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Review article

The clinical and prognostic value of motor abnormalities in psychosis, and the importance of instrumental assessment

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ABSTRACT

Motor abnormalities comprise several clinical signs intrinsic to psychosis. Critically, these features are of prognostic value in individuals at-risk for psychosis, and for those in early stages of psychotic disorders. Motor abnormalities such as tremor, rigidity, and neurological soft signs often go unrecognized. Currently, advances in this area are limited by a paucity of theoretical conceptions categorizing or linking these behaviours to underlying neurobiology affected in psychosis. However, emerging technological advances have significantly improved the ability to detect and assess motor abnormalities with objective instruments in a timely and reliable manner. Further, converging evidence has laid the groundwork for theoretically and empirically derived categorization and conceptualization. This review summarizes these advances, stressing the importance of motor abnormalities for understanding vulnerability across different stages of psychosis and introducing these innovative instrumental approaches. Patients, researchers and clinicians will benefit from these new developments, as better assessment aids the development of targeted interventions to ultimately improve the care for individuals experiencing psychosis.

1. Introduction

Motor abnormalities have been observed in chronic patients with schizophrenia, antipsychotic naïve patients in their first episode, individuals identified as at ultra high-risk (UHR) for psychosis, unaffected first-degree relatives of schizophrenia patients, schizotypal patients, and relatively healthy individuals with verbal auditory hallucinations. The predictive value of motor symptoms for the development and course of psychosis, (Cuesta et al., 2014; Mittal et al., 2008a) as well as what is known of the functional neuroanatomy of motor abnormalities, suggests that these features are an integral part of psychotic psychopathology (Fervaha et al., 2014).

Current diagnostic systems predominantly use mental, cognitive, and affective symptoms to characterize psychotic disorders. Yet, the reliability and accuracy of these traditional diagnostic techniques have been called into question because of factors such as observer bias as well as the confounding influence of particular clinical features such as suspiciousness, cognitive deficits and amotivation. Further, the current diagnostic system weighs positive symptoms heavily, but de-emphasizes critical cognitive and negative symptoms categories, which may be more closely tied to the underlying pathophysiology of psychosis. In this context, it is important to consider that growing evidence indicates that motor abnormalities may make up an objectively measureable symptom dimension of psychosis. Importantly, motor abnormalities can be quantified with innovative instruments, yielding sensitive, valid and reliable data. Also, portable devices allow for continuous monitoring of motor abnormalities outside the clinic and enable the examination of how motor abnormalities may predict aspects of everyday functioning.

In this review we provide a comprehensive primer on motor abnormalities in psychosis (see Table 1 and Fig. 1), discuss related diagnostic, prognostic and treatment value, and describe relationships with cognitive and affective symptoms observed in psychotic disorders. We also discuss new technical developments in the assessment of motor function and future directions in the study of motor abnormalities across a spectrum of psychotic disorders.

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Table 1
Definitions (including some comments) of motor abnormalities studied in psychosis.

Motor Abnormality Category	Motor Abnormality	Definition	Comments
Hyperkinetic	Dyskinesia	Involuntary movements most commonly seen in the limbs, mouth, or tongue resembling either chorea (i.e., flinging, jerking) or athetosis (i.e., writhing) (Mittal et al., 2011a; Mittal et al., 2010b; Pappa and Dazzan, 2009) (see Figs. 1C and 3B-1).	• Historically, both spontaneous and antipsychotic medication induced (i.e., tardive) dyskinesia have been measured via rating scales (e.g., AIMS, DISCUS) developed to assess for tardive dyskinesia, wherein observers code for the presence and severity of dyskinetic movement (e.g., slow, irregular movement of wrists, hands, or fingers; puckering; lip smacking)(Guy, 1976; Kalachnik and Sprague, 1993). • Instrumental measures sensitive to more subtle manifestations of dyskinesia have been developed and successfully implemented (for example see Fig. 3B-2). These more subtle manifestations of dyskinesia have been assessed during voluntary movement tasks and include force variability secondary to irregular muscle contractions (Caligiuri et al., 1997; Cortese et al., 2005; Mittal et al., 2011a) and dysfluent movement secondary to discoordinated muscle activity (Caligiuri et al., 2010; Teulings et al., 1997).
	Tremor	Involuntary movement that is rhythmic and oscillatory(Deuschl et al., 1998) (see Fig. 1B).	• In the motor abnormalities in literature about schizophrenia, tremor is described and conceptualized as one of several parkinsonian symptoms (see below for hypokinetic parkinsonian symptoms rigidity and bradykinesia) (Pappa and Dazzan, 2009). • Tremor is a component of rating scales assessing extrapyramidal side effects (e.g., SAS (Simpson and Angus, 1970)) and Parkinsonism (e.g., UPDRS(Fahn et al., 1987)). • Instrumental assessments of tremor have been developed wherein individuals sustain short periods of constant isometric force and frequencies of the force signal that are of interest to tremor are analysed (e.g., (Caligiuri et al., 1993; Dean et al., 2004; Koning et al., 2011a)).
	Catatonia	Marked psychomotor disturbance characterized by at least 3 of the following symptoms: stupor, catalepsy, waxy flexibility, mutism, negativism, posturing, mannerism, stereotypy, agitation, grimacing, echolalia, echopraxia(Association, 2013) (hyperkinetic catatonia symptoms are discussed at right).	• Catatonia is a heterogeneous construct(Association, 2013), with a history of inconsistent definitions and with symptoms spanning motor, volitional, and affective domains(Walther and Strik, 2012). • Of the pure motor signs highlighted by Walther and Strik (Walther and Strik, 2012), those characterized by abnormally increased movement are listed below: • Posturing (maintaining positions and postures against gravity actively and spontaneously)(Association, 2013) • Mannerisms (normal actions are caricatured)(Association, 2013) • Stereotypies (movements that are not goal-directed but are repetitive and abnormally frequent)(Association, 2013) • Grimacing
Hypokinetic	Bradykinesia	Movement slowness (Marsden, 1989).	• *As with tremor (see above), bradykinesia is rated on various clinical rating scales, and is considered a classic parkinsonian symptom.* • Instruments have been developed to measure duration (Caligiuri et al., 1993; Caligiuri et al., 2010) and speed (Caligiuri et al., 2010) of movement (for example see Fig. 3B-2). • Individuals with bradykinesia have diminished ability to increase movement velocity proportionally to increased movement distance (i.e., decreased velocity scaling)(Cortese et al., 2005), potentially secondary to dysfunctional movement velocity programming(Caligiuri et al., 1998). Instruments have been developed that quantify both the speed and size of movements of different sizes in order to compute velocity scaling (e.g., (Caligiuri et al., 1998; Caligiuri et al., 2009; Caligiuri et al., 2006; Dean and Mittal, 2015; Koning et al., 2011a)).
	Rigidity	Increased resistance in response to passive movement about a joint when relaxed(Deuschl et al., 1998); stiffness (Caligiuri et al., 1993) (see Fig. 1B).	• *As with tremor (see above), rigidity is rated on various clinical rating scales, and is considered a classic parkinsonian symptom.* • Instrumental assessment of rigidity has been accomplished through passive displacement, subsequent quantification of the amount of displacement and the force that was required for the displacement, and calculating the relationship between these two variables(Caligiuri and Galasko, 1992; Caligiuri et al., 1993). Given the central nervous system contribution to parkinsonian rigidity specifically (as opposed to simple muscle stiffness)(Webster, 1966), this same procedure is conducted while the contralateral limb is active, and the relationship between displacement and force in this activated condition is compared to that in the passive

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