

SELF-MONITORING IMPAIRMENT
AND SYMPTOMS OF SCHIZOPHRENIA

by

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ABSTRACT

A deficit in self-monitoring is thought to underlay certain symptoms of schizophrenia, namely hallucinations, delusions of control, and delusions of thought insertion. However, past evidence for this theory has not isolated self-monitoring from proprioceptive ability. Twenty-four patients with schizophrenia or schizoaffective disorder and 12 healthy controls matched on age, gender, and parental education, completed a self-monitoring task independent of proprioceptive ability, as well as tests of proprioception. Results revealed that patients with hallucinations, delusions of control, and delusions of thought insertion ($n = 14$) performed at the same level as healthy controls on all tests. In integrating these results with past findings, an information processing bias is proposed to underlay the symptoms of interest.

Keywords: Schizophrenia; Self-monitoring; Proprioception

Subject Terms: Schizophrenia; Cognitive Psychology; Neuropsychology; Neurocognition

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INTRODUCTION

Self-Monitoring and Schizophrenia

The diagnostic criteria for schizophrenia define a heterogeneous disorder, so that a variety of patients with distinct symptomatology are diagnosed. In addition, schizophrenia is associated with increased heterogeneity of performance on a variety of neurocognitive measures (Heinrichs, 2001). Three approaches have been taken by investigators interested in the neurocognitive underpinning of schizophrenia to address the observed heterogeneity of symptoms. Firstly, investigators have assumed that some common pathology or core neuropsychological deficit underlies all of the symptoms seen in schizophrenia. In line with this assumption, neurocognitive deficits common to all schizophrenics have been sought out, and a variety of frequently occurring deficits have been identified (see Heinrichs & Zakzanis, 1998, for a review). Secondly, researchers have assumed that common pathologies or deficits underlie clusters of symptoms. Numerous studies have investigated the associations between neurocognitive performance and symptom dimensions, which are composed of symptoms that co-occur with the highest frequency (see Basso, Nasrallah, Olsen, & Bornstein, 1998; Donahoe & Robertson, 2003, for a review). A third approach assumes that individual symptoms are associated with unique pathology, or unique combinations of common pathological processes, and that heterogeneity is due to variable disease processes (Heinrichs, 2001).

Advocates of this approach, such as Frith (1992), emphasize its potential to offer a more sophisticated neurocognitive account of the disorder.

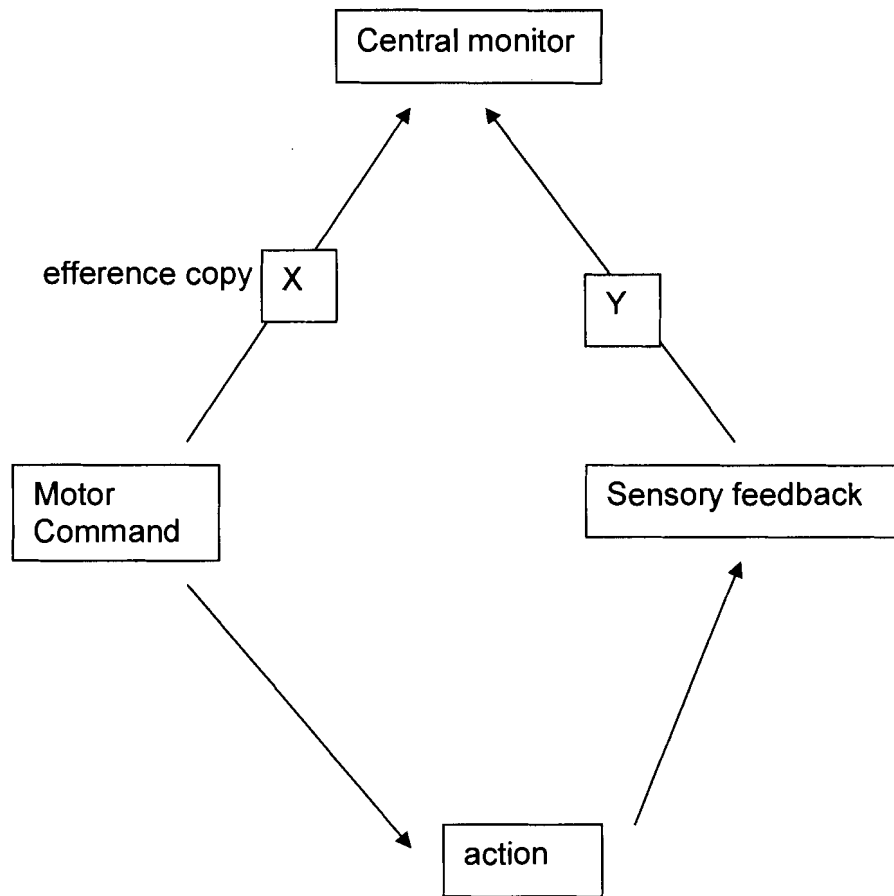
Following the third approach described above, the current study will investigate neurocognitive abnormalities associated with delusions of control, delusions of thought insertion, and auditory hallucinations. Delusions of control (or passivity experiences) are false beliefs that someone else is controlling one's actions. Thought insertion is the delusion that someone else is inserting thoughts into one's mind. Auditory hallucination is the experience of hearing imaginary voices. Frith (1992) proposes that three fundamental cognitive deficits may underlie the symptoms of schizophrenia. Of interest to the current study, a deficit in what Frith calls "self-monitoring" is thought to lead to delusions of alien control, delusions of thought insertion, and certain auditory hallucinations. The present study will investigate and attempt to clarify the purported link between self-monitoring and these symptoms.

Frith (1992) proposed that delusions of control, delusions of thought insertion, and auditory hallucinations result from a deficit in self-monitoring, a process by which we identify our actions as our own. Self-monitoring occurs through a comparison of the actual sensory consequences of an action with the predicted sensory consequences. When predicted and actual sensory consequences of an action match, we assume the action is our own. When there is a mismatch between predicted and actual consequences, the involvement of external forces is assumed (Blakemore & Frith, 2003). The symptoms listed above may result from chronic mismatches between predicted and actual

sensory consequences of behavior. In this framework, actions can be either external (such as moving a limb), or internal (such as thought or internal speech). In addition, the “sensory consequences” referred to above can result from input from the external world (as in proprioceptive feedback from moving limbs), or input from within the brain (the sensory experience of internal speech or thoughts). Thus, a mismatch between internal action (internal speech or thought) and corresponding sensation results in auditory hallucinations or thought insertion, whereas a mismatch between external action and corresponding sensation results in delusions of control.

How might these mismatches occur? Frith (1992) hypothesized the existence of a “central monitor” in the brain, a module that is responsible for the comparison of actual sensations and predicted sensations. This central monitor receives a neural copy of the motor/intentional commands (an efference copy, or corollary discharge) when an action is initiated. The monitor also receives input from a sensory pathway (Figure 1). It is the monitor that detects matches or mismatches between efference copy and sensory inputs in order to determine agency for our actions. One’s ability to detect a match between the inputs is, of course, contingent upon the integrity of the inputs. Frith (1992) proposed that a disconnection in the efference copy pathway (disconnection X in Figure 1) is responsible for a breakdown in self-monitoring in patients with delusions of control, auditory hallucinations, and thought insertion. Without the efference copy, the monitor only becomes aware of self-initiated actions through the sensory pathway. This leads to the subjective experience of a lack of a “sense of

Figure 1. Frith's model of self-monitoring.



Effort”, or feeling of intendedness, associated with one’s own actions, and the belief that they were caused by external forces.

Studies of Self-Monitoring in Schizophrenia

A number of studies have investigated impaired self-monitoring in patients with schizophrenia. One area of investigation has been motor error-correcting behavior. It is thought that patients with impaired appreciation of the sense of effort may not correct errors in movement under conditions of reduced sensory feedback because they lack awareness of the movement they have just initiated.

In Frith and Done (1989) patients with schizophrenia, psychiatric controls, and normal controls were required to complete a task disguised as a video game. The video game was designed to elicit errors which participants were able to correct by responding within a short period afterward. Participants could sometimes see the consequences of their action on the computer screen and sometimes could not. Schizophrenic patients with delusions of control had difficulty correcting their errors in the absence of visual feedback, as compared to other schizophrenic subjects, psychiatric controls, and normal controls. Similarly, a study by Malenka, Angel, Hampton and Berger (1982) compared the abilities of schizophrenics, alcoholics and normal controls to correct errors on a task requiring movements of a cursor to track a line displayed on an oscilloscope. In the absence of visual feedback, schizophrenic participants were less likely to correct errors (schizophrenia symptom types were not examined) but were equally likely to make corrections when visual feedback was present. Therefore under some conditions patients presumed to have self-monitoring deficits have difficulty correcting errors.

It has been suggested that difficulties in the above tasks do not necessarily represent self-monitoring deficits (Kopp & Rist, 1994). In both tasks, errors were elicited through frequent changes in the response rule. For example, in the Malenka et al. (1982) study, moving a joystick to the right sometimes resulted in the movement of the cursor to the right, and sometimes to the left. After each block of ten trials, the relationship between joystick and cursor movement would be reversed (the participants were verbally warned of the

switch each time). Kopp and Rist (1994) suggested that poor memory for the appropriate response rule is responsible for reduced rates of error correction in such tasks. In a modified error-correction task in which reminders of the response rule appeared on-screen, individuals with schizophrenia did not show reduced rates of error correction compared to controls under conditions of minimal sensory feedback (Kopp and Rist, 1994). Therefore difficulties experienced by individuals with schizophrenia on error-correction tasks may result from memory deficits rather than self-monitoring deficits.

Self-monitoring in schizophrenia has also been investigated through a task requiring the sensory discrimination of self-produced versus other-produced actions. In patients with impaired self-monitoring ability, impaired ability to distinguish these two types of actions is expected. Blakemore, Smith, Johnstone, and Frith (2000) tested whether ratings on the dimensions “intense”, “tickly”, and “pleasant” differed for a self-produced versus other-produced action in patients with schizophrenia, psychiatric controls, and normal controls. Specifically, a stimulus on the left palm was produced by the subject moving an apparatus with his/her right hand, or by the experimenter moving the same apparatus. It was found that normal control subjects and those psychiatric patients with neither auditory hallucinations nor passivity experiences reported reduced ratings on the above dimensions for self-produced as compared to other-produced stimulation. In contrast, schizophrenic patients with auditory hallucinations or delusions of control reported equally high ratings for both self-produced and other-produced stimulation. The results may be seen as evidence for a self-monitoring

impairment. In the absence of an efference copy (carrying information from the motor command), patients cannot attenuate the sensory consequences of a self-produced action, therefore a self-produced action feels like an other-produced action.

