group of nonhallucinators was found to differ significantly from the control group with regard to percent change in time. As pointed out in the discussion above, it is not terribly surprising that the nonhallucinator group performed differently from the control group. There is growing evidence that the self-monitoring deficits are not exclusive to those schizophrenic participants who suffer from hallucinations. Furthermore, these participants were not entirely without positive symptoms of some nature, at least by history. The second finding that there were no significant differences between the two schizophrenic groups was contrary to prediction, but not surprising. Differences in self-monitoring between hallucinators and nonhallucinators, and even those differences between participants with positive and negative symptoms have been described more in terms of trends where those with prominent positive symptoms typically have scores that are slightly higher than those without, but the differences are not always statistically significant.

The comparison between the hallucinator group and the control group was almost identical to the comparison between the nonhallucinator group and the control group with regard to effect size, and was found to approach statistical significance. While it was clear that there were no differences between the schizophrenic groups, it was somewhat surprising that the hallucinators were not more clearly distinct from the control group as it was anticipated that they would be the most significantly affected by the DAF.

Based on these results, it seems that the findings of increased dysfluency in DAF conditions are not specific to those patients with hallucinations as they were also found in the nonhallucinators. However, this finding still does not rule out the possibility dysfluency in DAF is related to positive symptomotology because as noted above, this particular nonhallucinator group did have some positive symptoms.

Beyond the delayed auditory feedback condition, an additional distraction condition was utilized in this experiment to further explore whether schizophrenics are affected by any alteration to feedback, and not specifically to DAF. The results of the distraction condition proved to be extremely revealing but did not support the theory as hypothesized. It was clear from the results of the distraction condition, that all participants in the study, and most notably the schizophrenics, were minimally affected by the distraction and performed extremely well. Specifically, the results of the experiment indicated that many of the participants demonstrated little or no difference in performance from baseline, and others actually completed the protocol with faster response rates. The faster rates during the distraction condition may have resulted from two possible sources. In general, most participants were slightly more familiar with the stimuli, and may have been demonstrating normal practice effects. Another possible reason for this finding was the fact that some participants found the distraction to be irritating, and seemed to forced themselves through the material at a faster rate in an attempt to complete the task as quickly as possible. Regardless of the reason, there was no indication that any of the schizophrenics were slower in their productions because of the alteration in feedback.

As the results indicate that schizophrenics are affected by delayed auditory feedback, but not affected by a distraction that reduced their overall feedback; the theory as proposed requires further revision. One possible reason that the schizophrenics did not perform differently during the distraction task, is that the task did not truly impact their speech and language systems because the content of the distraction stimuli was completely different from the information the participants were reading. The traditional impact of the delayed auditory feedback arises because there is a latency discordance between the act of speaking and the auditory feedback of the *same material*. During the distraction condition, there was no discordance between the speech product and the auditory feedback because the information was completely different. It is logical that when the information that is being heard is clearly different from that being spoken, there is no natural tendency to compare the expected speech product to the acoustic information. Retrospectively, the distraction condition selected did not actually "alter" the speech product at all, so it is not particularly surprising that the condition did not produce the predicted effect. A potentially interesting study that could closely examine this type of effect is a situation in which the participant's actual speech products are altered in another manner.

Recent work in the area of altered feedback (published after the onset of this project) has reported that patients with schizophrenia have greater difficulty distinguishing their own spoken words from words spoken by others (Johns et. al 2001). While this is interesting in respect to the current theory, no other studies have been done which have specifically examined distortion on fluency.

Other information that may be gleaned from this distinction between the delayed auditory feedback and the distraction condition is the fact that effect of the delay is not simply an effect of distraction. If the DAF effect were solely attributable to distraction then the distraction condition should have had more of an effect on the participants. Rather it seems that the effect of the DAF has more to do with the delay in time of the same speech product.

In the Goldberg et al. study (1997), the authors specifically analyzed the participants' performance on a measure of digit span to ensure that differences between the groups could not be attributed to differences in attention. While this was clearly a noble effort on their behalf, the digit span subtest is only one measure of a cognitive ability that may have multiple dimensions. In the current experiment, correlations were analyzed examining the relationships between divided attention, selective attention, and general intellectual ability with the DAF effect. The results of these correlations revealed only a weak, nonsignificant relationship to IQ; however, strong relationships did exist between DAF and both measures of attention. While this correlation does not prove causation of the effect, there appears to be a stronger relationship between the attention and self-monitoring than previously indicated.

