

A Delusion of Control: What happens to a sense of Agency in Schizophrenic patients?



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Agency is the feeling of control over your own actions and their effect on the external world. This gives us a sense of power and freedom to act to achieve some motivated goal and explains our movements and actions as our own decisions. This sense of agency is one of the first cognitive processes to develop in Paget's Neoconstructivism model of development. This theory suggests infants first know that they have agency before they recognise others do and even believe objects exist only when they act on them. Research suggests that such an innate part of our sense of self may be impaired in schizophrenia. A loss^{1,2,3} or gain⁴ of agency is a characteristic feature of psychosis and a first rank symptom of schizophrenia. However, this does not appear in DSM-5 as a diagnostic criterion for schizophrenia.

A possible model for the sense of agency was first used to describe the control of motor systems and then also used for the sense of agency. The comparator model involves the comparison between the predicted sensory feedback of an action and the actual sensory feedback of doing the action.⁵ A goal or desired state produces a motor command and an efference copy that feeds into an internal prediction or forward model. The internal prediction model uses this efference copy of the motor command to predict the sensory feedback that would ensue after doing the action. A controller system or inverse model produces the motor command that achieves the desired state or goal given the context of the environment. This leads to a motor output or action, which leads to an actual state and subsequent sensory feedback of the actual state. The comparator model suggests that the predicted sensory feedback based on the efference copy of the motor command and the actual sensory feedback are compared. This produces an error signal that can be used to improve the internal predictions or the controllers that determine the appropriate motor command to achieve a goal. In terms of agency, no error signal would lead to a sense of agency since the actual sensory feedback matches the predicted sensory feedback based on the representation of the motor command, therefore the action is generated by the self. If there is an error signal due to a mismatch in content or the temporal aspect of predicted and actual sensory feedback, it would lead to a diminished sense of agency or none at all according to this model. This describes a retrospective sense of agency since it occurs after the action and is affected by retrospective external cues such as sensory feedback and its comparison with internally predicted sensory feedback from the efference copy of the motor command (the output of the comparator model).

The comparator model is good at explaining a sense of non-agency when there is such a mismatch and is useful in suggesting a mechanism for the loss of agency seen in schizophrenia. However, it does

not seem adequate in accounting for the increased sense of agency seen in schizophrenia,⁴ or the fact that a sense of agency may not be dependent on the predictability of outcomes.⁶ Furthermore, it has also been shown that a sense of agency may be felt at the time of action selection rather than retrospectively after the action has been carried out.⁷ This suggests that a prospective sense of agency exists and it can be affected by external prospective cues that occur before the action, such as subliminal priming, which affects the fluency of action selection, and internal predictions based on efference copies of motor commands. The comparator model is difficult to falsify,⁸ however, it seems to need some modification to account for these points. This led to the development of Synofzik and colleague's 2-step model.⁹ In this model, the sense of agency is divided into a low-level feeling that you have control over your actions (feeling of agency) and high-level conscious interpretation or judgment of being in control of your actions (judgement of agency). In this model, the feeling of agency involves a multifactorial weighting of cues involved in the comparator model, such as efference copies and sensory feedback and the congruence of cues of many modalities, as well as prospective cues. The weighting and integration of these cues, that gives a low-level feeling of agency or non-agency, may differ based on context, the individual as well as between disease groups. Both retrospective and prospective cues are used to deliver a reliable sense of agency.¹⁰ If there is a deficit in either prospective or retrospective agency, there will be an over-reliance on the other. The second step of the 2-step model involves taking the feeling of agency and interpreting it based on belief stance, intentions, and social or contextual cues.

It has been suggested that in patients who suffer from schizophrenia, this integration of cues is altered. There seems to be an over-reliance on external sensory cues, such as visual or auditory perception, for a sense of agency and a deficit in internal monitoring process, such as action selection or parietal internal monitoring.¹¹⁻¹⁴ This may lead to an over-reliance on retrospective agency. Internal predictions and cues may be unreliable in schizophrenic patients, which leads to a greater weighting of external cues. This may cause the sense of agency of a schizophrenic patient to be altered by the events after their actions, invading beliefs, and resulting emotions. This shares features with some of the common symptoms of schizophrenia, for example, patients associating external events as an effect of their actions, due to an aberrant sense of agency, can explain delusions of reference. Patients may over-emphasise the salience of an external event unrelated to their actions and associate it to their agency. However, a schizophrenic patient may also fail to attribute sensory feedback of their actions

with a sense of agency due to unattended or unavailable internal cues, which may reduce their sense of agency for self-produced actions. Patients may understand this as external forces controlling their actions. This could partially explain delusions of influence.^{15,16}

In the most recent study of agency in patients with schizophrenia by M. Voss et al. in 2017,¹⁷ 16 schizophrenic patients and 16 healthy volunteers were taken and used in cued and free priming trials. They were matched for handedness, age and sex, and the patient's symptoms were evaluated with SANS ($\mu=23.42$) and SAPS ($\mu=21.6$) scores.¹⁸ An ego disturbance score was also calculated by summing up aspects of the SAPS score. This has been shown to be particularly relevant to a disturbance of control over one's actions.^{19,20} It is worth noting here however, that there was a large variation in the SANS and SAPS scores ($\sigma=14.08$ and 19.9 respectively). A possible extension to this study could be to make healthy volunteers take SANS and SAPS tests as well. This could be used to make a comparison between the healthy volunteers and schizophrenic patients or even to see if there is a correlation between a sense of agency and SANS or SAPS scores.