In another paradigm, patients are asked to make hand motions and see either their own hand or the experimenter's hand making the motions simultaneously on a video screen (Daprati et al, 1997). Patients with hallucinations have more difficulty than control subjects in distinguishing their own hand movements from those of the experimenter. Similarly, patients with delusions of control have greater difficulty identifying visually presented drawings that they have just produced in the absence of visual feedback (Stirling, Hallewell, & Ndlovu, 2001), and this difficulty appears to be unrelated to general recognition memory.

An Alternative Explanation: Proprioceptive Impairment

Rather than a self-monitoring deficit, an alternate explanation for the results of the above studies is that patients with delusions of control and auditory hallucinations suffer from a proprioceptive impairment (see Figure 1). It may be the case that normal controls rely on proprioception (i.e., one's sense of limb position) to complete the above tasks. In Blakemore et al.'s (2000) study, proprioceptive information from the subject's moving hand may be used to attenuate the sensory consequences felt on the left palm. In the Daprati et al. (1997) and Stirling et al. (2000) studies, proprioceptive information from the moving hand may be matched with the drawing / image of hand motion to

determine action ownership. Thus, the above results may reflect a proprioceptive rather than a self-monitoring impairment. There is some evidence that proprioception is impaired in schizophrenia, although the relationship of proprioception to particular symptoms has not been examined. Evidence for a proprioception deficit will be examined in the following section.

Evidence for a Proprioceptive Deficit

In past studies of proprioception and schizophrenia, weight discrimination tasks have been used. In such tasks, the subject can be asked to match weights on one side of the body to weights on the other side. More commonly, patients have been asked to report which of two weights placed one after the other into the same hand is heavier (eg. Chapin, Rosenbaum, and Fields, 1996, Ritzler & Rosenbaum, 1974). Evidence that the task heavily relies on proprioception comes from studies of deafferented patients (i.e., patients without proprioceptive abilities due to large myelinated sensory neuron loss). When visual feedback is occluded, such patients perform significantly poorer on the task than control subjects (Fleury et al, 1995).

Ritzler and Rosenbaum (1974) and Chapin et al (1996) found that individuals with schizophrenia performed poorer than controls in weight discrimination tasks using light weights, while Erwin and Rosenbaum (1979) found significant impairments for both schizophrenics and patients with parietal lobe lesions in weight discrimination. Leventhal, Schuck, and Clemons (1982) failed to find differences between individuals with schizophrenia and normal controls using as a measure of differential discrimination of light and heavy weight, which they felt

better reflected proprioceptive impairment. However, the schizophrenic group significantly differed from controls on both light and heavy weights, a finding which is consistent with previous studies. These results indicate that schizophrenia may be associated with a proprioceptive impairment.

Behavioural Dissociation Between Proprioception and Self-Monitoring

In the current study, self-monitoring in patients with delusions of control, thought insertion and auditory hallucinations will be examined through a task that minimizes the influence of proprioception. Performance on this task will be contrasted with performance on a similar task that relies on proprioception. A selective deficit on the former task in patients with the symptoms of interest would support the self-monitoring hypothesis, that is, delusions of control, thought insertion, and auditory hallucinations result from a disconnection in the efference copy pathway. A selective deficit on the latter task in these patients would suggest a role for proprioception in the pathogenesis of these symptoms.

A force-matching task will be used as a measure of self-monitoring, while a movement-matching task will be used as a measure of proprioception. Ample evidence suggests that the sensation of applied force arises from the efference copy, whereas the sensation of movement arises from proprioceptive information (see McCloskey, 1981; Gandevia, 1996, for reviews). Evidence that proprioception is critical to movement perception comes from studies in which proprioceptive sensation is unavailable. When proprioceptive sensation is blocked through anesthetization, movement is not perceived in the affected body

part even if voluntary movement is successful (Goodwin, McCloskey, & Matthews, 1972). Patients suffering from paralysis do not sense movement in the affected limbs when attempting to move them (McCloskey, 1981). Moreover, patients deprived of proprioception due to large myelinated sensory fiber loss show gross impairment in tasks requiring the use of limb position information (Farrer, Franck, Paillard, & Jeannerod, 2003).

Evidence that the sensation of applied force arises from the efference copy comes from studies in which the relationship between motor commands and the resulting force applied is altered. This altered relationship is present in muscle fatigue, in which a given motor command, or amount of “neural drive”, results in less force applied by the corresponding muscle over time. When made to exert a particular force for a long period, subjects perceive themselves as exerting more and more force, and choose greater matching forces with the non-fatigued limb as the fatigue proceeds (McClosky, Ebeling, & Goodwin, 1974, Weerakkody, Percival, Morgan, Gregory, & Proske, 2003). This effect cannot be due to changes in proprioceptive signaling, as the signaling ability of proprioceptive receptors is unaffected by fatigue (Gregory, Brockett, Morgan, Whitehead, & Proske, 2002). Similarly, an altered relationship between motor commands and resulting force is present in hemiparesis due to stroke. Patients suffering from this condition perceive weights lifted on the affected side to be heavier, even when sensory impairments are absent (Gandevia, 1996).

Additional evidence that the sensation of applied force does not arise from proprioceptive receptors comes from studies of involuntary reflex movement

(such as the Tonic Vibration Reflex), which have shown that these movements do not lead to perceived increases in applied force. In addition, voluntary movements aided by the tonic vibration reflex lead to the perception of decreased applied force, as expected due to the decreased neural drive necessary to complete such movements (McCloskey, 1981). It appears that when instructed carefully, subjects can use perceived intramuscular tension as an estimate of force applied. However, almost all normal subjects appear to spontaneously use efference copy information to perceive force (McCloskey, 1981).

Force Matching: A Test of Self-Monitoring

The Force-Matching task that will be adapted for use in the current study comes from Lafargue, Paillard, Lamarre, & Sirigu (2003). This task involved two grip strength dynamometers, each hooked to an electrical transducer that allowed the force applied to affect a display on a computer screen. First, the participant was required to match a certain force with one hand by causing a bar representing force applied to rise to a certain point on the computer screen (the relationship between force applied and the height to which the bar rises was varied so that bar height was uninformative). Next, the participant was required to duplicate the force with his/her other hand without receiving any external feedback. Lafargue et al. (2003) showed that a woman deprived of proprioception, touch and pressure senses was able to duplicate the required force as well as controls, when the initial peak force applied was examined. The authors concluded that the patient had a preserved "implicit sense of effort".

Thus, as expected, performance on the task does not seem to critically depend on sensory feedback, since a patient deprived of all sensory feedback was able to perform the task as well as controls.

Movement-Matching: A Test of Proprioception

The Movement-Matching task to be used will be similar to that used by Farrer et al. (2003). In this task, participants moved a joystick to different locations, and were to report whether or not the angle of movement displayed on a computer screen matched the movement of their hand. In a variation of the task, the participants rested their hand on the joystick while the experimenter moved it, and the participants made the same judgement with respect to the displayed image. In both conditions, the performance of a woman deprived of proprioception was significantly poorer than that of controls.

In the current study, variants of the isometric force-matching and movement-matching tasks will be contrasted in order to tease out the relative contributions of self-monitoring and proprioception to the symptoms of interest. If a self-monitoring deficit exists in delusions of control, thought insertion and auditory hallucinations, the group with these symptoms will be expected to show impairment on the force-matching task but not on the movement-matching task. If a proprioceptive deficit exists, the opposite pattern will be expected. If some other deficit exists that may impact performance, such as a deficit in attention, or a deficit in the ability to match stimuli, impairment will be expected on both tasks, since the tasks are designed to require equal levels of these cognitive components, and performance on the two tasks should be highly correlated in

the symptoms-of-interest group. If dual deficits in proprioception and self-monitoring contribute independently to the symptoms of interest, then performance on the two tasks in the symptoms of interest group should be uncorrelated.

Force Rating: A Test for Conscious Sense of Effort

Interestingly, despite being able to match forces accurately, the patient tested in the Lafargue et al. (2003) study did not report conscious feelings of "fatigue" or "effort" associated with her performance, indicating that such feelings may require the integration of sensory feedback with the efference copy (i.e., at the level of the conscious monitor in Figure 1). Thus, the intactness of the efference copy appears to dissociate from the conscious "sense of effort" under the condition of eliminated proprioceptive feedback. This suggests a new hypothesis regarding delusions of control, thought insertion, and hallucinations: Perhaps patients with such symptoms are impaired in their ability to integrate efference copy and proprioceptive/sensory information to form a conscious sense of effort, though the efference copy and proprioception/sensory pathways are themselves intact. In the current study, this hypothesis will be examined through the inclusion of a measure of conscious sense of effort. The participant will be required to match a certain force with one hand as in the force-matching task, but will then be asked to rate the strength of force applied from 1 to 100. Impairments in the conscious sense of effort, which may be due to deficits in integration of proprioception and the efference copy, or a deficit in either of these areas, will be reflected in a discrepancy between the actual force applied and estimates of

force applied. A similar control task, Movement Rating, will be used to rule out alternate explanations for poor Force Rating performance, such as a general inability to use proportions to describe movements. Conscious awareness of movement is not expected to depend on the proposed integrative process, since sensed movements need not be self-initiated. However, if both proprioceptive and self-monitoring deficits exist, both Force Rating and Movement Rating could be affected. In order to distinguish this situation from a general inability to recognize proportions, a Percentage Recognition test requiring participants to recognize visually presented proportions will be employed.

A Test of Insight

A variety of symptoms of schizophrenia are commonly associated with poor insight (Goodman, Knoll, Isakov, & Silver, 2005). Insight refers to patients' awareness that they suffer from a mental illness, their symptoms are pathological, they need treatment, and the source of their symptoms is an illness (Beck, Baruch, Balter, Steer, & Warman, 2004). However, it is unclear how poor insight may be related to the pathological processes of self-monitoring impairment and impairment in integration described above. Impairment in integration, which implies an inability to accurately form conscious percepts regarding the self, seems particularly related to the concept of insight. Within the current study, an exploratory investigation of the relationship between insight and self-monitoring / integration deficits will be conducted through the inclusion of a measure of cognitive insight, the Beck Cognitive Insight Scale (BCIS, Beck et al, 2004).