General Discussion and Conclusions

The theories of Frith and Feinberg have suggested that a possible mechanism for many of the positive symptoms of schizophrenia, including auditory hallucinations, involves a deficit of corollary discharge associated with internal thoughts, or to use Frith's language, a lack of self-monitoring of the willed intention for self-generated action. To examine these conceptual theories a new literature has emerged that has revealed deficits of self-monitoring in patients with schizophrenia. In short, the bulk of these reports have found that patients with schizophrenia do tend to perform more poorly on measures of self-monitoring. Furthermore, two other trends in the literature have suggested that 1) patients with positive symptoms tend to perform worse on self-monitoring tasks than those patients without positive symptoms, and 2) performance on self-monitoring tasks decreases as the demands on self-monitoring increase and less external feedback is provided. The majority of these tasks have been conducted utilizing measures that included a significant motor component, and frequently involved additional cognitive abilities such as working memory. While these measures have been very effective, it remains plausible that many of the deficits identified in previous research could be attributable to differences in motor control and speed of processing which have also been frequently identified in schizophrenia. In order to expand this line of research, the goal of this dissertation project was to further explore the nature of self-monitoring deficits in schizophrenia by examining several tasks of speech-monitoring ability.

Previous work in the self-monitoring of language has been pioneered by Levelt, whose model of language generation and monitoring was utilized to conceptualize and develop the studies conducted in this experiment. Levelt's theory calls for three different types of self-monitoring. The first type of self-monitoring occurs within a module identified as the conceptualizer whose function is to formulate a preverbal plan based on conceptual ideas. This type of self-monitoring consists of deciding what ideas should be expressed, and eliminating generated thoughts that would not be appropriate at the current time. Previous work has suggested that patients with schizophrenia have deficits of this nature, but examination of monitoring of this type was considered beyond the scope of the current project.

The second type of speech monitoring in Levelt's conceptualization involves monitoring of internal speech, or an internal phonetic plan; and the third type of monitoring involves examination of the overt speech product that occurs by means of auditory analysis. According to the self-monitoring theory of positive symptoms proposed by Frith, Feinberg, and their colleagues, it was hypothesized that patients with schizophrenia should have difficulty when attempting to monitor speech utilizing the internal monitoring system, but should perform normally when provided with external auditory feedback.

Two of the experiments conducted in this study were specifically designed to tap this internal monitoring system. The first of these experiments involved monitoring of internal speech for particular sounds during silent reading, and the second involved monitoring of speech errors during the recitation of tongue twisters in a white noise environment. When the performances of the schizophrenic participants of this study were examined as a combined group and compared to the control participants, consistent deficits were identified on both tasks of internal self-monitoring. This suggests that consistent with the previous work in the area, schizophrenics as a group are impaired on tasks that place an emphasis on internal self-monitoring. However, on an additional condition in which the schizophrenics had access to the acoustic feedback, the results were extremely similar and the groups were still found to differ significantly. This suggests that the self-monitoring deficit may be more global in nature, and not limited to internal self-monitoring as initially proposed. As noted previously this finding may be a result of speech monitoring tasks that were utilized and may not truly distinguish between monitoring of internal mental processes, and stimulus driven behavior.

In the final experiment, it was found that schizophrenics were significantly more dysfluent in a delayed auditory feedback environment. This finding successfully replicates previous work with delayed auditory feedback and schizophrenics, and is consistent with the notion of a speech-monitoring deficit. While this finding is consistent, the rationale for explaining the finding needs to be readdressed. At the onset of the experiment, it was argued that if schizophrenics had a deficit of *internal* self-monitoring, they would become more reliant on external feedback and hence become more dysfluent in the DAF condition. While a strong positive correlation was found between speech monitoring deficits and dysfluency adding further support for this notion, the results of the tongue twister experiment indicated that speech monitoring deficits were not specific to internal speech monitoring but instead were more global in nature. While it may be that deficits of internal monitoring cause the schizophrenics to become more reliant on the external feedback, it is also possible that self-monitoring deficits in general are responsible for the finding. If schizophrenics have deficits of self-monitoring of their speech in general, they may simply struggle to a greater extent with the speech process in such a manner that they are more vulnerable to alterations in feedback. Regardless of the mechanism involved, it was clear from the additional data of the distracter condition, that the phenomenon is not simply related to the distracting nature of additional auditory feedback, but was more related to the actual alteration of the speech output.

