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Deeper into schizotypy and motor performance: Investigating the nature of motor control in a non-psychiatric sample

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Abstract

Numerous studies have demonstrated that motor control deficits are characteristic of patients diagnosed with schizophrenia and those at-risk for the development of the disorder. Recent advances in the quantification of motor dysfunction have confirmed this, but these methods fail to consider an important aspect of subject performance: the *qualitative* nature of their psychomotor dyscontrol. We report on a novel technique used to quantify the qualitative nature of psychomotor performance and its relation to schizotypy. Control ($n = 35$) and schizotypic subjects ($n = 47$) completed a line-drawing task that yields metrics for psychomotor control and predominant frequency. Schizotypes evidenced greater psychomotor dyscontrol and lower predominant frequencies than controls. These results are interpreted as evidence of reduced visual-motor integration, self-monitoring capacity, or adherence to basic motor principles in schizotypes. The potential use of these metrics as putative endophenotypes for the liability for schizophrenia and the implications of these findings for the relationship between schizophrenia and schizotypy are discussed.

Keywords

Schizotypy; motor control; action monitoring; visuomotor integration; schizophrenia; endophenotype

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Mark F. Lenzenweger co-designed the study, provided input on the predominant frequency analysis, oversaw all statistical analyses, and participated in the preparation of the manuscript.

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1. Introduction

Motor abnormalities have long been recognized as a feature of schizophrenia (Blueler, 1911/1950; Kraepelin, 1919/1971). Despite this, the laboratory study of motor control in patients diagnosed with schizophrenia did not begin in earnest until the early 1980s (Manschreck, 1986). Since then, numerous studies have demonstrated that both fine and gross motor abnormalities are present in patients with schizophrenia (Manschreck, 1986; Blyler et al., 1997), their first-degree biological relatives (Ballard, 2000; Erlenmeyer-Kimling et al., 2000), and people with schizophrenia-spectrum pathology (Cassady et al, 1998; Neumann and Walker, 1999; Neumann and Walker, 2003; Kaczorowski et al, 2009). Further, these abnormalities have been shown to antedate the onset of a first-episode of psychosis (Fish, 1977, 1987; Walker and Lewine, 1990) and the initiation of treatment with antipsychotic medication (Manschreck, 1986; Wolff and O'Driscoll, 1999), and to predict earlier diagnosis of schizophrenia in affected individuals (Manschreck et al., 2004). Importantly, such abnormalities also correlate with schizotypic features in non-clinical populations uncontaminated by medication, deterioration, and other variables associated with treated psychiatric illness (Lenzenweger and Maher, 2002; Kaczorowski et al, 2009). Given the nature, abundance, and strength of this evidence, motor control issues have been identified as a potentially important endophenotypic marker for the liability for schizophrenia (Gottesman and Gould, 2003; Chan and Gottesman, 2008; c.f., Lenzenweger, 2013).

One factor that limits the potential value of motor control data is the use of observer-rating methods. Generally, observer-rating methods require advanced training for valid and reliable assessment. However, even when well-trained, but non-expert raters are used in lieu of experts, research has demonstrated that these raters do not necessarily produce valid assessments of observationally-defined constructs (Hooley and Richters, 1991). Further, observational ratings are known to be subject to experimenter bias (see Rosenthal and Rosnow, 2008 for discussion). Finally, observer-rating methods produce ordinal-level data that are limited in their precision and therefore, may fail to identify subtle deficits and serve to limit the application of the statistical methods that can meaningfully be applied to them (Nunnally, 1978). Simple, objective, and truly quantitative measures of psychomotor control circumvent these issues and as such, are highly desirable (Lenzenweger, 2010).