HYPOTHESES

The current experiment will investigate the following competing hypotheses:

1. Delusions of control, hallucinations and thought insertion are associated with impairment in the ability to monitor one's own movements independently of sensory feedback. This impairment in self-monitoring is due to a disconnection in the pathway carrying the efference copies of motor or intentional commands to the monitor (disconnection X in Figure 1), such that the use of the efference copy in motor planning or evaluation is greatly diminished in these patients. As a result, patients with the symptoms of interest will perform worse than patient controls and healthy controls on a test of implicit awareness of the efference copy, that is, the Force Matching task. Worse performance will be evidenced by greater deviations from the criterion force, as will be described in the next section. Lacking the information carried in the efference copy, they will also perform worse on a test of conscious awareness of movement, that is, the Force Rating task. However, the proprioception pathway (Y in Figure 1) will remain intact, leading to performance on the Movement Matching task that is either unimpaired or significantly less impaired.
2. Delusions of control, hallucinations and thought insertion are associated with impairment in the conscious integration of efference copy and

sensory information. The absence of such a unified conscious percept of effort regarding one's movements leads to the belief that one's actions are due to external causes. As a result, patients with the symptoms of interest will perform poorly on the Force Rating task, as evidenced by lower accuracy than that seen in patient controls and healthy control subjects. However, their performance on a test of implicit awareness of the efference copy, the Force Matching task, will be unimpaired, and their performance on a test of implicit awareness of proprioception, Movement Matching, will also be unimpaired.

The following secondary hypothesis will also be investigated:

3. Deficits in self-monitoring and integration are associated with decreased cognitive insight. As a result, deviation scores on the Force Rating and Force Matching tasks will negatively associated with BCIS scores.

METHODS

Participants

Prior to conducting the current study, a pilot sample from the community was recruited and tested for the purposes of ensuring the feasibility of the Force Rating and Force Matching procedures, and ensuring that an appropriate range of scores will be generated for each measure. Pilot data is summarized in Table 1.

Given that large effect sizes have previously been observed for comparisons between patients with the symptoms of interest and normal controls, as well comparisons between patients with and without the symptoms of interest on tests related to self-monitoring (eg. Daprati et al, 1997, $d = 1.5$, delusional versus controls, $d = 0.96$ delusional versus non-delusional, also,

Table 1. Pilot Data (n = 6)

Task	Mean (S.D)	Split-half Reliability
Force Matching	5 pounds (1.6 pounds)	0.89
Force Rating	12.6% (3.9%)	0.59
Movement Matching	1.2cm (0.48cm)	0.802
Movement Rating	6.5% (2.07%)	0.59

Stirling et al, 2001, $d = 1.4$, schizophrenic groups versus controls, calculated using the program d-stat), large effect were tested for in the present study. For power = 0.8, and assuming $d = 1.0$, 12 participants per group were suggested for the one-tailed t-tests that will be conducted.

Twenty four patients diagnosed with schizophrenia or schizoaffective disorder according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; American Psychiatric Association, 1994) were recruited from a population of inpatients at Riverview Hospital in Coquitlam, Canada. All patients were judged to proficient in the English language, and achieved Kaufman Brief Intelligence Test – II (K-BIT II, Kaufman & Kaufman, 2004) Vocabulary scores of greater than 70. Patients were excluded if they had 1) a history of head injury with loss of consciousness of more than five minutes, 2) a neurological illness (eg. Diabetes, hypothyroidism, epilepsy, HIV, hepatitis C), 3) an additional Axis I diagnosis (eg. Substance Abuse), 4) a diagnosis of mental retardation and/or pervasive developmental disorder.

Patients were split into two groups based on the presence/absence of hallucinations, delusions of control, and thought insertion. Details regarding this procedure, as well as the demographic characteristics of the two groups, will be discussed in the Results section.

Twelve healthy controls from the community were recruited. Participants met the exclusion criteria detailed above for the patients, and had not been previously been hospitalized with a DSM-IV disorder, according to a health questionnaire (described below). Demographic characteristics of this group will

be described in the Data Analysis section. All participants were paid \$5/hour, and also received travel allowance if travel to the appointment(s) was involved.

Materials / Tasks

Health Questionnaire

A standard lab questionnaire was used to obtain information on regarding the participant's education, parental education, and medical history.

SSPI

The Signs and Symptoms of Psychotic Illness (SSPI, Liddle, Ngan, Duffield, Kho, & Warren, 2002) provides a measure of a variety of symptoms that commonly occur in psychotic illness. Each symptom is ranked in severity by clinicians on a 0 to 4 scale, where a 0 reflects the absence of a symptom and a 4 reflects severe symptomatology. The SSPI has demonstrated good inter-rater reliability (all ICCs>0.68) and appears to be sensitive to changes in symptom severity, as demonstrated by correlations with clinical impressions, Liddle et al, 2002. Further information on the SSPI is provided in Appendix A.

NAART

The North American Adult Reading Test (Blair & Spreen, 1989) is comprised of 61 phonetically irregular words to be read by the patient. It will be used as a measure of premorbid IQ in the current study, in order to compare the patient groups to one another and to the controls. The NAART has shown excellent interrater and test-retest reliability (coefficients of .96 and .98,

respectively, Crawford, Stewart, Cochrane, et al., 1989). The NAART demonstrates good criterion validity, as correlations with FSIQ scores typically run in the range of .7 (Lezak, Howison, and Loring, 2004).

BCIS

The Beck Cognitive Insight Scale (Beck, Baruch, Balter, Steer, & Warman, 2004) is a 15 item self-report questionnaire that provides scores on Self-certainty and Self-reflectiveness scales, and a Composite score. The Composite score, which will be used in the current study, has shown convergent validity with other scales of insight, and criterion validity, in that it is able to differentiate inpatients with psychotic symptoms from inpatients without psychotic symptoms (Beck et al, 2004).

Symptom Questions Task

In order to gather more information on the symptoms of interest, patients were asked three questions: 1)“Do you ever feel as though some external force or some other person is controlling your movements?”, 2)“Do you ever feel as though some external force or person is putting thoughts into your head?”, and 3) “Do you ever hear voices in your head, or voices of people that are not there?”. If the patient answered affirmatively to any of the above questions, the following question was asked: “How often does this happen to you?”

Force Matching Task

For the Force-Matching task, two grip strength dynamometers were used. The overall goal of the task was to match grip forces exerted by one hand with

those exerted by the other. First, participants were required to produce a maximal grip force with each hand. After recording these maximal exertions, the test administrator calculated the forces corresponding to 10%, 30%, and 50% of the maximal grip force of the participant's weaker hand, and rounded these forces to the nearest 5-pound increment. The following instructions were then given: "This is how the task will work. I'm going to ask you to gradually increase force with one hand until I say "stop". When I tell you to stop, I would like you to maintain this force. While maintaining this force, I want you to match this contraction with the other hand, the matching hand. With the matching hand, gradually increase the force you exert until the effort you are putting into the contraction matches the effort you are putting into the other hand. Effort differs from force because we need to exert different efforts to exert the same force in different muscles, because some muscles are weaker than others, and we need to exert more effort to produce a given force when our muscles are tired. I'd like you to focus on the sensation of effort. In other words, slowly increase force with your matching hand until you are squeezing equally hard with both hands. Let me know when you think you are squeezing equally hard by saying "okay". I'll then tell you to relax your hands. Any questions?". These instructions were followed by four practice trials, and 12 experimental trials. There was a 15-second break between trials to avoid muscle fatigue. For half of the trials, the left hand was the matching hand, while the right hand matched on the other half of the trials. Left and right hand matching trials alternated to reduce muscle fatigue. Three criterion forces were used, approximating: 10%, 30%, and 50% of maximal

force as per the Lafague et al (2003) study. Left and right matching hand trials contained equal numbers of 10, 30, and 50% trials. The practice portion consisted of two trials at 10% and two at 50%. The experimental portion consisted of four trials each at 10%, 30%, and 50%. Trials at these three levels occurred in a pseudo-random order to reduce the chance that the participant would notice repeated criterion levels. Pilot testing highlighted the difficulty of stopping participants at exactly the desired criterion force. Thus, a stop by the participants within 5 pounds of the criterion force was deemed acceptable, and the criterion force achieved was recorded by the experimenter along with the matching force.

Force Rating Task

For this task, the participant put forward a force with the reference hand of 10%, 30%, or 50% in the same way as in the Force Matching task. The participant was then asked to rate the force applied as a percentage of maximum force as they maintain the force. The following instructions were given: "Now I'm going to ask you to squeeze with one hand, but this time, I want you to rate the percentage of maximum effort you are putting in. So I'm going to ask you to gradually increase force with one hand, then I'll tell you to stop, then rate the percentage of maximum effort, then I'll tell you to relax. Any questions?" As in the Force Matching task, right and left reference hand trials were interspersed, and trials at the three levels occurred in a pseudo-random order to reduce the chance that the participant would notice repeated criterion levels. As in the Force Matching task,

a stop by the participants within 5 pounds of the criterion force was deemed acceptable, and the criterion force achieved was recorded.

Movement Matching Task

For the Movement Matching task, a ruler was placed on the table in front of the participant, perpendicular to the edge of the table and in line with the center of the participant's body. The following instructions were given: "First I'd like you to bring your chair right up to the table so that your stomach is almost touching it. Sit with your back straight and resting against the back of the chair and your feet resting comfortably on the ground. While keeping your back straight, I'd like you to reach both arms out in front of you and touch the sides of the ruler with both index fingers. Reach as far up the ruler as you can while keeping your back resting against the chair." After recording maximum reach, the test administrator calculated the forces corresponding to 10%, 30%, and 50% of the maximal reach. The following instructions were then given: "From now on in the experiment you'll have to keep your eyes closed. Now I'm going to move one of your arms up the ruler so that your index finger touches a certain spot. Then I'll ask you to move the other arm to the same distance by sliding your index finger up the ruler." These instructions were followed by four practice trials, and 12 experimental trials. For half of the trials, the left hand was the matching hand, while the right hand matched on the other half of the trials. Left and right hand matching trials alternated. Three criterion forces were used, approximating 10%, 30%, and 50% of maximal force. Left and right matching hand trials contained equal numbers of 10, 30, and 50% trials. The practice portion consisted of two

trials at 10% and two at 50%. The experimental portion consisted of four trials each at 10%, 30%, and 50%. Trials at these three levels occurred in a pseudo-random order to reduce the chance that the participant would notice repeated criterion levels. The distance of the matching hand from the edge of the table was recorded by the experimenter.