While all of these findings arise from analyses of the combined group of schizophrenics, careful analyses of the differences between subgroups of schizophrenics with different symptom profiles revealed several findings that challenge the self-monitoring theory as it pertains to hallucinations at a fundamental level.

The first interesting finding involves the performance of the nonhallucinator group across the different experiments. Review of the performances of the nonhallucinator group across experiments indicates that they were: 1) impaired relative to controls on both measures of internal speech-monitoring, 2) impaired relative to controls on the speech-monitoring with external auditory feedback, 3) significantly more dysfluent than the controls in the delayed auditory feedback condition, and 4) not significantly different than the hallucinator group on any of the measures given. Based on these findings it can be inferred that the self-monitoring deficit in schizophrenia is not specific to patients with hallucinations, but may apply more generally to patients with schizophrenia. It is not clear from this experiment whether the deficits are limited to positive symptoms because some participants in the nonhallucinator group did have positive symptoms, although they were fewer in number. Specifically, review of the PANSS ratings indicated significant differences between the groups with regard to positive symptomotology, but the nonhallucinator group did contain participants with a history of delusional belief. These data are still consistent with those of Johns et al. (2001) who found that the differences between symptom-based groups are not as large as they were previously believed.

The analyses of the performances of the hallucinator group were surprising. Review of the results revealed that the hallucinator group was significantly different from both groups on the silent reading task, and significantly different from the control group in the normal feedback condition of the tongue twister task; but not significantly different from controls on either the white noise condition of the tongue twister task or the delayed auditory feedback test. These results are surprising for several reasons. First, it was anticipated that the hallucinators, as the subgroup of schizophrenics with the most significant positive symptoms, would not only demonstrate deficits of self-monitoring, but also demonstrate the most significant impairments of all groups examined. Second, since hallucinators by definition have symptoms that involve deficits related to the auditory processing or language systems, it was anticipated that of all possible tests of self-monitoring, they would be most impaired on tasks that involve the self-monitoring of speech. Finally, the results are surprising because they were not consistent across measures.

With regard to the last point, it is clear that there are differences between the silent reading task and the other measures administered during the task. First, the silent reading task requires reading, and as indicated previously, the groups were not specifically assessed for differences in reading ability. Aside from this distinction, the silent reading test also requires the greatest level of independent focus and application of effort, and this may have resulted in a difference on the participants' performances. On all of the speech tasks, and even the control measures of cognitive function, the testing environment required interactive participation with an examiner who was constantly refocusing the participants' attention and eliciting a response. In contrast, the silent reading task was a slightly more independent task for the participants in which they were required to work through the material and inform the examiner when they were done. This difference in modulating attention and effort may also offer a potential explanation for the differences across measures.

As for the lack of significance between the control group and the hallucinator in the white noise condition and the DAF protocol, close examination of the data reveals a large amount of variability in the hallucinator group, and effect sizes that were consistently fairly large. Based on these findings it seems that while the group as a whole was not statistically different from the control group, many of the participants demonstrated very large effects while others did not. This again points to the possibility that the symptom of hallucination is not specifically linked to self-monitoring ability.

Since this is the first study in the area of self-monitoring to report that a group of participants with greater positive symptomotology did not display more significant impairments in self-monitoring, the question remains as to why this group was not as impaired on the tasks used in this study. Analysis of the individual participants of the hallucinator group reveals a few possibilities. First, the group was heterogeneous with respect to age, and there were several members of the group who would be considered "first-break" patients. One possibility is that these individuals are less likely to demonstrate the deficits when compared to more chronic schizophrenics. It is important to note, however, that the inclusion of individuals who would be considered "first-break" was not isolated to the hallucinator group, but present in both groups. Another aspect that was not controlled in this experiment was the "state" of the participants' symptoms. While the participants recruited here had a history of hallucinations, and had expressed symptoms in the two weeks prior to testing, many of them were not reporting the symptoms at the time of testing.

Finally, with regard to the impact of this study to the self-monitoring hypotheses, the findings that the combined groups of schizophrenics and specifically the nonhallucinator group were impaired across all measures of self-monitoring, and not just conditions that focus on internal self-monitoring, open the possibility that the deficits identified on these types of tasks may simply be related to the myriad cognitive deficits that are found in schizophrenia, and not related to a lack of willed intention or deficits of corollary discharge. Additional evidence for this argument can be identified by the fact that many of the "self-monitoring deficits" that were identified in this study were significantly correlated to IQ, and all of the "self-monitoring deficits" with few exceptions were strongly correlated with measures of attention.