In the experiment, they differentiate between the effect of prospective and retrospective cues on a sense of agency.²¹ Both of these are examples of external cues.²² A prospective cue refers to an external stimulus that occurs before action selection, which also influences action selection. In this study, they used subliminal primes, which have already been shown to influence response time.²³ Subliminal primes have been shown to influence a sense of agency²⁴ and compatible primes have also been shown to induce a stronger feeling of control over external action than incompatible ones.⁷ A retrospective cue on the other hand, is an external stimulus that occurs after the action selection, which relates to the outcome of the action. It therefore cannot have an effect on the action selection but can still influence the feeling of control over that action.²¹ In this study, they used the appearance of coloured dots on a screen (the 'action effect') as a retrospective cue.

The trials used were carried out, on a screen, in the following way:

1. A priming arrow was shown for one frame, pointing either right or left. The participant is not consciously aware of the prime as was later shown in a prime visibility test. The prime is followed by a delay of two frames.
2. A target/mask was then shown. The target/mask randomly pointed in one direction in cued trials, either left or right, and the participants were instructed to follow this in their response. In free trials, the target/mask pointed in both directions and the participant was instructed to choose their response.
3. The participant responded, pressing a button (the action) for either left or right with their left or right hands respectively.
4. An action effect occurred consisting of four coloured dots (two for each hand). A different pattern of coloured dots was

shown depending on whether the prime was compatible or incompatible with the response. These dots appeared after intervals of either 100, 400 or 700ms, randomly. The interval between the action and the action effect is the action effect interval (AEI). This variation in the AEIs increases the range of judgements of control.^{7,25}

5. The participant was then asked to judge their feeling of their level of control over the coloured dots shown on a scale from 1-8.

The participants undertook this study in functional and structural MRI. The fMRI measured the BOLD response in areas of the brain such as the prefrontal cortex and the angular gyrus in the action selection phase, which was the time from the prime onset to the participant's response, and the control judgement phase. Functional connectivity was judged by correlating activation in different regions.

It is worth noting however, that due to natural constraints, this study was undertaken on relatively small and varied samples. The sample sizes were reduced further as some participants had to be excluded for excessive movement in the scanners or being able to notice the subliminal primes. The study is also measuring subjective responses, which may require large sample sizes to be meaningful. In fact, not only is a sense of agency subjective but it is also difficult to define as it is, by nature, a quale. This, again, may call into question the validity of the judgements of control made by the participants. It would be worth repeating this study to see if the results are reproducible.

The results for the trials showed multiple correlations. In the cued trials, the response time was faster with compatible primes, where the prime matched the response, than incompatible primes, for both groups. The responses were faster on cued trials than free trials. On free trials, both groups were more likely to select a response compatible with the primes than incompatible. The control group experienced higher levels of control over action effects following compatible prime-target associations than the patients ($P=0.005$). These results are all as was expected and show that the primes worked in terms of influencing response and control judgement. Since the priming occurs before the action, but it is influencing the participant's feelings of control over the action effect, it must be an example of a prospective cue for sense of agency. This shows that a sense of agency can depend on premotor processing before the action.

AEI occurs after the action and so is an example of a retrospective cue. Both groups reported higher experienced levels of control for shorter AEIs. However, the patients felt more control than the controls for shorter AEIs, and less for longer AEIs. In other words, they experienced greater variation depending on the AEI. Since AEI is a retrospective cue for sense of agency, this may reflect a schizophrenic's greater reliance on retrospective, external cues for a sense of agency. This effect in Schizophrenia has been shown by other studies.^{17,26}

With regards to the fMRI results, in cued trials, the dorsolateral prefrontal cortex (dlPFC) and right inferior occipital cortex were more active if the prime and response were compatible. If the prime and response were incompatible, there was instead activation in the insular and fusiform gyrus bilaterally, however the activation in the fusiform gyrus did not survive correction for multiple testing. Note that these are not the same areas used in explicit, conscious conflict, where the anterior cingulate cortex is active.^{6,27} In free trials, there was strong activation in the rostral/medial PFC if they were compatible, and activation in the inferior orbitofrontal cortex if they were incompatible. Since the dlPFC and rostral/medial PFC were more active on compatibility, their activity reflects the ease of action selection. Hence, they were more active with fluent primes. These results are comparable with the classic routes for internally and externally triggered routes of action. Namely, that externally driven responses, as in the cued trials, are dependent on a lateral route, via the dorsolateral PFC and then the lateral premotor area. Internally driven responses are dependent on a medial route, via the rostral/medial PFC and then the supplementary motor area (SMA). The primes still had the same effect on response in both cued and free trials, however. It appears that the prime enters frontal action selection areas but can then influence either the medial or lateral route. The schizophrenic patients showed the same pattern of activity in these areas and showed the same influence of the prime on their responses, suggesting that their frontal action selection areas and, by extension, their motor performance is normal. In this way, we can dissociate the subjective feeling of control from motor performance.

