



When one's sense of agency goes wrong: Absent modulation of time perception by voluntary actions and reduction of perceived length of intervals in passivity symptoms in schizophrenia



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ABSTRACT

Passivity symptoms in schizophrenia are characterised by an absence of agency for actions, thoughts and other somatic experiences. Time perception and intentional binding have both been linked to agency and schizophrenia but have not been examined in passivity symptoms. Time perception and intentional binding were assessed in people with schizophrenia ($n = 15$ with, $n = 24$ without passivity symptoms) and 43 healthy controls using an interval estimation procedure (200, 400 and 600 ms intervals) with active, passive and observed movements. People with passivity symptoms did not display action-modulation of time perception, while those without passivity symptoms estimated intervals to be the same after active and observed movements. Additionally, both clinical samples reported intervals to be shorter with increasing interval length. We propose that impaired predictive processes may produce an overreliance on external cues and, together with shorter perceived intervals, lead to the subjective loss of agency.

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1. Introduction

One of the key features of schizophrenia is an impairment of the ability to correctly discriminate between internally-generated and externally-generated events. Individuals with passivity symptoms display a particularly severe form of this characteristic feature and report a lack of normal sense of ownership for thoughts and actions, alongside the subjective experience that one's will is replaced or influenced by some external agent. Despite strong phenomenological evidence (Wing et al., 1990), epidemiological and symptom cluster analyses (Carpenter, Strauss, & Muleh, 1973;

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Jablensky et al., 1992; Kimhy, Goetz, Yale, Corcoran, & Malaspina, 2005; McGorry, Bell, Dudgeon, & Jackson, 1998), functional brain imaging evidence (Franck, O'Leary, Flaum, Hichwa, & Andreasen, 2002; Shergill et al., 2014; Spence et al., 1997), heritability evidence (Cardno, Sham, Farmer, Murray, & McGuffin, 2002) and neurocognitive theoretical frameworks (Graham, Martin-Iverson, Holmes, Jablensky, & Waters, 2014; Maruff, Wilson, & Currie, 2003; Waters & Badcock, 2010) that indicate passivity symptoms are distinct from other positive symptoms, research into these symptoms remains relatively sparse.

The precise neurocognitive mechanisms that lead to passivity symptoms are poorly understood. Emerging evidence suggests that internal timing dysfunctions may contribute in a significant way to the self-disturbances seen in passivity symptoms (Graham et al., 2014; Spence, 1996; Waters & Jablensky, 2009). Timing mechanisms are the neurological and neuropsychological processes that dictate the internal experience of the flow of time, and play a key role in the coordination of neural circuits and events (Buhusi & Meck, 2005; Ivry & Richardson, 2002; Ivry & Spencer, 2004). Intact timing is necessary for a smooth orchestration of actions and integration of motor, sensory and cognitive information (Artieda, Pastor, Lacruz, & Obeso, 1992; Mates, Müller, Radil, & Pöppel, 1994; Meck, 1996; Repp, 2005), in order for behaviour to be synchronised appropriately with the external environment that the behaviour is directed towards. In addition, precise synchronisation of movements relative to the external world is critical for generating a sense of self (relative to others) and for attributing agency, the sense that 'I' did it (Elliott, Welchman, & Wing, 2009; Spence, 1996). Dysfunctions in these mechanisms, by contrast, may cause distortions in both self-monitoring processes and subjective experiences of action causation (B. Martin et al., 2014).

1.1. Time perception in schizophrenia and passivity symptoms

Studies have demonstrated that the perception of time on scales typical of motor processes strongly influences if an action is perceived to be self-generated (Ebert & Wegner, 2010; Sato & Yasuda, 2005) and is crucial to the processes that associate causation between mental and external events (Haggard, Clark, & Kalogeras, 2002; Wegner & Wheatley, 1999). People with schizophrenia (undifferentiated by symptoms) show wide-ranging changes in time perception, as shown using a range of methods and tasks across short and long durations (see Waters, 2013 for a review). A consistent finding is that people with schizophrenia perceive intervals less than 1 s to be shorter, relative to healthy controls (Carroll, Boggs, O'Donnell, Shekhar, & Hetrick, 2008; Elvevåg, Brown, McCormack, Vousden, & Goldberg, 2004; Elvevåg et al., 2003; Lee et al., 2009; B. Martin, Giersch, Huron, & van Wassenhove, 2013; Papageorgiou et al., 2013; Rammsayer, 1990; Waters & Jablensky, 2009). However, it is not clear which dysfunctional mechanism underlies these changes in time perception. Typically, the findings of a reduction in the perceived time of intervals has been interpreted as alterations in the rate of an internal pacemaker; either a decrease in clock speed (e.g. Elvevåg et al., 2003; Rammsayer, 1990) or an increase in variability of that speed (e.g. Carroll, Boggs, O'Donnell, Shekhar, & Hetrick, 2008; Lee et al., 2009; Papageorgiou et al., 2013). An alternative explanation suggests that these changes are correlated to deficits in working memory that affect the accumulator stage of timing processes, rather than differences in an internal pacemaker (Lee et al., 2009; Roy, Grondin, & Roy, 2012).

1.2. Significance of changes in internal timing processes

In relation to the functional significance of changes in time perception, Spence (1996) proposed that such changes in sensorimotor processes may result in the awareness of the actual movement preceding awareness of the intention to act in schizophrenia. This situation is contrary to the normal experience of self-generated actions, and may lead to experiences of passivity. Few studies have addressed this proposal of a more pronounced alteration of time perception in passivity symptoms.

Using the rubber hand illusion task, we recently demonstrated decreased sensitivity to a time delay of 500 ms in the multimodal sensory integration of (visual and tactile) events in a group of people with passivity symptoms ($n = 20$). More specifically, people with passivity symptoms continued to experience the rubber hand illusion (an increase in embodiment and feelings of agency over the 'other' hand) during asynchronous stimulation, when healthy controls and patients without passivity symptoms do not experience the illusion (Graham et al., 2014). We speculated that a disruption in internal timing causes these individuals to experience events to be closer together in time. In support, it was also shown that people with passivity symptoms perceived the interval between two external auditory stimuli to be shorter than healthy controls or people without passivity symptoms (Waters & Jablensky, 2009). Using a task which relied on self-other judgements based on visual feedback, Daprati et al. (1997) also demonstrated that people with passivity symptoms ($n = 7$) more often erroneously reported that an image of a hand performing a movement on a screen in front of them was their own. This occurred both when that hand was someone else's hand performing a movement different from the subjects, or someone else's hand performing the same movement as the subject's hand, indicating an insensitivity to distorted visual feedback.

1.3. Intentional binding in schizophrenia

One important phenomenon that links time perception with agency is intentional binding, the subjective contraction of time between a voluntary action and its sensory consequence/s (Haggard et al., 2002). This contraction of time occurs only after self-produced actions and not after actions caused by external agents (Engbert, Wohlschläger, & Haggard, 2008). As such, intentional binding is specific for internal motor representations of self-produced actions. It has been proposed that,

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