One such measure is the Maher Line Drawing Task (Blyler et al., 1997). This fine motor control task requires participants draw four diagonal lines and then uses a regression procedure to objectively and precisely quantify the degree of motor deviance in those lines (Maher, 1993). The MLDT has been found to be related increased Parkinsonian symptoms and decreased integrative functions, but unrelated to dyskinetic movements in patients with schizophrenia (Blyler et al., 1997). Empirically, the MLDT has been used to distinguish patients diagnosed with schizophrenia (Blyler et al., 1997; Manschreck et al., 2004) and their first-degree biological relatives (Ballard, 2000) from control subjects, and the MLDT's motor control output variable has been found to correlate with multiple measures of positive schizotypy and schizophrenia proneness (Lenzenweger and Maher, 2002). Importantly, MLDT performance has been demonstrated to be independent of a variety of potentially

confounding variables (e.g. attentional deficits, age, symptom intensity, medication dosage) in non-clinical (Lenzenweger and Maher, 2002) and psychiatric samples (Manschreck et al., 2004).

While the MLDT confers many advantages over observer ratings, it is limited in that a potentially valuable aspect of motor performance goes unanalyzed: the qualitative nature of the motor performance. That is, different line patterns (e.g. arc, sine wave) can give rise to the same deviance value and the MLDT's output variables do not capture these differences. Evaluating this qualitative aspect of participant's lines quantitatively may thus provide important information about the nature (i.e. degree of tremulousness) and cause of their motor deviance and thereby increase the usefulness (e.g. predictive or discriminating power) of MLDT data.

In light of the above data, our purpose in conducting this study was twofold. First, we sought to extend the study of motor control in schizotypy by demonstrating that schizotypes (psychometrically-defined) have increased levels of psychomotor dyscontrol as compared to non-schizotypic control subjects. Lenzenweger and Maher's (2002) results suggest, but do not confirm this conjecture, thus inviting empirical study. We anticipated, building upon Lenzenweger and Maher (2002), that schizotypes would display increased motor deviance as compared to controls

Second, extending beyond Lenzenweger and Maher (2002), we sought to apply a novel quantitative method that defines the qualitative nature of the psychomotor dyscontrol captured by the MLDT to determine if the nature of the lines schizotypic subjects draw distinguishes them from controls. The method of analysis we employed (described in detail below) involves identifying the predominant sinusoidal frequency present in participants' lines and was developed in our laboratory (Roche et al., 2009). The results of a pilot study (Roche et al, 2009), which employed a completely independent sample from the one described herein, demonstrated that measures of positive schizotypy correlated with lower predominant frequency scores (i.e. less tremulous lines). As such, we also hypothesized here that schizotypes would draw lines that were characterized by lower predominant frequencies than non-schizotypic control subjects.

2. Method

2.1 Subjects

In this study, 1000 SUNY- Binghamton undergraduate students completed the Perceptual Aberration (PAS; Chapman et al., 1978) and Magical Ideation scales (MIS; Eckblad and Chapman, 1983), as well as the Jackson Infrequency Inventory (INF; Jackson, 1984). From this sample, participant selection followed the standard psychometric high-risk method (Lenzenweger, 1994). First, respondents with scores 3 or greater on the INF were removed from the dataset, as scores in this range suggest a random or reckless response style. Second, participants who scored in excess of two standard deviations from the sample mean on either the PAS or MIS were recruited for our schizotypy group ($n=45$); and, participants who scored from the bottom of the distribution to within a half of a standard deviation above the sample mean on both measures ($n=37$) were recruited for our control group. In exchange for

their participation, participants received experimental credit in an undergraduate psychology course. All experimental procedures were reviewed and approved by SUNY-Binghamton's Institutional Review board and informed consent was obtained prior to subject participation.

2.2 Measures

2.2.1 Schizotypy Scales—Each subject completed the PAS and MIS. The PAS is a 35-item true-false measure of body image and perceptual aberrations (Chapman et al., 1978). The MIS is a 30-item true-false measure of belief in forms of causation that by conventional standards are invalid (Eckblad and Chapman, 1983). A vast corpus of empirical studies support the reliability and validity of these scales as measures of schizotypy (Chapman et al., 1994; Chapman et al., 1995; Lenzenweger, 2010). We are mindful that there are many measures of schizotypy available, however the PAS and MIS enjoy a level of construct validation that is remarkable.