When correlating with the judgements of control, in cued trials, the left angular gyrus was more active at low levels of feelings of control in incompatible trials. In free choice trials, it was the right angular gyrus that was activated on incompatibility, so there seems to be some hemisphere specificity. The angular gyrus is known to be crucial for a sense of agency.^{6,28,29,30} It is also involved in agency via both prospective and retrospective cues.^{28,29} Since it is more active at low reported levels of control, it appears that activity codes for non-agency rather than agency. As is seen with very young infants in the sensorimotor phase of Paget's model, they initially believe objects only exist when they act upon them, and only have a comprehension of their own agency, and not of anyone else's or any other causes for action. The brain then later develops enough to be able to inhibit sense of agency. Therefore, it may be that the brain works by first assuming the action was caused by the being in question, and then coding for non-agency if there is a mismatch. Crucially, this modulation of activity in the angular gyrus by the sense of control occurred in healthy volunteers but not in patients, and so may be the cause of their reduced reported feelings of control in compatible trials.

In cued, incompatible trials, there was increased frontoparietal connectivity between the dlPFC and the angular gyrus bilaterally in controls. The relationship was such that increased activation in the dlPFC reduced activity in the angular gyrus. The same relationship was found in free choice trials but between the medial PFC and the angular gyrus. This is likely to be the method by which a prospective cue codes for later agency over an action. This change in connectivity did not occur in the patients, however, and may explain their lessened sense of control in response to prospective cues. It is important to remember that the patients still reported the same variation in levels of feelings of control, however this variation was not as correlated to prime compatibility to the response. After statistical analysis it was found that the increase in variation of feelings of control depending on AEI roughly balanced this. Therefore, in schizophrenia, patients may not monitor prospective cues as well due to a lack of coding in the angular gyrus and a disrupted functional connectivity with the frontal action selection areas, and so to compensate, they rely more heavily on retrospective cues. The connection from the frontal action selection areas to the angular gyrus seems to form part of a monitoring circuit of the action taking place, with the angular gyrus acting as a metacognitive monitoring hub for many processes, including coding a sense of agency. A simplified schematic for how this might work can be seen in Figure 1.

This experiment design is a useful way

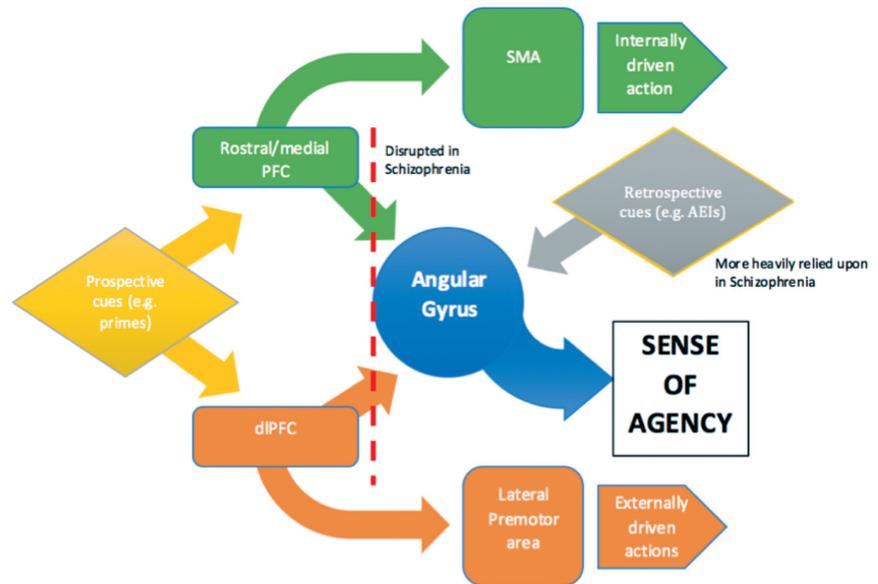


Figure 1: A simplified proposal schematic of how a sense of agency may be elicited, and how it is disrupted in schizophrenia.

of investigating the difference in sense of agency between patients and healthy volunteers, however it may be difficult to scale this up to explain delusions seen in schizophrenia, because delusions are far more complex than the experimental design. Also, our ability to infer conclusions about the hypothesis that the sense of agency is affected in schizophrenia, is limited due to the small sample size and the subjective measure of the sense of agency. The

results of this study are especially pertinent as we can start to elucidate a cognitive and neurobiological model for the loss of agency and possibly some of the positive symptoms of schizophrenia. This may lead to useful diagnostic tools and therapy for schizophrenic patients. Giving a schizophrenic patient back their control over their actions, emotions and perceptions is the ultimate goal in their therapy.

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