Psychiatry Research xx (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Psychiatry Research

journal homepage: www.elsevier.com/locate/psychres

Self is “other”, other is “self”: poor self-other discriminability explains schizotypal twisted agency judgment

Tomohisa Asai*

NTT Communication Science Laboratories, Human Information Science Laboratory, Kanagawa, Japan

ARTICLE INFO

Keywords:
Agency
Schizophrenia
Schizotypal personality traits
Psychophysics
Slope
Motor control

ABSTRACT

Anomalous agency has been reported clinically and empirically for people with schizophrenia. This finding is expected to contribute to understanding positive symptomatology in schizophrenia in terms of a general neurocomputational model of motor control, because anomalous agency has also been reported in schizotypal traits in the general population. However, superficially opposite conclusions have been suggested: over-attributed or under-attributed agency in patients. In this work, healthy participants (N=104) were presented continuous morphed self-other visual feedback of their reaching movements and rated the agency they felt for it. The slope of the regression line in stimuli-response coordination as a function of self-other discriminability was estimated for each participant. The estimated slopes were significantly associated with positive schizotypal symptomatology. Higher schizotypal participants exhibited a lower slope, indicating poorer discriminability between their own and others' movements. Furthermore, the estimated regression lines in the high and low groups are predicted to cross at the approximately center point in the coordinates, which should produce both over-attribution and under-attribution errors for the high group compared with low group. The pattern of schizotypal attribution error depends on the S/N (signal-to-noise) ratio of the given stimuli within our sensorimotor system where the self-originated stimulus is the signal to be detected. The current study, for the first time, suggests both over- and under-attribution within participants scoring high on schizotypy.

1. Introduction

The sense of agency refers to the subjective experience of controlling one's own action (Gallagher, 2000; Haggard and Chambon, 2012). In this decade, this sense has drawn attention from researchers in philosophy, psychology, neuroscience, psychiatry, and other fields because it could be a window to knowing how we are aware of ourselves and might help in understanding some mental illnesses like schizophrenia (Haggard and Chambon, 2012). Indeed, various measurements in many empirical studies have suggested that people with schizophrenia or even with schizotypal personality traits have “anomalous” agency (Asai and Tanno, 2012; Daprati et al., 1997; David et al., 2008a, 2008b; Fourneret et al., 2002; Franck et al., 2001; Haggard et al., 2003). However, there is a serious inconsistency among studies regarding how anomalous their agency is. The first meta-analytic study, which focused on the relationship between schizophrenia and agency, concluded that such patients have “reduced self-recognition” (Waters et al., 2012), indicating their agency is weaker (under-attribution). On the other hand, another meta-analytic study concluded that patients have an “exaggerated sense of self” (Hur et al., 2014), indicating their agency is stronger (over-attribution). This inconsistency has often been questioned but is still unresolved (van der Weiden et al., 2015; Werner et al., 2014). The current study aimed to explain these superficially contradictory results in terms of the psychophysics of agency (Repp and Knoblich, 2007).

1.1. Mechanism for agency

It has been proposed that we have a mechanism for discriminating between self- and other-originated sensory information (Miall and Wolpert, 1996). The forward model (Wolpert and Miall, 1996) can predict the sensory outcome of a motor command to be matched with the actual sensory outcome (i.e., feedback). Since this forward modeling should be able to predict self-originated sensory outcomes, little mismatch (i.e., prediction error) between predicted and actual outcomes means that that sensory information is highly likely to have come from the self. On the other hand, unless our own motor representation is confounded with others' though a mirror system (e.g., motor resonance, e.g., Kilner et al., 2003), other-originated sensory outcomes are not associated with that prediction, so a large

* Correspondence address: 3-1, Morinosato-Wakamiya, Atsugi-shi, Kanagawa-ken 243-0198, Japan.
E-mail address: asai.tomohisa@lab.ntt.co.jp.

http://dx.doi.org/10.1016/j.psychres.2016.10.082
Received 7 February 2016; Received in revised form 1 October 2016; Accepted 17 October 2016
Available online xxxx
0165-1781/

mismatch should be detected. As a result, the feeling of no-large-error is the sense of agency (Asai, 2015; Knoblich and Sebanz, 2005). Empirically, as the inserted bias gets larger in action feedback, participants detect mismatch more easily and feel less agency for that feedback (Asai and Tanno, 2008, 2012). On the contrary, when fake feedback, congruent with the prediction, is presented, participants feel illusory agency for it (Asai, 2015; Nielsen, 1963). When this motor prediction process is uninformative or less reliable, cognitive inferences of agency might also be influential (Moore et al., 2009; Synofzik et al., 2008; van der Weiden et al., 2015), as summarized as Wegner's principle: exclusivity, priority, and consistency (Wegner, 2003). When the outcome has no other sources except for the action, when the action precedes the outcome, and/or when the action follows a reasonable outcome, we judge cognitive self-agency over that outcome. Though the interplay between motor and cognitive processes for agency is also of great interest (Khalighinejad and Haggard, 2016), the current study focused more on the motor prediction process for agency (see also Fig. 5), where the newly-developed task manipulates prediction errors continuously.