2.2.2 Infrequency Scale—Participants completed the Jackson Infrequency Inventory (Jackson, 1984) to assess for random, invalid, or reckless response styles.

2.2.3 Psychotropic medication—Information about psychotropic medication usage was collected using an author-generated form. Participants were asked to circle “Yes” if they were taking any psychiatric medication or “No” if they were not. Information about the types of medications participants were taking was not recorded.

2.2.4 Axis I Pathology—The Computerized Diagnostic Interview Schedule IV (CDIS; Blouin et al, 1988) was used to assess for lifetime history of psychosis. The CDIS is a computer-based, structured, self-report measure designed to assess for current or past DSM-IV-TR Axis I psychopathology (Robins et al., 1981; Blouin et al, 1988) and previous research (Blouin et al, 1988) has demonstrated the reliability of the computer-based procedure and its equivalence to the interview-based Diagnostic Interview Schedule.

2.2.5 Intellectual functioning—We used the Digit Symbol Coding (DSC) task from the Wechsler Adult Intelligence Scale-III (Wechsler, 1997) to estimate general intellectual functioning. The DSC has excellent test-retest reliability and correlates highly with full scale IQ (Wechsler, 1997).

2.2.6 Maher Line Drawing Task (MLDT)—The MLDT is a measure of fine motor performance that requires participants to draw four diagonal lines. Participants were instructed to draw diagonal lines in 2×2 ” boxes using both their right and left hands. Lines were always drawn from the bottom corners to the top corner diagonally opposite. Ultimately, lines are drawn in two directions (left-to-right and right-to-left) with each hand. Participants were asked to draw lines that were as straight as possible and to use their wrist, as opposed to their arms, to create the lines. These lines are then digitized using a flatbed scanner, X-Y coordinates are extracted using the UN-SCAN-IT software package (1998, version 5.0), and the primary outcome variables, psychomotor dyscontrol (*logRMS*) and absolute laterality (*logAL*), are calculated. In keeping with previous research, participants only completed this task once and no time demands were imposed on their performance

(e.g., participants were not asked to draw as quickly as possible). Previous research has demonstrated the validity of this task as a measure of psychomotor control (Blyler et al., 1997) and its reliability (Candela, unpublished results). Furthermore, previous research (Blyler et al., 1997) has demonstrated the scanning process to be highly reliable with correlations between the output of repeated scans ranging from 0.94 to 1.0. The resolution of the scanning procedure is quite high with a typical scanned line consisting of 300 data points. Finally, in addition to collecting objective motor performance data, as a measure of handedness, participants are also asked which hand they normally write with.

To derive *logRMS* scores, a first-order regression line is passed through each line a participant draws and the standard deviation of the residuals (RMS) from each regression is computed. The RMS scores for each individual line are then summed and logarithmically transformed to produce *logRMS*. Lower *logRMS* scores indicate less psychomotor dyscontrol, while higher scores indicate greater psychomotor dyscontrol.

In addition to *logRMS*, a quantitative measure of the shape of participant's lines, predominant frequency (*PF*), was derived. *PF* represents the normalized spatial frequency that best characterizes the line a subject has drawn. Calculating *PF* is a three-step process. First, the Fourier transform is applied to the residuals created in the RMS calculations. The Fourier transform is a mathematical technique that allows one to determine the degree to which a range of frequencies are present in time series data. More specifically, for each possible frequency the Fourier transform outputs a number (i.e. magnitude) that indicates the degree to which that frequency is present in the time series. Second, the frequencies with the 30 highest magnitude scores are selected and entered into a statistical stepwise regression. Finally, *PF* is calculated by entering the frequencies retained in the regression into a weighted average. The numerator of the weighted average is the sum of the retained frequencies multiplied by their associated magnitude and the denominator of the weighted average is the sum of the magnitudes of the retained frequencies. To create a composite variable, like *logRMS*, that represents *PF* across all of a participant's lines, *PF* values for each of a participant's lines were averaged together.