Movement Rating Task

For this task, the participant's arm was moved to 10%, 30%, or 50% of maximal reach in the same way as in the Force Matching task. The participant was then asked to rate reach distance as a percentage of maximum reach. The following instructions were given: "Once again I'd like you to reach both arms out in front of you, touching the sides of the ruler with both index fingers, and reach as far up the ruler as you can while keeping your back straight. I'd like you to remember this distance as 100% of your maximum reach. Now put both fingers at the bottom of the ruler, at the edge of the table. I'd like you to consider this 0% of your maximum reach. Now close your eyes. I'm going to move one of your arms up the ruler so that your index finger touches a certain spot. Then, I'd like you to rate the percentage of your maximum reach at this spot." As in the Movement Matching task, right and left reference hand trials were interspersed, and trials at the three levels occurred in a pseudo-random order to reduce the chance that the participant would notice repeated criterion levels. The practice portion consisted of two trials at 10% and two at 50%. The experimental portion consisted of four trials each at 10%, 30%, and 50%. Estimates of percentages of maximum reach were recorded.

Split-half reliability was calculated for the Grip Force Matching, Grip Force Rating, Movement Matching, and Movement Rating tasks using the data of the control group. For each of these tasks, there were four trials each at 10%, 30%, and 50% of maximum reach / force. The two trials of each level that occurred first contributed to one "form", whereas the last two trials of each level composed another "form". Scores from the two forms were correlated, and the Spearman-Brown Prophecy formula was applied to obtain an estimate of full-scale reliability. The reliability coefficients estimated for the Grip Force Matching, Grip Force Rating, Movement Matching, and Movement Rating tasks were 0.94, 0.87, 0.86, and 0.95, respectively.

A second reliability coefficient was calculated for each measure by correlating the average score at the 10% level with the average score at the 50% for each control participant. This calculation was performed test whether the high split-half reliability coefficients in the Rating tasks were due to the use of the anchoring and adjustment heuristic. That is, participants may have made initial estimates of percentage of force/reach for each level (10/30/50%) arbitrarily, for example, guessing "20" for the initial 10% trial, "44" for the initial 30% trial and "70" for the initial 50% trial. Estimates for the following 10%, 30%, and 50% trials may have been based on these initial anchor points, rather than on an accurate appreciation of percentage of force/reach.

The Spearman-Brown prophecy formula was applied to each reliability coefficient calculated in this way in order to increase comparability with the split-half reliabilities described above. The reliability coefficient for the rating tasks

were low, the Grip Force Rating task with a coefficient of 0.32 and the Movement Rating task with a coefficient of -0.18 . In contrast, reliability coefficients for the Grip Force Matching and Movement Matching tasks were 0.68 and 0.86, respectively. This suggests that the Rating tasks may have inadequate reliability, while the Matching tasks demonstrate acceptable reliability.

Percentage Recognition Task

For this task, stimulus cards developed by the experimenter were employed. First, a card with two lines marked as 0% and 100% was presented. The following instructions were given: "I'd like you to consider this line 0% and this line 100%. I'll show you a line between these two and I'd like you to say what percentage you think it represents." Next, a series of cards representing 10%, 30%, and 50% were presented. The practice portion consisted of two trials as 10% and two at 50%. The experimental portion consisted of four trials each at 10%, 30%, and 50%.

Procedure

Two groups of patients, those with any of the symptoms of interest (patient experimental group), and those without any of the symptoms of interest (patient control group) were formed based upon patients' SSPI scores and answers to the Symptom Questions. The criterion for inclusion in the patient experimental group was an answer on either of the two instruments indicating that a patient had suffered from hallucinations, delusions of control, or thought insertion within the past two weeks. For the SSPI, scores of 2 or higher on the Schneiderian or

Hallucinations ratings could qualify a patient for the patient experimental group. However, if a score of 2 or higher was achieved only on the Schneiderian scale, the patient was placed in the patient experimental group only if their self-reported symptoms included delusions of control and/or thought insertion. For the symptom questions, an affirmative answer to any of the questions, and a frequency estimate indicating that the patient had experienced the symptom in the past two weeks placed the patient in the patient experimental group.

After giving informed consent, all patients were administered the SSPI in a first session. In a second session (corresponding to the first session for controls), participants were first administered the NAART (Blair & Spreen, 1989). Participants then completed the Force Matching and Movement Matching tasks, in an order dictated by a counterbalancing procedure. This was followed by the administration of the Force Rating and Movement Rating tasks. Participants who first completed the Force Matching task were also administered the Force Rating task first, while participants who first completed the Movement Matching task were administered the Movement Rating task before the Force Rating task. This was followed by the administration of the Percentages task. Patients were then administered the BCIS and Symptom Questions. All groups then completed the Health Questionnaire.

Data Analysis

For the Force Matching, Movement Matching, Force Rating, and Movement Rating tasks deviation scores were calculated for each experimental trial, representing the absolute value of the difference between the criterion

force/distance/percentage and the force/distance/percentage given by the participant. For each participant, an average deviation score was calculated for each task. A between groups ANOVA was employed to test for significant differences between the control, patient control, and patient experimental groups in terms of performance on these four tasks. Tests of homogeneity of variance were conducted. If significant differences were observed for a given dependent measure, the Welch statistic was also calculated to test for mean differences across groups. As the distribution of scores in the patient experimental group was skewed on several tasks, a Kruskal-Wallis test was also employed to test for differences between groups. In the case of a significant F ratio / chi-square, follow-up post-hoc tests were used to test the hypothesis that the patient experimental group obtained higher deviation scores than both patient controls and healthy controls.

To evaluate the hypothesis that insight is related to self-monitoring and integration impairment, Spearman correlations between BCIS scores and Force Rating/Force Matching deviation scores were calculated, using all patients.

One-way ANOVAs or Chi-square tests (as appropriate) were used to check for significant differences in age, gender, parental education, and premorbid intelligence between groups. Where such a difference was indicated, the corresponding variable was entered as a covariate, and the analyses re-run. Chlorpromazine equivalent medication doses were calculated for each patient (Bezchlibnyk-Butler & Jeffries, 2005). A t-test was used to check for a between difference patient groups on this measure of cholinergic load.

RESULTS

Although a recruitment of an even number of patients in each group was attempted, in two cases, symptoms of interest were not identified until the administration of the Symptom Questions. Thus, 14 patients were placed in the “patient experimental group”, and 10 were placed in the “patient control group”. There were 12 healthy control participants. Demographic information is summarized in Tables 2 and 3. There was a significant difference in NAART scores between groups ($F = 3.98, p = .03$). Post-hoc tests revealed a significant difference in NAART scores between the patient experimental and healthy control groups ($t = -2.8, p = 0.01$), while all other tests were non-significant (see table 4). Sex, number of years of parental education, and age did not significantly differ across groups. There was a significant difference between patient groups in terms of cholinergic load, with the patient experimental group receiving greater chlorpromazine-equivalent doses ($t = 2.1, p = 0.049$).

Performance across groups on the primary experimental tasks is summarized in Table 5. Histograms displaying the distributions of scores in each group, for each task are displayed in Appendix B. Boxplots for each task are displayed in Appendix C. There appeared to be an outlier on the Force Matching task, as subject 16 obtained a score more than 2 standard deviations away from the group mean. Additionally, an outlier was noted on the Force Rating task, as

Table 2. Patient Demographics

Means are presented, with standard deviations in parentheses. Where data is missing, the number of observations is also reported in parentheses.

	Diagnosis (# schizophrenic / # schizoaffective)	Reality Distortion (SSPI)	Disorganized Symptoms (SSPI)	Psychomotor Poverty (SSPI)	Age of onset	Meds: CPZ equivalent
all patients (n = 24)	11/13	3(2.7)	1.3(1.3)	2(2.4)	20.5(6.6) (n = 20)	546(463) (n = 22)
patient exp (n = 14)	8/6	4.9(1.8)	1.8(1.3)	1.7(1.9)	20.1(6.4) (n = 12)	690(498)
patient control (n = 10)	3/7	0.5(1.3)	0.5(0.8)	2.6(3)	21(7.3) (n = 8)	292(256) (n = 8)

Table 3. Patient and Control Demographics

	Controls (n = 11)	Patient experimental (n = 14)	Patient control (n = 10)	F/chi-square value, sig
NAART*	109.6(10.5)	99(9.5)	101(10.5)	3.98, 0.03
AGE	39.5(16.5)	33.6(12.4)	37.9(13.2)	0.6, 0.55
SEX(m/f)	6/6	10/4	9/1	4.16, 0.13
PARENTAL EDUCATION (yrs)	13.5(3.7)	11.6(2.1)	12.1(1.1)	1.67, 0.2

*p<0.05 for one-way ANOVA, or chi-square, as appropriate

Table 4. NAART Tests – Post Hoc

Comparison	t-test value (sig)
Patient cont vs. patient exp	t = 0.5 (p = 0.62)
Patient cont vs. healthy cont	t = -2 (p = 0.06)
Patient exp vs. healthy cont	t = -2.8 (p = 0.01)

Table 5. Performance on experimental tasks

	Patient experimental	Patient control	Healthy control	F-value
Force Match	11.5(7.4)	8.8(3.7)	8.3(2.7)	1.3 (p=.28)
Force Rate	18.8(9.4)	12.8(5)	18.9(5.6)	2.6 (p=.09)
Movement Match	1.3(0.7)	1.2(0.2)	1.4(0.6)	.3 (p=.75)
Movement Rate	10.4(4.1)	11.8(5)	8.5(4)	1.6 (p=.21)
Percent Recognition	2.8 (1.8)	3.0 (2.3)	1.9 (1.7)	.84 (p=.4)

subject 24 obtained a score more than 2 standard deviations away from the group mean. These subjects were not initially excluded.