While this concept appears inconsistent/incongruous with the theories of Frith and Feinberg, it does not necessarily disprove their theories. It may be the case that the mechanisms of self-monitoring described by the theorists are actually responsible for the presentation of positive symptoms, but that those mechanisms of self-monitoring are different from the type of self-monitoring that is elicited through the error correction and speech monitoring studies that have been developed in the literature (and utilized in this study). If hallucinations occur via a neurophysiological process similar to corollary discharge, it is quite possible that the deficit occurs at such an automatic level of subconscious processing that we will not be able to detect or isolate it with the measures that have been proposed thus far.

While the initial goal of this project was to provide further clarity to a complicated set of research findings, the results were not as consistent with the pre-existing models as anticipated. While it was hypothesized that a specific group of participants (hallucinators) would display a particular type pattern of deficits, it was instead found that schizophrenics as a group are impaired on measures of speech-monitoring and that these deficits are clearly not specific to patients with hallucinations. Furthermore, hallucinators were not even consistently impaired in measures of speech monitoring, suggesting that impaired mechanisms of self-monitoring cannot fully explain the symptom of hallucination. Nonetheless, this exploration of speech-monitoring has yielded useful data with respect to conceptualizations about the fundamental impairments in schizophrenia, and in the spirit of the cognitive psychology model, there are still many possible directions for fruitful and exciting research in this area.

References

Angel, R.W. (1976). Efference copy in the control of movement. *Neurology, 26,* 1164-1168.

Angel, R.W., & Higgins, J.R. (1969). Correction of false moves in pursuit tracking. *Journal of Experimental Psyhology*, *82*, 185-187.

Bentall, R.P. (1990). The illusion of reality: a review and integration of psychological research on hallucinations. *Psychological Bulletin, 107,* 82-95.

Bentall, R.P., & Slade, P.D. (1985). Reality testing and auditory hallucinations: a signal detection hypothesis. *British Journal of Clinical Psychology, 24*, 159-169.

Blakemore, S.J., Smith, J., Steel, R., Johnstone, E.C., & Frith, C.D. (2000). The perception of self-produced sensory stimuli in patients with auditory hallucinations and passivity experiences: Evidence for a breakdown in self-monitoring. *Psychological Medicine, 30*, 1131-1139.

Braff, D.L., Callaway, E., & Naylor, H. (1977). Very short-term memory dysfunction in schizophrenia. *Archives of General Psychiatry, 34*, 25-30.

Buchner, A., Erdfelder, E., & Faul, F. (1997). How to Use G*Power [WWW document]. URLhttp://www.psycho.uniduesseldorf.de/aap/projects/gpower/how_to_use_gpower.html

Cahill, C., Silbersweig, D., & Frith, C. (1996). Psychotic experiences induced in deluded patients using distorted auditory feedback. *Cognitive Neuropsychiatry, 1,* 201-211.

Chapman, J. (1966). The early symptoms of schizophrenia. *British Journal of Psychiatry, 12*, 225-251.

Chaturvedi, S.K., & Sinha, V.K.(1990). Recurrence of hallucinations in consecutive episodes of schizophrenia and affective disorder. *Schizophrenia Research, 3*, 103-106.

Cleghorn, J.M., Garnett, E.S., Nahmias, G., Brown, G.M., Kaplan, R.D., Szechman, H., Szechtman, B., France, S., Dermer, S.W., & Cook, P. (1990). Regional brain metabolism during auditory hallucinations in chronic schizophrenia. *British Journal of Psychiatry, 157,* 562-570.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd edition). Hillsdale, NJ: Erlbaum.

Collicutt, J.R., & Hemsley, D.R. (1981). A psychophysical investigation of auditory functioning in schizophrenia. *British Journal of Clinical Psychology, 20*, 199-204.

Crow, T.J. (1980). Molecular pathology of schizophrenia: More than one disease process? *British Medical Journal, 280*, 66-88.

Cutting, J.C. (1994). Evidence for right hemisphere dysfunction in schizophrenia. In A.S. David & J.C. Cutting (Eds.), *The neuropsychology of schizophrenia.* Hillside, NJ: Lawrence Erlbaum.