2.3 Procedure

Participants completed the psychometric measures during Mass Testing sessions and the MLDT as part of three larger laboratory studies. Participant selection was performed by the third author (MFL) and all study staff were blind to participant group until the data were analyzed. Selected students were contacted by trained research assistants or graduate students, and invited to participate in the study. Participants completed the experiment individually in well-lighted, climate controlled, and quiet laboratory rooms that were free of extraneous noise and other distractions. The MLDT was completed in the presence of a researcher to ensure lines were drawn with the appropriate hands and in accordance with the task's instructions. The CDIS was completed at individual computer workstations before participants completed the MLDT and the DSC was completed after.

2.4 Statistical Analysis

Our initial efforts were aimed at understanding the nature of *PF* and its relationship with *logRMS*. To this end, we explored the average number of frequencies used by the *PF* algorithm to reconstruct participants' lines and the average amount of variance in participants' original lines that was explained by lines reconstructed using the frequencies included in the *PF* algorithm. Next, to establish *PF* as a construct independent of *logRMS*, correlational analyses were performed. Both forms of analysis were performed for the full sample and each participant group individually. Subsample specific descriptive statistics and correlations between MLDT metrics were then compared between participant groups using independent samples *t*-tests and tests for the comparison of independent correlation coefficients.

For between group comparisons on MLDT variables, independent samples *t*-tests were used. The tests for *logRMS* and *PF* were conducted one-tailed as previous research (Lenzenweger and Maher, 2002; Roche et al, 2009) indicated schizotypic subjects should obtain higher *logRMS* scores and lower *PF* scores than controls. The choice to use one-tailed tests was made *before* data analyses were conducted and based on our directional, *a priori* hypotheses. Their use was designed to increase the power and precision of our statistical tests (Rosenthal and Rosnow, 2008; Lenzenweger, 2010).

Medication usage, digit symbol performance, sex, ethnicity, age, and handedness data were not available for 18 subjects in our psychometric schizotypy group. Schizotypes with and without these data did not differ on *logRMS*, *PF*, the number of frequencies used to reconstruct their lines, or the amount of variance lines reconstructed using the *PF* analyses explained in their original lines. All statistics related to demographic variables therefore refer to a subgroup of 27 schizotypic participants; all between groups analyses for MLDT variables include all 45 schizotypes. For full transparency, the results of between-group analyses comparing the subgroup of schizotypic participants with all demographic data to controls for all MLDT output variables are included as a footnote.

3. Results

In the schizotypy group, mean PAS scores were 17.64 (*SD* = 6.72) and mean MIS scores were 16.33 (*SD* = 5.54); in the control group, mean PAS scores were 0.35 (*SD* = .48) and mean MIS scores were 1.56 (*SD* = 2.93). The groups did not differ in terms of age ($t(62) = 1.377, p = 0.174$), handedness preference ($\chi^2 = 0.166, p = 0.684$), composition in terms of gender ($\chi^2 = 0.0001, p = 0.993$) or race ($\chi^2 = 3.01, p = 0.698$), proportion of participants taking psychotropic medication ($\chi^2 = 1.44, p = 0.230$), or digit symbol performance ($t(61) = 1.13, p = 0.262$). Additionally, the interaction between the above-listed variables and group did not significantly influence *logRMS* or *PF* scores. Finally, no participant screened positively for episodes of psychosis on the CDIS.

3.1 Characteristics of PF

On average, the *PF* analysis used 14 frequencies to determine the predominant frequency for each subject's line and lines reconstructed using these frequencies explained 62% of the variance in the original line (i.e., reconstructed lines correlated with the original line $r =$

0.79). That is, when the frequencies included in the PF analysis were entered into an inverse Fourier Transform to create a series coordinates, this output correlated highly ($r = 0.79$) with the coordinates from the original scans of participants' lines. The average number of frequencies included in PF analysis ($t(80)=1.45$, $p = 0.152$, $d = 0.31$) and average amount of variance explained ($t(80)=1.10$, $p = 0.274$, $d = 0.24$) by the reconstructed lines did not differ between groups. Taken together, these results suggest the validity and robustness of the PF analysis as it does excellent job characterizing the lines subjects draw across both participant groups.