One-way ANOVA revealed no significant differences across groups on any of the experimental tasks (Table 5). Similar results were obtained after covarying for NAART scores (Table 6). As the distribution of patient experimental group scores was skewed for the Force Matching, Movement Matching, and Force Rating tasks, the nonparametric Kruskal-Wallis test was also used. This test suggested no significant differences between groups at the alpha = .05

Table 6. One way ANOVA results, after co-varying for NAART scores

	F-value
Force Match	1.2 (p = .34)
Force Rate	2.5 (p = .08)
Movement Match	.23 (p = .88)
Movement Rate	1.2 (p = .32)
Percent Recognition	.86 (p = .47)

Table 7. Kruskal-Wallis tests

	Chi-square
Force Match	.83 (p = .66)
Force Rate	5.75 (p = .06)
Movement Match	1.28 (p = .53)
Movement Rate	2.56 (p = .28)
Percent Recognition	1.23 (p = .54)

Table 8. Follow-up comparison: Patient experimental vs. Patient control

	Mann-Whitney U (one-tailed p)
Force Match	59 (p = .27)
Force Rate	40.5 (p = .04)
Movement Match	55 (p = .2)
Movement Rate	62 (p = .33)

Table 9. Follow up comparison: Patient experimental vs. Healthy control

	Mann-Whitney U (one-tailed p)
Force Match	67 (p = .2)
Force Rate	71 (p = .26)
Movement Match	64.5 (p = .16)
Movement Rate	61.5 (p = .13)

level. However, the chi-square value for the comparison of groups on the Force Rating task was 5.75 (p = 0.06) (Table 7). Given this statistical trend, and skewness in the patient experimental group, follow-up one-tailed Mann-Whitney U tests were conducted to test the hypothesis that the patient experimental group obtained higher deviation scores than both patient controls and healthy controls. For the comparison of the patient control and patient experimental groups, Mann-Whitney U = 40.5, one-tailed p = .042, indicating that patient experimental group obtained higher deviation scores than the patient control group (Table 8). When the previously mentioned outlier (point 24) was excluded from the analysis, the difference between groups was no longer significant (Mann-Whitney U = 40.5, one-tailed p = .065). For the comparison of the patient experimental group and

the healthy control group, Mann-Whitney $U = 70$, $p = 0.73$, indicating no significant difference in deviation scores between groups (Table 9). When point 24 was excluded, a similar result was obtained (Mann-Whitney $U = 59$, $p = 0.16$). Given the possible mean difference between the two patient groups and the similar performance of the patient experimental group to the healthy control group, a follow-up two-tailed test comparing the two control groups on the Force Rating test was conducted. The patient control group performed significantly worse than the healthy control group on the task (Mann-Whitney $U = 24.5$, $p = .02$).

In order to investigate whether deficits in self-monitoring are associated with decreased insight, Force Matching and Force Rating deviation scores were correlated with the three BCIS scores (Table 10). No statistically significant relationships were observed.

In further exploratory analysis, the SSPI scales of Reality Distortion, Psychomotor Poverty and Disorganization, and the BCIS Composite were correlated with performance on Grip Force Matching, Grip Force Rating, Movement Matching, and Movement Rating (Table 11). No statistically significant correlations between these variables were observed.

Table 10. BCIS Spearman's correlations (n = 24)

	BCIS Composite	BCIS reflectiveness	BCIS self-certainty
Force Match	$r = .02$ ($p = .9$)	$r = .1$ ($p = .65$)	$r = .2$ ($p = .34$)
Force Rate	$r = .21$ ($p = .33$)	$r = .31$ ($p = .13$)	$r = .13$ ($p = .55$)

Table 11. Symptoms and Experimental Task Performance (Spearman's r_s , n = 24)

	Force Matching	Force Rating	Movement Matching	Movement Rating
BCIS Composite	$r = .02$ ($p = .9$)	$r = .21$ ($p = .33$)	$r = .34$ ($p = .11$)	$r = -.21$ ($p = .33$)
SSPI – reality distortion	$r = -.18$ ($p = .4$)	$r = .21$ ($p = .32$)	$r = -.1$ ($p = .65$)	$r = .14$ ($p = .51$)
SSPI – psychomotor poverty	$r = .34$ ($p = .11$)	$r = -.16$ ($p = .44$)	$r = .11$ ($p = .62$)	$r = -.26$ ($p = .22$)
SSPI – disorganization	$r = .14$ ($p = .51$)	$r = .24$ ($p = .27$)	$r = .13$ ($p = .55$)	$r = .28$ ($p = .19$)

DISCUSSION

The current study was conducted in order to test Frith's self-monitoring theory of delusions of control, thought insertion, and auditory hallucinations. Frith hypothesized that a breakdown in the efference copy pathway, leading to a lack of sense of effort associated with one's movements, causes these symptoms. While past studies provided some support for this theory, the possible confound of differential proprioceptive abilities in patients with the symptoms of interest had not previously been addressed. In the current study, a self-monitoring task that appears to be performed solely on the basis of efference copy information was employed (Grip Force Matching). Additionally, a test of proprioception that is not performed based on efference copy information was given (Movement Matching). Results indicated that patients with the symptoms of interest do not differ from other patients or healthy controls in terms of proprioception ability or efference copy pathway integrity. Thus, while past findings relating self-monitoring and the symptoms of interest were not likely a result of differential proprioceptive ability, they were also not likely the result of simple efference copy disconnection.

Unlike past studies that have provided the strongest evidence for self-monitoring impairment in patients with auditory hallucinations, delusions of control and thought insertion (eg. Blakemore et al, 2000, Daprati et al, 1997), the current study employed a non-self-report task (Force Matching). While past self-monitoring studies have tapped into the patient's subjective conscious

experience by obtaining ratings of the intensity of sensation, and encouraging attributions of hand movement ownership to the self or others, the current study required a demonstration of self-monitoring on a more implicit, non-conscious level through the use of the Force-Matching task. The results of the current study appear consistent with past attempts to tap into more implicit self-monitoring processes (eg. Kopp and Rist, 1994), and suggest that implicit self-monitoring is unimpaired in patients with the symptoms of interest.

In addition to exploring implicit self-monitoring, the current study attempted a clarification of the nature of the subjective experience associated with self-monitoring in patients with the symptoms of interest through the use of the Force Rating task. According to Frith's theory, the symptoms of interest are produced by awareness of one's own actions in the absence of an accompanying sense of effort. In constructing the Force Rating task, the absence of a sense of effort was operationally defined as poor conscious appreciation of the magnitude of force applied. Results did not reveal poorer performance in the symptoms-of-interest group on the Force Rating task. This finding suggests that conscious self-monitoring deficits in patients with the symptoms of interest are not mediated by sense of effort abnormalities.

The overall picture of patients with the symptoms of interest appears to be one of abnormality in subjective sensation and attributions of ownership, and normal conscious and implicit awareness of efference copy information. This picture is consistent with a biased-based rather than a self-monitoring-based account of these symptoms. Patients experience self-produced stimulation as

higher in subjective intensity than controls because of an information processing bias towards external sensation, and patients make misattributions regarding action ownership for the same reason. In terms of a delusion of control experience, for example, a strong focus on proprioceptive sensation (an external sensation) as the patient moves his/her hand could lead to the subjective experience of externally controlled hand movement. This bias account differs from the self-monitoring account, as it does not imply that the abnormal experience of sensation results from a disconnection of internal, or efference copy-mediated, experience. Therefore, in situations in which the patient is asked to perform tasks that demand a focus on internal, efference-copy information, such as in the current study, the patient is able to shift focus and attend to such information. Further support for this bias-based account could be provided by studies demonstrating that patients can attenuate sensory input from self-movement when the task demands a focus on internal information. For example, if patients are encouraged to attend to their moving hand in the Blakemore et al (2000) study by producing a given applied force on the mechanism, will ratings of ticklishness decrease?

It could be argued that differences between patient groups on the experimental tasks in the current study could have reached the level of statistical significance had the sample size been larger. The difference between patient groups on the Force Matching task, a measure dependent on the implicit sense of effort, corresponds to a small-moderate effect size ($d = .43$). Removal of an outlier (subject 16) reduces this effect size to $d = .22$. It could be argued that

such small effects might become significant with greater sample size. However, the primary aim of the current study was to determine whether past large effect size findings relating self-monitoring to particular symptoms of schizophrenia could be accounted for through deficits tapped by the tasks used in the current study. The lower effect size difference on Force Matching cannot likely account for past large-effect size findings. When a patient group with the symptoms of interest was compared to a control group in the study of Daprati et al (1997), a large effect size was found ($d = 1.5$). In the current study, the comparison of the patient experimental group to the control group yields an effect size of $d = .56$, with a 95% confidence interval of -0.24 to 1.36 . When the outlier is removed, $d = .4$ with a 95% confidence interval of $-.39$ to 1.2 . Thus, the deficit underlying previously detected differences between patients with the symptoms of interest and controls is unlikely to be solely due to a deficit in the implicit self-monitoring, as measured by the Force Matching task. This effect-size based analysis is valid to the extent that the task used in the Daprati et al. (1997) study is of similar reliability to the Force Matching task. Unfortunately, reliability information is not reported for the Daprati et al. (1997) task.

An even larger difference between patient groups was observed for the Force Rating task, and this difference was statistically significant (Mann-Whitney $U = 40.5$, one-tailed $p = .042$), although not after removal of an outlier (Mann-Whitney $U = 40.5$, one-tailed $p = .065$). However, the difference between the patient experimental group and the healthy control group was non-significant, and of very small effect size ($d = .06$). This finding suggests increased conscious

self-monitoring ability in the patient control group as compared to the patient experimental group and the healthy control group. This result should be interpreted with caution, however, due to the lower reliability of the Force Rating task.

It is possible that the manner in which the patient groups were formed was not optimal for evaluating the relationship between self-monitoring ability and symptoms. Patients were grouped based upon symptoms experienced in the last two weeks, such that the relationship between *current* symptoms and self-monitoring ability was examined. Self-monitoring ability was assumed to represent a state-related variable, and it was thought that periods of decreased self-monitoring ability may lead to the symptoms of interest. It may be the case, however, that self-monitoring ability expresses a more trait-related variable that bears a stronger relationship to the symptoms of interest. Perhaps life-long poor self-monitoring ability, dictated by genetic factors, predisposes one to occasionally experience the symptoms of interest. If this were the case, patients who had experienced the symptoms of interest at any point in the past would be expected to display poorer self-monitoring than patients who had never experienced the symptoms of interest. In the current study, the patient control group was presumably composed of both patients who had and had not experienced the symptoms of interest in the past, such that the current analysis was less sensitive to a relationship between trait-related self-monitoring ability and the symptoms of interest. On the other hand, if it is assumed that greater a self-monitoring deficit represents greater genetic predisposition to experiencing

the symptoms of interest, it might be predicted that greater a self-monitoring deficit would lead to greater symptom frequency. This leads to a prediction regarding the data of the current study, as patients with a higher frequency of the symptoms of interest were more likely to be placed in the patient experimental group than patients with a lower frequency of the symptoms of interest. The patient experimental group, however, did not show reduced self-monitoring ability, providing some evidence arguing against a symptom-frequency-linked, trait-related deficit in self-monitoring.