Dalby, J.T., & Williams, R. (1986). Preserved reading and spelling ability in psychotic disorders. *Psychological Medicine*, *16*, 171-175.

David, A.S., & Cutting, J.C. (1994). *The neuropsychology of schizophrenia*. Hillside, NJ: Lawrence Erlbaum.

Evarts, E.V. (1971). Feedback and corollary discharge: a merging of the concepts. *Neurosciences research progress bulletin, 9*, 86-112.

Feinberg, I. (1978). Efference copy and corollary discharge: implications for thinking and its disorders. *Schizophrenia Bulletin, 4,* 636-640.

Feinberg, I. & Guazzelli, M. (1999). Schizophrenia- a disorder of the corollary discharge systems that integrate the motor systems of thought with the sensory systems of consciousness. *British Journal of Psychiatry, 174*, 196-204.

Flor-Henry, P. (1969). Psychosis and temporal lobe epilepsy: A controlled investigation. *Epilepsia, 10*, 363-395.

Fourneret, P., Franck, N., Slachevsky, A., & Jeannerod, M. (2001). Self-monitoring in schizophrenia revisited. *Neuroreport, 12*, 1203-1208.

Frith, C.D. (1987). The positive and negative symptoms of schizophrenia reflect impairments in the perception and initiation of action. *Psychological Medicine, 17,* 631-648.

Frith, C.D. (1992). *The cognitive neuropsychology of schizophrenia*. Hillside, NJ: Lawrence Erlbaum.

Frith, C.D., & Done, J. (1988). Towards a neuropsychology of schizophrenia. *British Journal of Psychiatry, 153,* 437-443.

Frith, C.D., & Done, J. (1989). Experiences of alien control in schizophrenia reflect a disorder in the central monitoring of action. *Psychological Medicine, 19*, 359-363.

Gibbs, C.B. (1965). Probability learning in step-input tracking. *British Journal of Psychology, 56*, 233-242.

Goldberg, G. (1985). Supplementary motor area structure and function: review and hypotheses. *Behavioural and Brain Sciences, 8,* 567-616.

Goldberg, T.E., Gold, J.M., Coppola, R., Weinberger, D.R. (1997). Unnatural practices, unspeakable actions: A study of delayed auditory feedback in schizophrenia. *American Journal of Psychiatry, 154*, 858-860.

Gould, L.N. (1948). Verbal hallucinations and the activity of vocal musculature: An electromyographic study. *American Journal of Psychiatry, 105*, 367-373.

Green, M.F. (1998). *Schizophrenia from a neurocognitive perspective.* Boston: Allyn and Bacon.

Heilbrun, A.B. (1980). Impaired recognition of self-expressed thoughts is patients with auditory hallucinations. *Journal of Abnormal Psychology, 89*, 728-736.

Heinrichs, R.W. & Zakzanis, K.K. (1998). Neurocognitive deficit in schizophrenia: A quantitative review of the evidence. *Neuropsychology, 12,* 426-445.

Higgins, J.R., & Angel, R.W. (1970). Correction of tracking errors without sensory feedback. *Journal of Experimental Psychology, 84,* 412-416.

Hoffman, R.E. (1986). Verbal hallucinations and language production processes in schizophrenia. *Behavioral and Brain Sciences, 9,* 503-548.

Hoffman, R.E., & Rapaport, J. (1994). A psycholinguistic study of auditory/verbal hallucinations: preliminary findings. In A.S. David & J.C. Cutting (Eds.), *The Neuropsychology of Schizophrenia*. Hillside, NJ: Lawrence Erlbaum.

Inouye, T., & Shimuzu, A. (1970). The electromyographic study of verbal hallucinations. *Journal of Nervous and Mental Diseases, 151*,415-422.

Johns, L.C., Rossell, S., Frith, C., Ahmad, F., Hemsley, D., Kuipers, E., & McGuire, P.K. (2000). Verbal self-monitoring in state and trait hallucinators. *Schizophrenia Research, 41*, 282-283.

Johns, L.C., Rossell, S., Frith, C., Ahmad, F., Hemsley, D., Kuipers, E., & McGuire, P.K. (2001). Verbal self-monitoring and auditory hallucinations in patients with schizophrenia. *Psychological Medicine, 31*, 705-715.

Kay, S.R., Fiszbein, A., & Opler, L.A. (1987). The positive and negative syndrome scale (PANSS) for schizophrenia. *Schizophrenia Bulletin, 13,* 261-276.