The distributions for PF did not significantly depart from normality in the full sample ($Z = 1.04$, $p = 0.230$) or in either of the two participant groups ($Z = 0.597$, $p = 0.869$ and $Z = 0.984$, $p = 0.288$, respectively). As such, no data transformations were applied to PF. Finally, no outliers were identified in the full sample or either participant group.

3.2 Correlations between logRMS and PF

The correlation between *logRMS* and *PF* in the full sample ($r = -0.51$, $p < 0.001$), and schizotypy ($r = -0.55$, $p < 0.001$) and control ($r = -0.42$, $p = 0.009$) groups were moderate in size and statistically significant. The sample specific correlations did not significantly differ ($z = 0.73$, $p = 0.465$). These results suggest that lines displaying more psychomotor dyscontrol are characterized by lower sinusoidal frequencies. Further, given these measures share only 25% of their variance, they indicate that *logRMS* and *PF* measure two different aspects (or qualities) of psychomotor performance and as such, can be considered two distinct constructs.

3.3 Group Comparisons for logRMS, PF, and logAL

The descriptive statistics and results for the analyses comparing schizotypic and control participants on *logRMS*, *logAL*, and *PF* are contained in Table 1. Consistent with our *a priori* directional hypothesis, schizotypes drew lines that were characterized by higher *logRMS* scores [$t(80)=1.99$, $p = 0.024$, one-tailed, $d = 0.44$] and lower predominant frequencies [$t(80)=1.92$, $p = 0.029$, one-tailed, $d = 0.42$] than controls¹. For both variables, the effect size separating the two groups on *logRMS* and *PF* were sizable and similar to the effect sizes reported for established deficits in schizotypy such as sustained attention (Lenzenweger et al., 1991; Gooding et al., 2006), smooth pursuit eye-tracking (O'Driscoll et al., 1998; Gooding et al., 2000) and working memory (Park et al., 1995). There was no difference between groups on *logAL* [$t(80)=0.432$, $p = 0.674$]. Importantly, the data satisfied the assumptions for parametric analyses.

4.0 Discussion

The purpose of this study was to explore issues of psychomotor control in schizotypic and control samples using a simple motor task that can be scored in a straightforward, but genuinely ratio-scale manner. The results of our analyses confirmed our hypotheses that

¹When only schizotypic participants with complete demographic information were compared to control participants, the psychomotor dyscontrol finding was no longer significant ($t(62)=1.55$, $p = 0.062$, one-tailed, $d = 0.40$), but the between-group difference for predominant frequency remained significant ($t(62)=2.16$, $p = 0.017$, one-tailed, $d = 0.56$).

schizotypes would evidence greater psychomotor dyscontrol and have lines characterized by lower predominant frequencies than non-schizotypic controls. Both of these findings were associated with robust effect sizes ($d > 0.4$), which compare favorably with those of established schizotypic deficits like impairments in working memory, sustained attention, and smooth pursuit eye-tracking.

Our psychomotor dyscontrol findings align with the existing research corpus demonstrating psychomotor control deficits in schizophrenia and schizotypy. Our results extend those of Lenzenweger and Maher's (2002), in two ways. First, through a rigorous quantification process, they reveal the qualitative aspect of line drawing performance associated with psychomotor deviance in schizotypic samples. Second, they demonstrate that increased psychomotor dyscontrol is not simply a correlate of schizotypy indicators, but rather, a feature of schizotypic individuals. That is, correlations between schizotypy scale scores and experimental task performance obtained from individual differences studies of schizotypy, i.e., those that include people scoring throughout the full range of possible scores on schizotypy measures, may result from (1) a relatively strong relationship between individual differences in schizotypy scale scores and task performance in non-schizotypes, but little-to-no relationship between the variables in schizotypic individuals; or (2) little-to-no relationship between schizotypy scale scores and task performance in non-schizotypes, but a relatively strong relationship between the variables in schizotypic individuals. As a result, correlational studies can only suggest performance on an experimental task is schizotypy-related, while between group studies, like this one, that contrast people highly likely to be schizotypes with people who are highly unlikely to be schizotypes, can provide more persuasive evidence that performance on an experimental task is schizotypy-related.