REFERENCES

- American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Authors.
- Basso, M.R., Nasrallah, H.A., Olsen, S.C., & Bornstein, R. A. (1998). Neuropsychological correlates of negative, disorganized and psychotic symptoms in schizophrenia. *Schizophrenia Research*, *31*, 99-111.
- Beck, A. T., Baruch, E., Balter, J. M., Steer, R. A., Warman, D. M. (2004). A new instrument for measuring insight: the Beck Cognitive Insight Scale. *Schizophrenia Research*, *68*, 319-329.
- Bezchlibnyk-Butler, K. Z., & Jeffries, J. J. (Eds.) (2005). *Clinical handbook of psychotropic drugs* (15th ed.). Seattle, WA: Hogrefe & Huber.
- Blair, J.R. & Spreen, O. (1989). Predicting premorbid IQ: A revision of the National Adult Reading Test. *The Clinical Neuropsychologist*, *3*, 129-136.
- Blakemore, S.J. & Frith, C.D. (2003). Self-awareness and action. *Current Opinion in Neurobiology*, *13*, 219-224.
- Blakemore, S.J., Smith, J., 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.
- Chapin, K.J., Rosenbaum, G. & Fields, R.B. (1996) Multiple deficit theory of schizophrenia: Incidence of markers vs. symptoms. *Journal of Clinical Psychology*, *52*(2), 109-123.
- Daprati, E., Franck, N., Georgieff, N., Proust, J., Pacherie, E., Dalery, J., et al. (1997). Looking for the agent: An investigation into consciousness of action and self- consciousness in schizophrenic patients. *Cognition*, *65*, 71-86.
- Donohoe, G., & Robertson, I.H. (2003). Can specific deficits in executive functioning explain the negative symptoms of schizophrenia? A review. *Neurocase*, *9*(2), 97-108.

- Erwin, B.J. & Rosenbaum, G. (1979) Parietal lobe syndrome and schizophrenia: Comparison of neuropsychological deficits. *Journal of Abnormal Psychology, 88*(3), 234-241.
- Farrer, C., Franck, N., Paillard, J., & Jeannerod, M. (2003). The role of proprioception in action recognition. *Consciousness and Cognition, 12*, 609-619.
- Fleury, M., Bard, C., Teasdale, N., Paillard, J., Cole, J., Lajoie, Y., et al. (1995) Weight judgment: The discrimination capacity of a deafferented subject. *Brain, 118*, 1149-1156.
- Frith, C. (1992). *The cognitive neuropsychology of schizophrenia*. Cambridge: Oxford University Press.
- Frith, C., & Done, J. (1989). Experiences of alien control in schizophrenia reflect a disorder in the central monitoring of action. *Psychological Medicine, 19*, 359-363.
- Gandevia, S.C. (1996). Kinesthesia: Roles for afferent signals in motor commands. In L. Rowell & J. Shepherd (Eds.), *Handbook on integration of motor, circulatory, respiratory, and metabolic control during exercise* (pp. 128-172). Bethesda, MA: American Physiological Society.
- Goodman, C., Knoll, G., Isakov, V. & Silver, H. (2005). Insight into illness in schizophrenia. *Comprehensive Psychiatry, 46*(4), 284-290.
- Goodwin, G.M., McCloskey, D.I., & Matthews, P.B.C. (1972). The contribution of muscle afferents to kinaesthesia shown by vibration induced illusions of movement and by the effects of paralyzing joint afferents. *Brain, 95*, 705-748.
- Gregory, J.E., Brockett, C.L., Morgan, D.L., Whitehead, N.P., & Proske, U. (2002). Effect of eccentric muscle contraction on Golgi tendon organ responses to passive and active tension in the cat. *Journal of Physiology (London), 538*, 209-218.
- Heinrichs, R.W. (2001). *In search of madness: Schizophrenia and neuroscience*. New York: Oxford University Press.
- Heinrichs, R.W., & Zakzanis, K.K. (1998). Neurocognitive deficit in schizophrenia: A quantitative review of the evidence. *Neuropsychology, 12*(3), 426-445.
- Kaufman, A.S., & Kaufman, N.L. (2004). *Kaufman Brief Intelligence Test, Second Edition*. Circle Pines, MN: American Guidance Service.

- Kopp, B., & Rist, F. (1994). Error-correcting behavior in schizophrenic patients. *Schizophrenia Research, 13*, 11-22.
- Lafargue, G., Paillard, J., Lamarre, Y. & Sirigu, A. (2003). Production and perception of grip force without proprioception: Is there a sense of effort in deafferented subjects? *European Journal of Neuroscience, 17*, 2741-2749.
- Leventhal, D.B., Schuck, J.R. & Clemons, J.T. (1982) Proprioception in schizophrenia. *Journal of Nervous and Mental Disease, 170*(1), 21-26.
- Lezak, M.D., Howieson, D.B. & Loring, D.W. (2004). *Neuropsychological Assessment (4th Ed)*. New York, NY: Oxford Press.
- Liddle, P.F., Ngan, E.T.C., Duffield, G., Kho, K., & Warren, A.J. (2002). Signs and Symptoms of Psychotic Illness (SSPI): A rating scale. *British Journal of Psychiatry, 180*, 45-50.
- Malenka, R., Angel, R., Hampton, B., & Berger, P. (1982). Impaired central error Correcting behavior in schizophrenia. *Archives of General Psychiatry, 39*, 101-107.
- McCloskey, D.I. (1981) Corollary discharges: Motor commands and perception. In J. Brookhart, V. Mountcastle, V. Brooks, & S. Geiger (Eds) *Handbook of Physiology, Section 1: The nervous system*. Bethesda, MA: American Physiological Society.
- McCloskey, D.I., Ebeling, P. & Goodwin, G.M. (1974) Estimation of weights and tensions and apparent involvement of a 'sense of effort'. *Experimental Neurology, 42*, 220-232.
- Ritzler, B. & Rosenbaum, G. (1974) Proprioception in schizophrenics and normals: Effects of stimulus intensity and interstimulus interval. *Journal of Abnormal Psychology, 83*(2),106-111.
- Stirling, J.D., Hallewell, J.S.E., & Ndlovu, D. (2001) Self-monitoring dysfunction and the positive symptoms of schizophrenia. *Psychopathology, 34*, 198-202.
- Weerakkody, N., Percival, P., Morgan, D.L., Gregory, J.E. & Proske, U. (2003) Matching different levels of isometric torque in elbow flexor muscles after eccentric exercise. *Experimental Brain Research, 149*(2), 141-150.

APPENDICES

Appendix A. SSPI Information

Two SSPI subscales (Hallucinations, Scheiderian Delusions) and three summary scales (Psychomotor Poverty, Reality Distortion, and Disorganization) were used in the current study. The relevant mandatory questions, as well as criteria for scoring each scale, are as follows:

Hallucinations

Relevant questions:

Do you hear voices even when there is nobody else there?

Criteria:

0. Absent
1. Vague descriptions of hallucinations; hypnogogic or hypnopompic hallucinations; illusions with insight.
2. Hallucinations which the patient accepts as arising from within his/her own mind, or illusions without insight.
3. Definite hallucinations occurring occasionally (eg. < once/day), and producing no substantial effects on behavior.
4. Definite hallucinations which are frequent and/or influence observable behavior.

Schneiderian Delusions

Relevant Questions:

Have you had any strange or unusual experience recently?

Can other people hear what you are thinking?

Does anything or anybody interfere with your thoughts?

Does any outside power or influence take control of you?

Criteria: delusions of control, thought insertion, thought withdrawal, thought broadcast, somatic passivity are rated on the following scale:

0. Absent
1. Vague idea which might be delusional; peculiar ideas which do not conflict with evidence in a clear-cut manner.
2. Belief contrary to evidence, but patient has partial insight in the unrealistic nature of the belief.
3. Definite delusions, but the delusional beliefs do not have a pervasive influence on thinking or behavior.
4. Definite delusion, which have a pervasive influence on thinking and/or influence observable behavior.

Psychomotor Poverty

This summary scale is computed by summing scores on the Underactivity, Flattened Affect, and Poverty of Speech Scales. Answers to all questions are relevant, as behavioral observation determines contributes to these scores.

Asking about daily activities contributes to Underactivity. The criteria for Underactivity follows:

0. Absent
1. Reports of mild apathy; questionable sluggishness at interview.
2. Reported periods of up to 1 hr sitting or lying unoccupied and/or clearly detectable lack of movement at interview.
3. Reports of periods of inactivity for many hours and/or only occasional changes of position or use of gesture at interview.
4. Reported to be active rarely unless prompted and virtually inert at interview.

The criteria for Flattened Affect follows:

0. Absent
1. Reserved manner near limit of normal range.
2. Noticeable decrease in intensity of emotional expression, but some animation is detectable some of the time, especially when personally important topics are discussed.
3. Only shows animation such as smiling or altering tone of voice two or three times during interview.
4. No substantial animation or expression of emotional involvement observed or elicited.

The criteria for Poverty of Speech follows:

0. Absent
1. Speech deficient in detail, near limit of normal range.
2. Abnormal brevity of replies such that interviewer needs to prompt for more information on several occasions.

3. Majority of utterances are no more than one brief sentence.
4. Majority of replies are single words or replies are absent; virtually no spontaneous speech.

Disorganization

The Disorganization Scale is computed by summing the Innapropriate Affect and Disordered Thought sub-scales. Answers to all questions are relevant, as behavioral observations contribute to these scores.

The criteria for inappropriate affect follow:

0. Absent
1. Giggles in a questionably understandable manner; mildly fatuous.
2. One instance of definite incongruity between affect and circumstances.
3. Several instances of definite incongruity during interview.
4. Displays incongruity at least once every 2 or 3 minutes.

The criteria for Disordered Thought are as follows:

0. Absent
1. Pedantic, stilted, or occasionally irrelevant speech.
2. At least on instance of definite tangentiality, derailment, incoherence, clanging, or markedly idiosyncratic word usage.
3. Communication substantially impaired due to tangentiality, derailment, incoherence, clanging or peculiar word usage, but at least half of utterances are comprehensible.
4. More than half of utterances are difficult to comprehend.

Reality Distortion

The Reality Distortion score is computed by summing the Hallucinations and Delusions sub-scales. Criteria for scoring delusions are listed above. Criteria for scoring hallucinations and delusions are listed above. Further questions relevant to delusions are as follows:

Have you any special abilities?

Are you a special person in any way?

Do people talk about you?

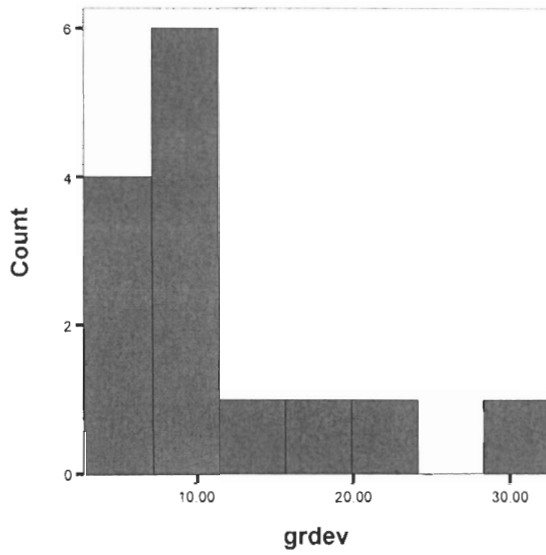
Has there been any reference to you on television?