Kinsbourne, M. (1990). Voiced images, imagined voices. *Biological Psychiatry, 27*, 811-812.

Kremen, W.S., Seidman, L.J., Faraone, S.V., Pepple, J.R., Lyons, M.J., & Tsuang, M.T. (1996). The 3 R's and neuropsychological function in schizophrenia: An empirical test of the matching fallacy. *Neuropsychology*, *10*, 22-31.

Kopp, B., & Rist, F. (1994). Error-correcting behavior in schizophrenic patients. *Schizophrenia Research, 13*, 11-22.

Lackner, J.R., & Tuller, B.H. (1979). Role of efference monitoring in the detection of self-produced speech errors. In W.E. Cooper & E.C.T. Walker (Eds.), *Sentence processing: psycholinguistic studies presented to Merrill Garrett.* Hillside, NJ: Lawrence Erlbaum.

Lee, B.S. (1950). Effects of delayed speech feedback. *Journal of the Acoustic Society of America, 22,* 824-826.

Leudar, I., Thomas, P., & Johnston, M. (1994). Self-monitoring in speech production: effects of verbal hallucinations and negative symptoms. *Psychological Medicine, 24*, 749-761.

Leudar, I., Thomas, P., Johnston, M. (1992). Self-repair in dialogues of schizophrenics: effects of hallucinations and negative symptoms. *Brain and Language, 43,* 487-511.

Levelt, W.J.M. (1983). Monitoring and self-repair in speech. *Cognition, 14*, 41-104.

Levelt, W.J.M. (1989). *Speaking: From intention to articulation.* Cambridge: MIT Press.

Liddle, P. (1987). The symptoms of chronic schizophrenia: A reexamination of the positive negative dichotomy. *British Journal of Psychiatry, 151*, 145-151.

Malenka, R.C., Angel, R.W., Hampton, B., & Berger, P.A. (1982). Impaired central error-correcting behavior in schizophrenia. *Archives of General Psychiatry, 39,* 101-107.

Malenka, R.C., Angel, R.W., Theimann, S. Weitz, C.J. & Berger, P.A. (1986). Central error-correcting behavior in schizophrenia and depression. *Biological Psychiatry, 21*, 263-273.

Mintz, S., & Alpert, M. (1972). Imagery vividness, reality testing and schizophrenic hallucinations. *Journal of Abnormal Psychology, 79*, 310-316.

Mlaker, J., Jensterle, J., & Frith, C.D. (1994). Central monitoring deficiency and schizophrenic symptoms. *Psychological Medicine, 24*, 557-564.

Motley, M.T., Camden, C.T., & Baars, B.J. (1982). Covert formulation and editing of anomalies in speech production: evidence from experimentally elicited slips of the tongue. *Journal of Verbal Learning and Verbal Behavior, 21*, 578-594.

Pantelis, C., & Nelson, H.E., (1994). Cognitive functioning and symptomotology in schizophrenia: the role of frontal-subcortical systems. In A.S. David & J.C. Cutting (Eds.), *The neuropsychology of schizophrenia*. Hillside, NJ: Lawrence Erlbaum.

Penfield, W. (1974). The mind and the highest brain mechanism. *American Scholar*, *43,* 237-246.

Postma, A., Noordanus, C. (1996). Production and detection of speech errors in silent, mouthed, noise-masked, and normal auditory feedback speech. *Language and Speech, 39*, 375-392.

Rabbitt, P. (1966). Error correction time without external error signals. *Nature, 212*, 438.

Rabbitt, P. (1967). Time to detect errors as a function of factors affecting choice-response time. *Acta Psychologica, 27,* 131-142.

Schretlen, D. (1989). The Brief Test of Attention.

Siegel, S., & Castellan, J. (1988). *Nonparametric Statistics for the Behavioral Sciences*. New York: McGraw-Hill.

Shafer, E.W.P., & Marcus, M.M. (1973). Self-stimulation alters human sensory brain responses. *Science, 181*, 175-177.

Silverstein, A.B. (1982). Two- and four-subtest short forms of the wechsler adult intelligence scales – revised. *Journal of Consulting and Clinical Psychology, 50,* 415-418.

Slade, P.D. (1976). Towards a theory of auditory hallucinations: Outline of a hypothetic four factor model. *British Journal of Social and Clinical Psychology, 15,* 415-423.

