LETTER TO THE EDITOR

The Bayesian equation and psychosis

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Sir, Chambon et al. (2011) use the Bayesian equation to design an exacting experiment to differentiate the responses of psychotic subjects and controls in a variety of ‘mentalizing’ tasks. Psychotic subjects correctly inferred basic non-social intentions, but in the non-social superordinate condition they relied on prior expectations over sensory evidence, a finding that correlated with positive symptoms. Social paradigms showed less dependence on prior conditions and more reliance on sensory evidence, which correlated with negative symptoms. What conclusions might be drawn if one were to apply their results and the Bayesian equation directly to psychosis in vivo as typically observed in clinical practice? Clinical experience suggests that the errors in judgement in psychosis involve particular combinations and exaggerations of biases found in non-psychotic individuals (Bentall et al., 2001), coupled with departures from the Bayesian equation, which may be unique to psychosis. In the simplest form of the Bayesian equation, the probability that a belief 'B' is true/the probability it is not true, after receiving information 'D', is a function of four independent variables arrayed as two ratios, the likelihood ratio and the prior odds (PO) ratio (Fischhoff and Beyth-Marom, 1983; Hemsley and Garety, 1986). The likelihood ratio is the information value of data D with respect to belief B being true (D true) divided by the information value of D for B being false (D false). The PO ratio is the likelihood of B being true in light of all experience prior to D (PO true) divided by the likelihood of B being false in light of all prior experience (PO false).

\[ \frac{\text{The probability belief B is true}}{\text{probability B false}} = \frac{(D\text{ true} / D\text{ false})}{(PO\text{ true} / PO\text{ false})}. \]

Consider a commuter who catches the 7:13 am train to work every day. He hears a train whistle at 7:11 am, which has very high information value in the commuter’s belief that his train is about to arrive. These data D, coupled with the past regularity of the train schedule, indicate a high probability that the train is approaching the station. In comparison, consider a psychotic man who notices two men who look at him as he enters the lobby of his apartment building. Data D are the fleeting glance of the strangers. He also notes that both strangers are wearing blue coats. He concludes that these men are FBI agents who have him under surveillance. Data D are likely to be only the latest in a sequence of self referential events D1 + D2 + D3 + D4 consistent with the patient’s belief. In vivo psychosis departs from the Bayesian equation in multiple ways. The information value of otherwise ordinary events is highly inflated; the importance of a lifetime of experience prior to the first psychotic episode is minimized; and, not true hypotheses are not seriously considered. The likelihood ratio in the above example is a large number because the ideas of reference assign very high information value to mundane events, like the passing glance of a stranger. This inflation of the likelihood ratio may occur because the symbolic meaning of data D inflates its information value, e.g. when the blue colour of the coats is symbolically linked to the blue in the American flag, the glance of two men wearing blue assumes high information value in the hypothesis that the strangers are government agents. Elevated dopamine levels may confer hypersalient significance on ordinary events, dramatically increasing their informational value (Kapur et al., 2005). The information value of D can be further increased if the patient not only observes the glance but also hears a ‘voice’ saying ‘It’s the FBI’. Contrary to the symbolic, hypersalient, self-referential events that commonly inflate the likelihood ratio in psychosis, Chambon et al. (2011), of necessity, chose tasks said to be meaningless to the subjects. In their study, longer exposure times increased sensory information, which increased the information value of the stimulus. In
psychosis, the opposite may occur. The information value of the events may increase the more sensory ambiguity they entail, as when a glance that lasts seconds becomes proof positive of surveillance, or a stranger’s mumbled words overheard at a distance (a low signal to noise ratio) indicate that the stranger is talking about the patient.

Regarding the PO ratio, absent psychosis, a person sums, averages and integrates prior experience to determine a baseline for the likelihood of a belief, as in the commuter train example. After the first psychotic episode, past experience bifurcates into pre-psychotic and post-psychotic experiences. Psychotic individuals largely disregard past experience prior to the psychosis. Hemsley (2005) calls this ‘a weakening of the influences of stored memories of regularities of previous input on current perception’. PO true/PO false = 1, meaning that pre-psychotic experience is largely irrelevant in assessing current events. Assuming that event D1 is associated with the first psychotic episode, subsequent hypersalient events D2 + D3 + D4 + D5 appear to be linked to D1 in a meaningful sequence. Instead of considering all past experience, the relevant past is redefined as beginning with D1. This transformational break with the past is occasionally reflected in a patient saying he now believes in miracles he once thought impossible. In the example above, the hypersalient D5 is inconsistent with prior pre-psychotic experience but perfectly consistent with prior post-psychotic experiences D1 + D2 + D3 + D4, which indicate FBI surveillance. In paranoid psychosis, the Bayesian equation might be rendered as follows. The information value of the hypersalient event D5 is very large. The denominator of this ratio is very small because the person gives little consideration to the possibility D5 might not be true. Consequently, the likelihood ratio is very large. The relevance of prior experience splits into two terms, a post-psychotic ratio and a pre-psychotic ratio. The PO true post-psychosis number is a very large number. PO false post-psychosis is very small, indicating a lack of interest in experience which does not confirm the delusion. The pre-psychotic ratio (PO true/PO false) approaches 1, indicating that pre-psychotic experience is largely irrelevant to assessing current beliefs. The Bayesian equation becomes:

$$\text{Delusion} = \frac{D_5 \text{ true}}{D_5 \text{ false}} < 1$$

$$\times \frac{\text{PO true post psychosis}}{\text{PO false post psychosis}} < 1$$

$$\times \frac{\text{PO true}}{\text{PO false}} = 1.$$

In our view, it is difficult to apply the Chambon et al. (2011) results to in vivo psychosis without distinguishing between pre-psychotic and post-psychotic prior experiences. Contrary to the study results, clinical psychosis patients with positive symptoms do not rely on their pre-psychotic prior experience with the world. They disregard the experience of a lifetime in favour of the delusion. However, once psychotic, patients rely heavily on post-psychotic experience in interpreting new events. Thus, the results of the Chambon et al. (2011) study are consistent with what one sees clinically in the maintenance of a psychosis but not the inception of positive symptoms. In the study, all prior expectations of the movements of blocks and hands are of the pre-psychotic kind. The experimental paradigm does not generate experience indicating that blocks and hands are capable of moving in ways never before encountered in the subject’s prior life, as would be the case in psychosis. For example, a psychotic person might have post-psychotic experiences that indicated hands can move blocks without touching them, or that hands can pass through blocks, or that blocks can move on their own, and so on. The study manipulates prior expectations but does not bifurcate past experience into pre- and post-psychotic events. We offer the above thoughts not because we have a better experimental model in mind than the one in the study but to foster an ongoing dialogue between clinical experience and laboratory models. In effect, every psychosis is an individual case study in multiple deviations from the Bayesian norm.

References