Has anyone been trying to harm you?

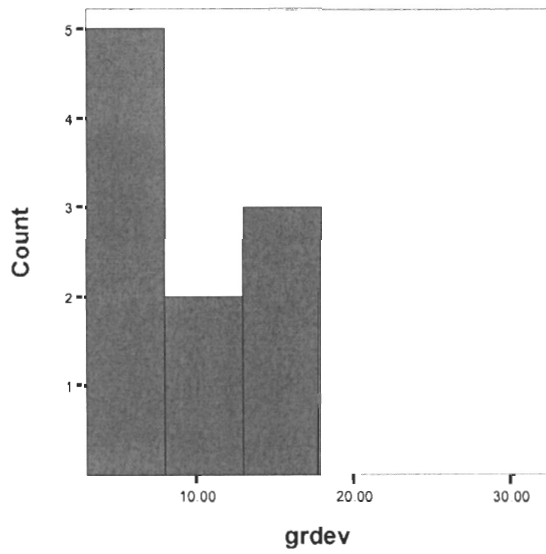
Appendix B. Histograms

Force Matching

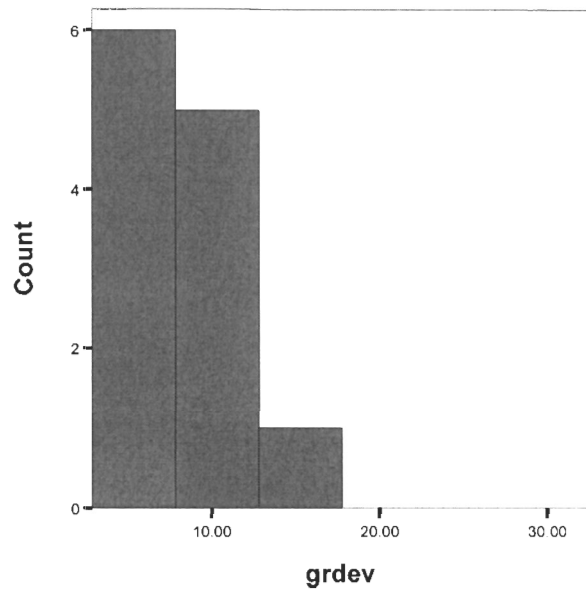
Patient Experimental



Patient control

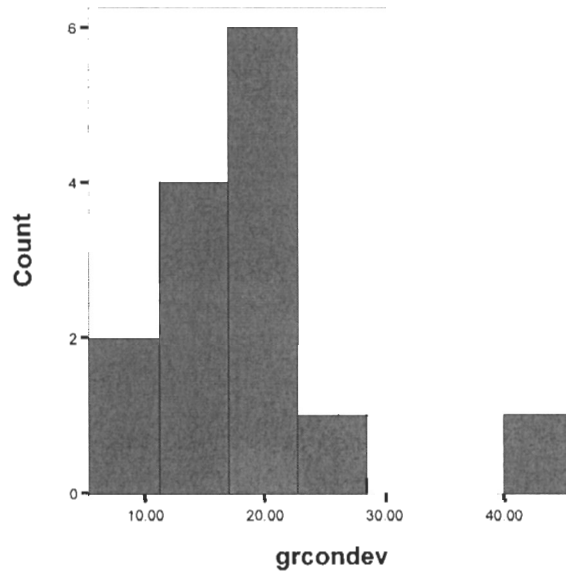


Normal control

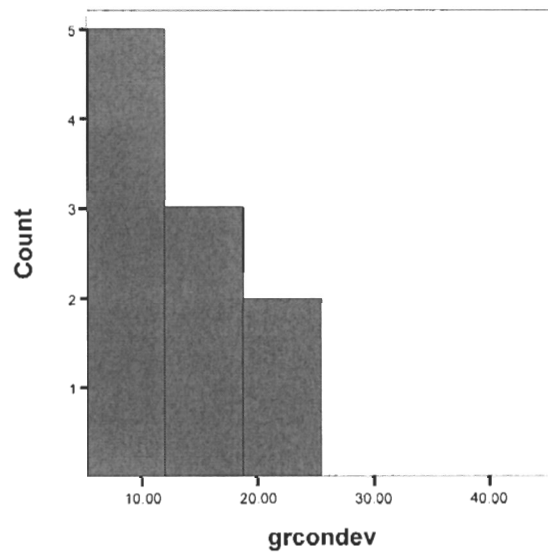


Force Rating

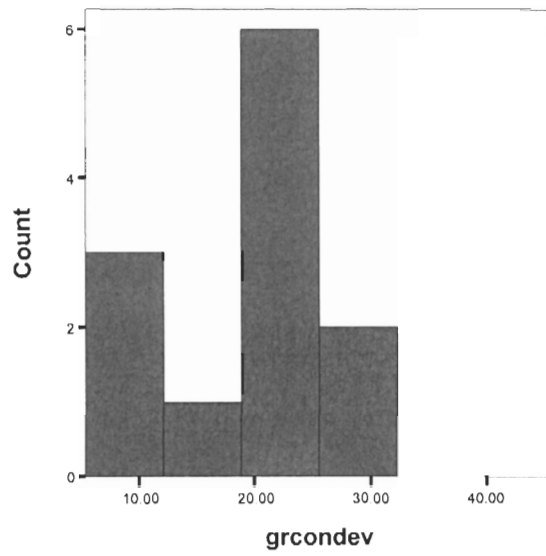
Patient Experimental



Patient Control

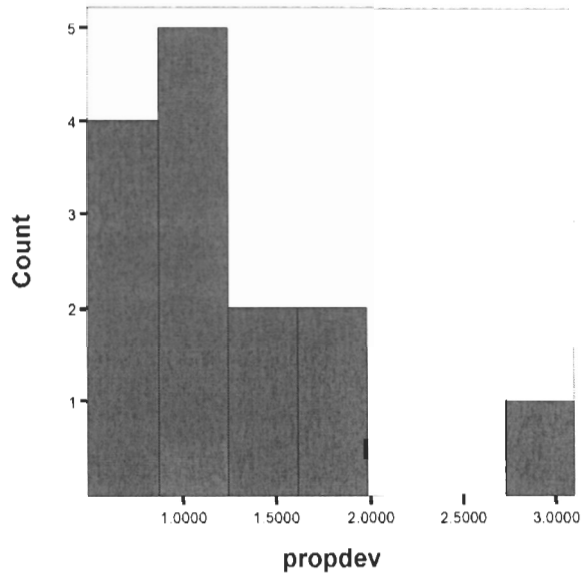


Healthy Control

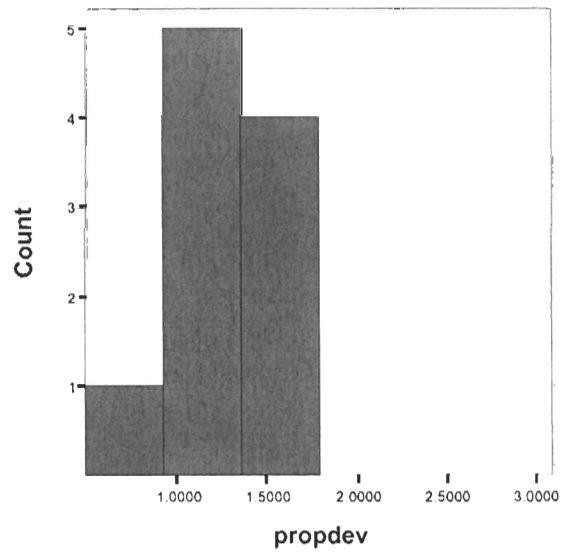


Movement Matching

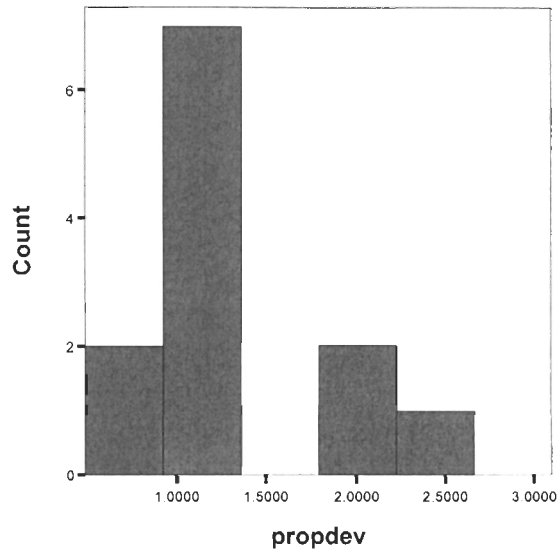
Patient experimental



Patient Control

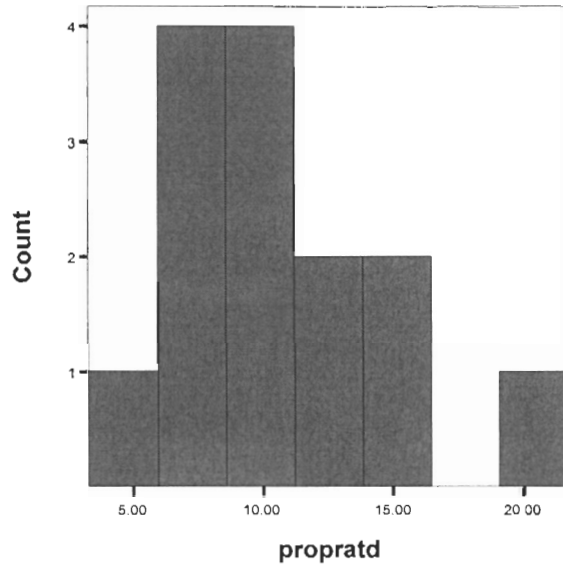


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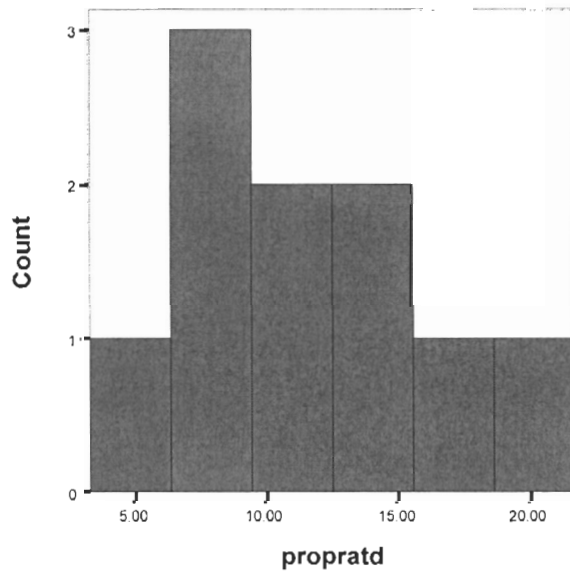