The finding that schizotypes draw lines characterized by lower sinusoidal frequencies than controls is both novel and fascinating, and we believe two interpretations of this finding are plausible. First, when these lower sinusoidal frequencies are considered in conjunction with our psychomotor dyscontrol finding we believe they may reflect a schizotypic deficit in visuo-motor action/self-monitoring (Frith et al., 2000a; Frith et al., 2000b; Jeannerod, 2009). Various authors have demonstrated that thresholds for the recognition of discrepancies between motor movements and their consequences varies from individual-to-individual and performance corrections are driven by *unconscious* error correction systems that rely on the integration of visual and motor information (Fournier and Jeannerod, 1998; Slachevsky et al., 2001; Slachevsky et al., 2003; Knoblich and Kircher, 2004; Sape and Serrien, 2010). Deficits in these functions have been reported in people diagnosed with schizophrenia (Knoblich et al., 2004) and their first degree biological relatives (Hommes et al., 2011), and poor visuomotor action monitoring has been found to correlate with scores on measures of positive schizotypy (Hommes et al., 2011). These results suggest that people diagnosed with or at increased risk for schizophrenia (i.e., schizotypes; Meehl, 1990; Lenzenweger, 2010) take longer to notice and make corrections for discrepancies between intended and actual movements. Within the context of the MLDT such a deficit would manifest itself as higher psychomotor dyscontrol scores (i.e., deviance from the goal of the task) and lower frequency scores (i.e., goal-oriented performance corrections).

Second, the combination of lower characteristic sinusoidal frequencies and greater psychomotor dyscontrol may result from the failure of schizotypic participants to adhere to the optimality principles of motor control (e.g., minimization jerk; Todorov, 2004). In short, these principles are used to explain how humans achieve some motor goal while minimizing goal achievement-related cost(s). To date, consideration of these principles in the study of motor control by schizophrenia and schizophrenia-spectrum researchers has been limited and the application of the mathematics related to optimality principles to such samples is non-existent. Unfortunately, in the absence of data on the timing of movements, applying such analyses to our data is not possible. Given we did not have participants complete a self-monitoring task or record movement speed, resolving which of the above interpretations of our results is most appropriate will need to be determined by future research.

Though characterized by a number of strengths, some study limitations are of note. First, schizotypy is a multidimensional construct characterized by negative, reality distortion, and disorganized symptom dimensions (Bosch, 1995; Vollema and Vollema and Hoijtink, 2000; Calkins et al., 2004; Kwapil et al., 2008) that mirror what is known about schizophrenia symptoms (Liddle, 1987; Lenzenweger and Dworkin, 1996). Our participant selection procedure only took into account positive schizotypy and we did not collect data on other schizotypy symptom dimensions. Therefore, it is unknown whether schizotypes identified using other schizotypy symptom dimensions (e.g. disorganized schizotypy) would have provided similar results or if other schizotypy symptom dimensions interact with positive schizotypy to meaningfully impact participants' psychomotor performance. Similarly, although Lenzenweger and Maher (2002) found that psychological state variables (e.g. depression) did not impact psychomotor performance when the entire range of individual differences in schizotypy were considered, it may be the case that within a population of schizotypes these variables do influence performance. Third, although we did not find psychotropic medication generally impacted MLDT performance and medication type and dosage have not been found to impact MLDT performance in psychiatric samples (Manschreck et al., 2004), it may be the case that specific medications do have an impact on psychomotor performance in schizotypes. In our study, few participants were taking medications ($n = 8$) so such analyses would not have been meaningful even if data had been collected, but this factor should be considered in subsequent research. Fourth, the validity of participants' self-report about their use of psychotropic medication, alcohol, and legal or illegal drugs is unknown. Any of these substances could influence motor performance and though we did not observe a relationship between schizotypy and substance use, previous research has suggested that undergraduate students with higher schizotypy scores are more likely to be use alcohol and illegal drugs than people with low schizotypy scores (Esterberg et al., 2009). Fifth, although participants were asked which hand they prefer to write with and there was no difference between groups on our measure of laterality, a handedness inventory was not administered and thus, performance differences that result from the degree of self-report handedness could not be assessed. Given previous research has suggested that schizotypes are less lateralized than control participants (Somers et al., 2009; c.f. Dragovic et al., 2005), including a measure of handedness would have strengthened our ability to conclude that handedness preference did not impact participant performance. Sixth, given the between-group analyses were hypothesis-driven, we did not correct for