1.2. Schizophrenia as a disorder of agency

Clinical and empirical observations have also suggested that schizophrenia, especially its positive symptomatology, is related to anomalous agency, though the two-tailed abnormalities have been reported as mentioned above (Haggard et al., 2003; van der Weiden et al., 2015). One end is the delusion of reference or megalomania, where patients have a strong belief that external events have a particular significance to them. Even when patients receive self-irrelevant sensory information, they might attribute it to themselves (Daprati et al., 1997; Haggard et al., 2003; Hauser et al., 2011a, 2011b; Hur et al., 2014). The other end is the delusion of influence or passivity symptom (the alien motor control, auditory verbal hallucination, or thought insertion), where patients have a strong belief that their body and mind are controlled by others. Even when patients receive their own action feedback, they might not recognize it as their own (Johns and McGuire, 1999; Waters et al., 2012; Werner et al., 2014). These clinical symptoms are all categorized as positive symptoms in schizophrenia. Their contradictory attribution patterns (illusory self-attribution as well as illusory other-attribution) are still big issues to resolve (van der Weiden et al., 2015).

The essential reason for the two-tailed abnormalities in people with schizophrenia might be their unoptimized motor prediction (i.e., forward modeling)(Asai et al., 2008; Izawa et al., 2015; Synofzik et al., 2010). In theory, if the predicted sensory outcome is imprecise, a false error would be detected even for a self-originated feedback (MISS response for self-attribution). At the same time, a false matching (*no*-error) would be judged even for an other-originated sensory outcome (False Alarm (FA) response). Of course, a "self" response for self-stimuli (HIT) and "other" response for other-stimuli (Correct Rejection (CR) are correct (e.g., David et al., 2008a), see also Fig. 1, right panel). Patients with schizophrenia often fail to detect that prediction error (Fourneret et al., 2002; Franck et al., 2001; Knoblich et al., 2004); hence, they feel illusional agency for other-attributed outcomes (biased feedback or other-originated outcomes, Daprati et al., 1997). They also often detect false error for their own non-biased feedback as well (Werner et al., 2014); hence, they feel less agency for self-attributed outcome (Johns et al., 2001).

1.3. Psychophysics of agency

These findings are all interpretable in terms of the psychophysics of agency (Repp and Knoblich, 2007)(Fig. 1). When we assume a continuum axis between self- and other-originated sensory information (x–axis), high discriminability among them in participants' response (y–axis) is expressed as a steep slope (gray line in Fig. 1; the ideal

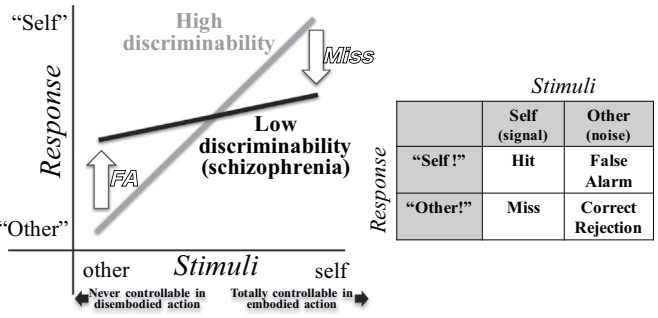

Fig. 1. Schematic hypothesis of the current study. Note: the poor discriminability between self and other stimuli can be expressed as a shallower slope, that could produce MISS and FA attribution errors at the same time depending on the stimuli when compared with people with high discriminability. Self-like stimuli might emerge only in embodied action while other-like stimuli might emerge only in disembodied action (see Discussion for detail).

standardized slope is 1.00, where a participant hits all self-originated stimuli and correctly rejects all others-originated stimuli), which might be realized by precise motor prediction. If the self-other discriminability is poorer, for example, for schizophrenia, the slope gets lower (black line in Fig. 1). Poor performance would yield a horizontal slope close to 0.00 (equivalent to a participant's randomly choosing an answer). As a result, when more self-like or self-sided sensory information (a higher S/N ratio, where the self-originated stimulus is the signal to be detected) is given (i.e., rightward in Fig. 1), patients might often make a MISS response for self-attribution, compared to healthy people. When more other-like or other-sided sensory information (S/N ratio is lower) is given (i.e., leftward in Fig. 1), patients might make a FA response for other-attribution. The point here is that patients' patterns in attribution error [MISS (under-attribution) or FA (over-attribution)] depends on the stimuli given, but these two-tailed errors do not contradict each other in a psychophysical illustration. Both should occur if the self-other discriminability is low.

1.4. The current study

The current study examined the above-mentioned hypothesis, where schizophrenia symptomatology (especially positive symptomatology) is thought to be related to a lower slope as a function of poorer self-other discrimination. For that purpose, it involved some methodological planning. First, a new paradigm—motion morphing between self and other movements—was developed. Though some previous studies manipulated self or other stimuli categorically (e.g., Daprati et al., 1997) (or manipulated the degree of bias in self stimuli, e.g., Franck et al., 2001; Kang et al., 2015), the motion morphing technique enables us to manipulate them continuously, such as self 0% (=other 100%) to self 100% feedback (see Method for details). This has a good fit with psychophysical methodology, where we can estimate a psychometric function (i.e., slope). Given the fact that people with schizophrenia or schizotypy exhibit opposing attribution errors depending on the self-other conditions, as mentioned above, just averaging over all conditions might lead to the false conclusion that they do not show any attribution errors.

Second, the current study recruited a relatively large sample of healthy participants (N=104) and examined individual differences in terms of schizotypal personality traits. This was because psychophysics requires many time-consuming conditions and trials, which may not always be easy for all clinical patients (screening is necessary, which might bias the results). Schizotypy study is now regarded as a good pilot or an analogous study for patients since we can generally see similar results for people with schizophrenia and schizotypy (van Os and Kapur, 2009). Investigating the schizotypal personality in the general population provides the opportunity to examine the biological and cognitive markers of vulnerability to schizophrenia without the