Force Rating

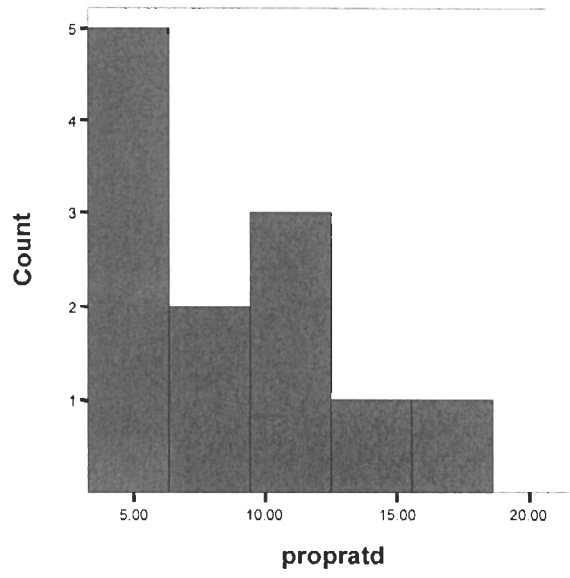
Patient experimental



Patient Control



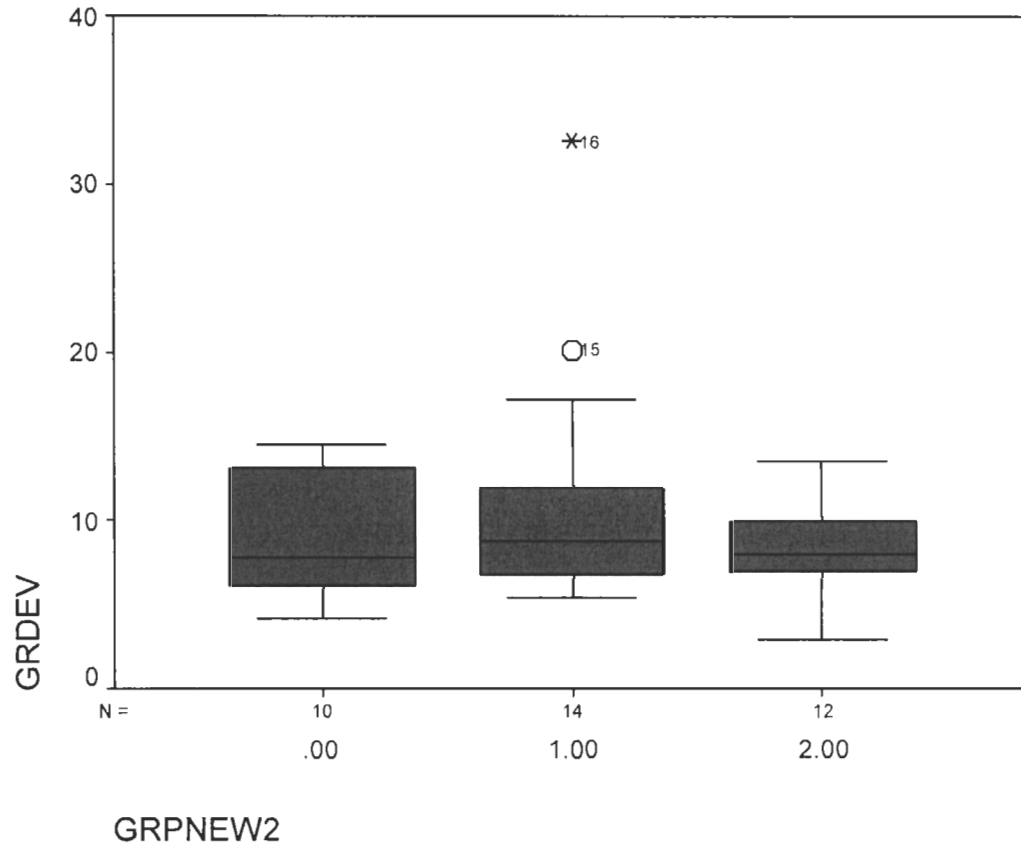
Healthy Control



Appendix C. Box-Plots

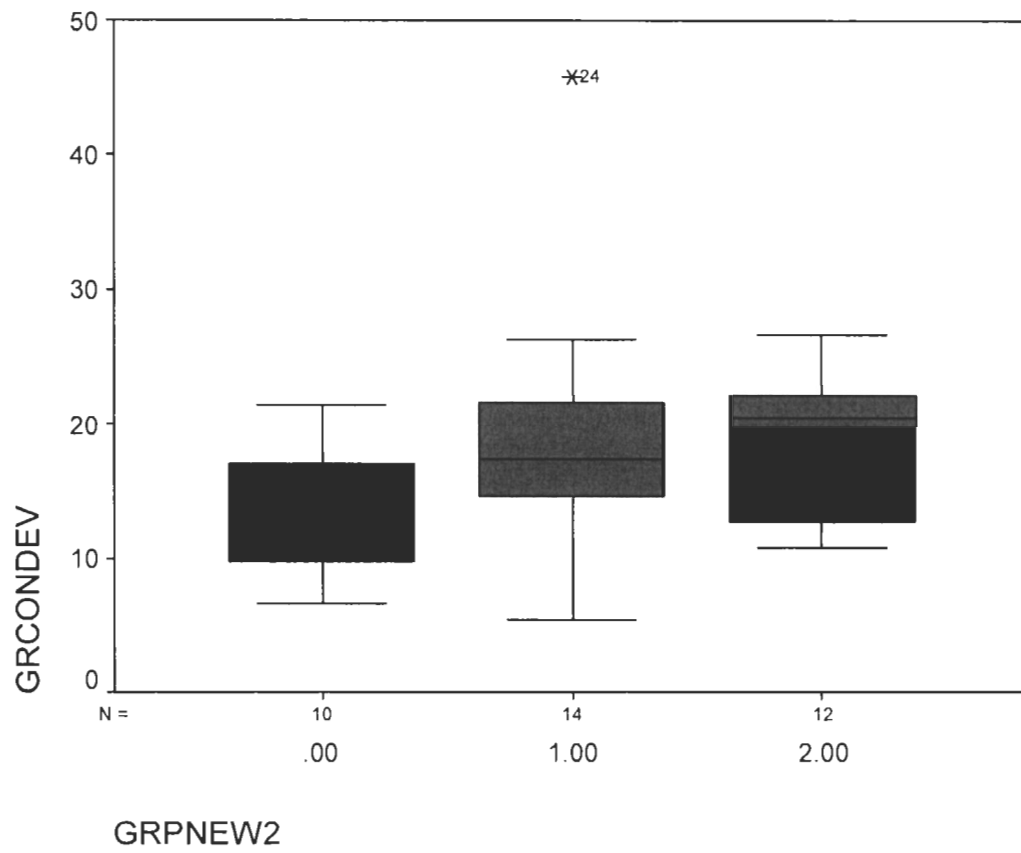
Force Matching

0 = patient control, 1 = patient experimental, 2 = healthy control



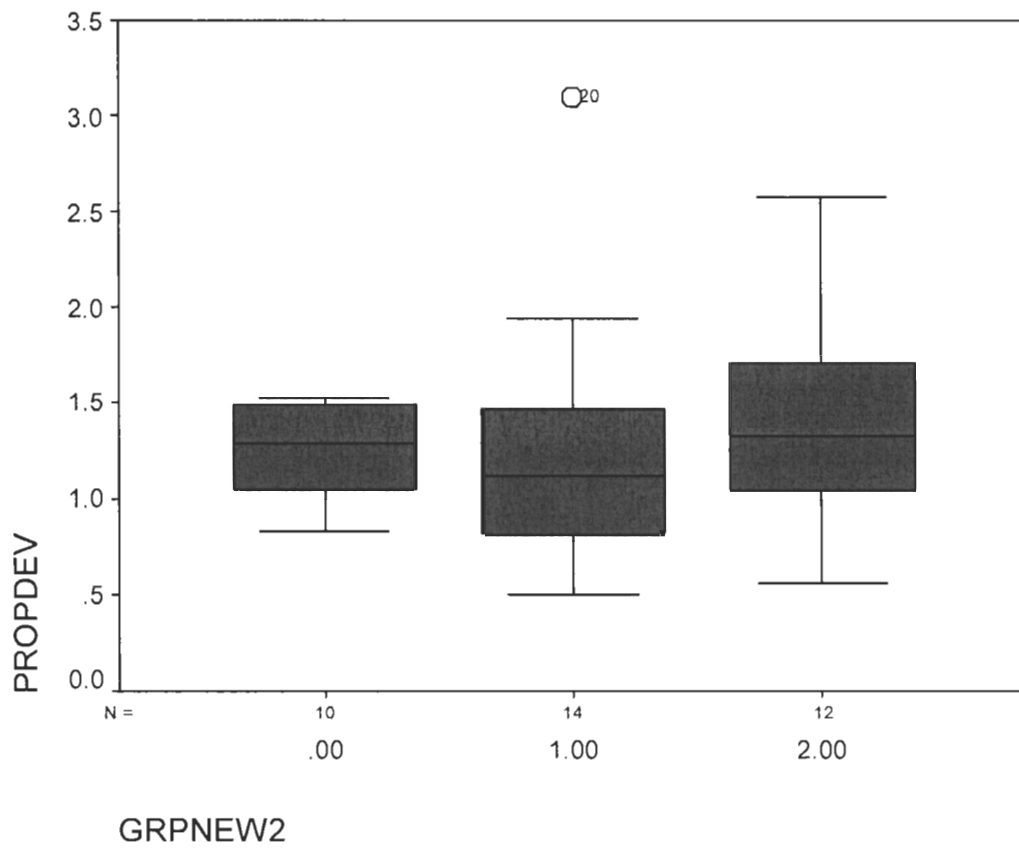
Force Rating

0 = patient control 1 = patient experimental 2 = patient control



Movement Matching

0 = patient control 1 = patient experimental 2 = patient control



Movement Rating

0 = patient control 1 = patient experimental 2 = patient control