multiple comparisons. That said, if we had applied a Bonferroni correction, our *logRMS* finding would have remained significant and the *PF* finding would have approached significance. Seventh, although the groups did not differ on the MLDT's measure of laterality (*logAL*), this measure is limited in that it provides the absolute difference for the left and right hands, but does not capture the magnitude of the difference between hands (e.g., 50% worse performance with the non-dominant hand). As such, whether the hand used to draw lines and additionally, whether the direction of drawing for each line influenced *logRMS* and *PF* scores differentially is unknown. Although we could not address these questions analytically, future researchers should employ statistical analyses that can evaluate these issues as previous research has suggested both may be important determinants of motor performance (e.g., see Teulings et al., 1997; Dounskaia et al, 2000). Finally, the time participants took to draw their lines was not recorded and we did not impose a time demand on participants. As such, within and across participants, there was likely variability in the amount of time it took them to draw their lines and it is possible that movement speed affected both psychomotor dyscontrol and predominant frequency scores. Furthermore, the speed of one's motor movement dictates the degree to which one can effectively monitor and adjust movements based on sensory feedback, and thus, has implications for the manner in which data like ours can be interpreted (i.e., whether psychomotor dyscontrol scores can be seen to represent deficits in self-monitoring). Given we did not record movement speed, we could not evaluate its impact in our analyses, but future researchers using the Maher Line Drawing Task should incorporate an assessment of motor speed in their project designs.

Even with these limitations in mind, we believe our results represent a meaningful contribution to the literature on schizotypy and psychomotor control. First, our *logRMS* finding strengthens the case for it as a potential endophenotype for the liability for schizophrenia, as patients with schizophrenia, their first-degree biological relatives, and now, schizotypes have all been demonstrated to obtain lower scores than control subjects. Second, our *PF* result gives context to the *logRMS* findings: for the first time, we know the exact nature of the psychomotor dyscontrol displayed by schizotypes. The combination of our *logRMS* and *PF* results potentially point to a deficit in visual-motor integration that has been suggested as important in schizophrenia (Fish, 1977, 1987) and couch our results within a well-regarded theory of symptom development (Frith et al., 2000b; Jeannerod, 2009). Alternatively, these results may indicate a failure of schizotypic individuals to adhere basic principles of human motor control. Either way, our results have importance and implications for those interested in using objective laboratory tasks for the identification of risk for the development of schizophrenia.

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Highlights

- A new quantitative method is developed to investigate the nature of motor control.
- Non-psychiatric schizotypes are compared to control participants.
- Schizotypes produce lines with greater psychomotor dyscontrol than controls.
- Schizotypes produce lines with lower sinusoidal frequencies than controls.
- Effects may result from poorer self-monitoring or non-adherence to motor principles.

Figure 1.
Scatterplot for logRMS and PF for the control and schizotypy groups.

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Table 1
Descriptive statistics and between group comparisons for *logRMS*, *PF*, and *logAL*

Variable	Control		Schizotype		<i>t</i>	<i>p</i>	<i>d</i>
	Mean	SD	Mean	SD			
<i>logRMS</i>	0.696	0.144	0.756	0.131	1.996	0.024	0.44
<i>PF</i>	1.814	0.251	1.713	0.230	1.918	0.029	0.42
<i>logAL</i>	-0.815	0.574	-0.864	0.481	0.423	0.674	0.09