Slade, P.D. (1994). Models of hallucinations: from theory to practice. In A.S. David & J.C. Cutting (Eds.), *The neuropsychology of schizophrenia*. Hillside, NJ : Lawrence Erlbaum.

Spear, F.G. (1963). Delayed auditory feedback: some effects on the speech of psychiatric patients. *British Journal of Psychiatry, 109*, 235-239.

Sperry, R.W. (1950). Neural basis of the spontaneous optokinetic response produced by visual neuron inversion. *Journal of Comparative Physiology and Psychology, 43,* 482-489.

Spreen,O., & Strauss, E. (1998). *A compendium of neuropsychological tests: Administration, norms and commentary* (2nd Ed.). New York: Oxford University Press.

Staley, C. T.(n.d.). The tongue twister database. Retrieved April 20, 2000 from http://www.geocities/athens/8136/tonguetwisters.html.

Stirling, J.D., Hellewell, J.S.E., & Ndlovu, D. *(2001).* Self-monitoring dysfunction and the positive symptoms of schizophrenia. *Psychopathology, 34,* 198-202.

Stirling, J.D., Hellewell, J.S.E., & Quraishi, N. (1998). Self-monitoring dysfunction and the schizophrenic symptoms of alien control. *Psychological Medicine, 28*, 675-683.

Sutton, S., Roehrig, W.C., & Kramer, J. (1963). Delayed auditory feedback of speech in schizphrenics and normals. *Annals of the New York Academy of Sciences, 105,* 832-844.

Tueber, H.L. (1966). The frontal lobes and their function: Further observations on rodents, carnivores, subhuman primates, and man. *International Journal of Neurology, 5,* 282-300.

Von Holst, E. (1954). Relations between the central nervous system and the peripheral organs. *British Journal of Animal Behavior, 2,* 89-94.

Von Holst, E., & Mittelstaedt, H. (1950). Das reafferenzprinzip. *Naturwissenschaften, 37*, 464-476.

Watson, S.J. (1974). Effects of delayed auditory feedback on process and reactive schizophrenic subjects. *Journal of Abnormal Psychology, 83*, 609-615.

Weinberger, D.R., Aloia, M.S., Goldberg, T.E., & Berman, K.F. (1994). The frontal lobes and schizophrenia. *Journal of Neuropsychiatry and clinical neurosciences*, *6,* 419-427.

Weiskrantz, L., Elliot, J., & Dralington, C. (1971). Preliminary observations of tickling onself. *Nature, 230*, 598-599.

Wiederholt, J.L., & Bryant, B.R. (1992). Gray Oral Reading Tests- Third Edition. Austin, TX: Pro-Ed.

Woodworth, R.S., & Schlosberg, H. (1954). *Experimental psychology* (2nd Ed.). New York: Holt.

Appendix A – The Biography of Victoria

Victor[redacted]a is Western Canada's oldest cit[redacted]. The Cit[redacted] b[redacted]gan in [redacted] as a Hudson Bay Compan[redacted] trading post, named in honor of Qu[redacted]n Victor[redacted]a. With the Fraser Vall[redacted] gold rush in [redacted], Victor[redacted]a grew rapidl[redacted] as the main port of entr[redacted] to the Colon[redacted]s of Vancouver Island and British Columb[redacted]a. When the colon[redacted]s combined, the Cit[redacted] b[redacted]came the colon[redacted]al capital and was established as the provincial capital when British Columb[redacted]a joined the Canad[redacted]an Confederation in 1[redacted]1.

For most of the ninet[redacted]nth centur[redacted], Victor[redacted]a r[redacted]mained the largest cit[redacted] in British Columb[redacted]a and was the foremost in trade and commerce. However, with construction of the Transcontinental railway, Vancouver, as its terminus, [redacted]merged as the major west coast port and the largest cit[redacted] in British Columb[redacted]a.

In the twent[redacted]th centur[redacted], Victor[redacted]a [redacted]volved primaril[redacted] as a cit[redacted] of government, r[redacted]tirement and tourism. The Cit[redacted] r[redacted]mains, however, Canada's western naval base and home to a major fishing fl[redacted]t. Shipbuilding and r[redacted]pair, as well as forest products and mach[redacted]ne manufacturing industr[redacted]s continue as significant sources of employment.

Incr[redacted]singl[redacted], the cit[redacted] is d[redacted]veloping as a mar[redacted]ne, forestr[redacted] and agricultural r[redacted]search centre. The Cit[redacted] is also noted for its fine educational institutions, which include the Universit[redacted] of Victor[redacted]a, Lester [redacted]. Pearson College of the Pacific (one of onl[redacted] six in the world operated by United World Colleges), and the r[redacted]centl[redacted] opened Royal Roads Universit[redacted].

Today with an estimated r[redacted]gional population of [redacted]26,000, a moderate climate and sc[redacted]nic setting, Victor[redacted]a has r[redacted]tained a ver[redacted] vital but comfortable qualit[redacted] of life. The Cit[redacted] is proud of its British heritage, its fine homes and neighborhoods, its historic and attractive downtown, the flowers and parks and, of course, the Inner Harbor with its vistas toward the famous Empress Hotel and the Parliament Buildings.

In a survey conducted by Travel magaz[redacted]ne, Victor[redacted]a was judged to b[redacted] one of the world's best cit[redacted]s, topping the list in the categor[redacted] of environment and amb[redacted]nce. In a cross-Canada survey, Victor[redacted]a residents registered the greatest satisfaction with their cit[redacted]. This satisfaction and r[redacted]gard for the qualit[redacted] of life and environment is perhaps the most notable f[redacted]ture of Victor[redacted]a today, and the challenge in its future.

Appendix B- Tongue Twisters[2]

1. Six sick slick slim sycamore saplings
2. Shy Shelly says she shall sew sheets.
3. Lenny loves lemon-lime liniment
4. Lesser leather never weathered wetter weather better
5. The sixth sheik's sixth sheep's sick
6. A Noisy Noise Annoys an Oyster.
7. She switched which Swiss wristwatch?
8. Tim, the thin twin tinsmith.
9. She threw six thick thistle sticks.
10. Which witch wished which wicked wish?
11. Sam's shop stocks short spotted socks.
12. A skunk sat on a stump and thunk the stump stunk.
13. Twelve twins twirled twelve twigs.
14. Many an anemone sees an enemy anemone.
15. Six shimmering sharks sharply striking shins.
16. Mrs. Smith's Fish Sauce Shop.
17. Cedar shingles should be shaved and saved.
18. Shelter for six sick scenic sightseers.
19. Listen to the local yokel yodel.
20. Six slippery snails slid slowly seaward.

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2 All tongue twisters were retrieved with permission from the Tongue Twister Database by C.T. Staley. They were utilized and reproduced with permission, but are referenced on the site as public domain.

Appendix C – Scoring Criteria for the Tongue Twister Test

1) Simple Correct - If the participant correctly states the tongue twister fluently without error, score the item as correct.
2) Simple Incorrect - If the participant makes an obvious error such as incorrect pronunciation, letter transposition, obvious stutter, syllable repetition, or extremely long pause score the trial as an error.
3) Mispronunciation exception- If the participant consistently mispronounces a word throughout all ten trials of a given tongue twister and fails to acknowledge the error, do not count the mispronunciation as an error.
4) Misreading-

   4a) Misreading exception- If the participant consistently misreads a tongue twister throughout the trials, score as correct unless there is another error in the trial. For example, if the participants states "Tim the thin twin *tinsmen*" instead of "Tim the thin twin *tinsmith*" consistently; score it as correct. (The goal of the scoring is to count self-monitoring errors, not reading errors.)

   4b) Discovery- If the participant should discovery a misread after several incorrect trials and then discover their error, score errors previous to the discovery with according to criteria 4a, and errors after the discovery as errors.

   Example: Participant made the following statements fluently:

   1) "Tim the thin twin tinsmen. Yes" Score = Correct
   2) "Tim the thin twin tinsmen. Yes" Score = Correct
   3) "Tim the thin twin tinsmen. No, that's tinsmith." Score = Incorrect
   4) "Tim the thin twin tinsmith. Yes." Score = Correct
   5) "Time the thin twin tinsmen. Yes." Score = Incorrect

Trials 1 and 2 in the example above are considered correct because they are misread. Trial 3 is incorrect because there is an identified error. Trial 4 is correct. Trial 5 is incorrect because the participant has now established a baseline of correct knowledge of the tongue twister and has made a subsequent error.

5) Pauses-

5a) Mild pauses between words are acceptable if the do not detract from overall understanding of each syllable in the tongue twister.

5b) Very long pauses (3s), pauses mid-word, or pauses that are followed by word repetitions should all be counted as errors.