

**Dysfunctional value-driven attentional capture based on
selection history could explain attention deficits in
psychosis**

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DYSFUNCTIONAL VALUE DRIVEN ATTENTIONAL CAPTURE IN PSYCHOSIS

Abstract

Psychosis is a mental disorder that does not have a high prevalence in society, but those who suffer from it are heavily impaired. Deficits in attention have often been linked to the onset and perseverance of psychosis, but the mechanisms responsible are unclear. In this review paper, aberrant attentional capture is investigated as it could give insights into the attentional problems encountered in psychosis. The examined literature provides further evidence for the dopamine hypothesis of schizophrenia. Not the physical saliency of stimuli but learnt salience based on aberrant dopamine regulation and subsequent associative learning processes attribute to the attentional deficits observed in psychosis. Previous paradoxical findings on attentional capture in psychosis can therefore be viewed in a different light. Future research should focus on the interaction between dysfunctional dopamine regulation and its relationship with other neurotransmitters known to be involved in the onset of psychosis, as well as identifying natural types of stimuli that capture attention in a value-driven way.

Keywords : psychosis, dopamine, attention deficits, attentional capture, selection history, saliency

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Introduction

Schizophrenia or psychosis (the terms are used interchangeably) is a debilitating mental disorder, characterized not only by aberrations in motor skills, cognition, emotions, attention, decision making but also the formation of delusions and hallucinations (Liddle, 1987). With an estimated prevalence of 0.5% throughout the American population (Wu, Shi, Birnbaum, Hudson & Kessler, 2006) psychosis might be discarded as a minor burden on society. However, those who suffer from it are heavily impaired and societal costs can rise into many billions (Knapp, Mangalore, & Simon, 2004). Although prevalence differs among countries, many studies have aimed to identify predictors of psychosis and have found consensus on some factors that contribute to the epidemiology and sensitivity of individuals to develop psychosis (McDonald & Murray, 2000). These range from genetics, substance abuse and extreme environments but are wrapped in intricate web of elusive co-dependencies.

Tackling psychosis requires more understanding than merely pointing out its predictors. Luckily, research on neurotransmitters has produced a strong link between psychosis, attentional deficits and aberrant dopamine regulation, which has been dubbed as the 'dopamine hypothesis of schizophrenia' (Toda & Abi-dargham, 2007). Dopamine is known to be strongly involved in many facets of selection and maintenance of attention (Rose, Schiffer, Dittrich, & Güntürkün, 2010, Nieoullon, 2002) as well as coding for saliency and reward (Berridge, 2007). Hyperactivity of dopamine transmission thus could therefore lead to attentional deficits, symptoms that are seen as key symptoms of the disorder (Cornblatt, Obuchowski, Schnur & O'Brien, 1997). Recent fMRI studies show that attribution of salience to reward-predicting stimuli and further computation of prediction errors is indeed altered in psychosis (Heinz & Schlagenhauf, 2010). Further evidence comes from medical studies reviewed by Kapur, Mizrahi & Li, (2005) that show how dopamine agonists can

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produce psychotic symptoms in healthy individuals whereas antagonists typically reduce psychotic symptoms in patients. Although evidence is strong, it is also known that serotonin (Quednow & Geyer, 2009) and glutamate (Coyle, 2006) are linked to psychosis and dysregulations of these neurotransmitters are seen as potential causes for other attentional deficits such as ADHD (Fox, Ridgewell, & Ashwin, 2009, Carrey, Macfaster, Gaudet & Schmidt, 2007). However, it remains unclear how these three neurotransmitters influence each other.

According to the dopamine hypothesis, hyperactive dopamine neurons attribute inappropriate significance and salience to stimuli, associations or objects (Kapur, 2003). Due to this inappropriate significance, basic associative learning processes produce irrelevant connections between stimuli over time, which can manifest itself into delusions or full blown psychosis. In other words, the confused observer attempts to rationalize his experiences of novelty and salience in these bizarre experiences. Aberrations in salience processing caused by dopamine dysregulation could therefore redirect attention to actual irrelevant stimuli, internal or external and this could account for the attentional problems seen in psychosis. In accordance with this theory, Japanese mental healthcare has been the first to rename the disorder Salience Syndrome (Van Os, 2009).

One of the testable attentional mechanisms that has been linked to such aberrant saliency processing is latent inhibition (LI). It has been formally described by Lubow (2009) as the “reduced ability of an organism to learn new associations to previously inconsequential stimuli“. In psychosis, latent inhibition is thought to be reduced, which means that an observer has difficulties filtering out irrelevant stimuli. Although studies have found a reduced LI in patients with schizophrenia (Baruch, Hemsley & Gray, 1988), it is contested whether or not this effect is due to the actual disorder or it’s pharmacological treatment (Williams et al, 1998). Furthermore, there are difficulties in accurately conceptualizing or

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modelling the relationship between latent inhibition and psychosis (Swerdlow, 2010). This conceptual difficulty seems to be supported by people who do not suffer from psychosis but do have self-proclaimed low LI, but actually benefit from it (Carson, Peterson & Higgins, 2003). This is hardly compatible with the distractibility that is seen in psychosis.

Another attentional mechanism that could illustrate the existence of aberrant saliency processing is attentional capture. Attentional capture has been described as the involuntary drawing of attention towards a location in an exogenous stimulus-driven manner (Yantis, 1993). A real world example would be a person reading a book in a park. He or she might become distracted by a cyclist that pops up in the peripheral visual field and subsequently has to halt the present task of reading due to the reallocation of attention towards the highly salient new object. Differences in the saliency of such objects (a speedy purple clothed cyclist compared to a slow black clothed cyclist) influence whether or not attention is relocated. Dysfunctions in this system could give rise to the attentional deficits in psychosis. In this review paper, recent findings on attentional capture and its possible role in the formation of psychosis will be highlighted. If disruptions in this mechanism are found in those with psychosis and are correlated with neuro-biological dysregulations of the above described neurotransmitters, it could lead to more consensus on what type of dysfunctional attentional mechanism lies at the heart of psychosis.

Physical saliency and attentional capture

Since the discovery of attentional capture there has been strong emphasis on physical saliency of stimuli (Koch & Ullman, 1987). The more salient a distractor is in its features such as colour, shape and motion, the more it is likely to capture your involuntary attention. Concurrently, it is also known that endogenous control has a modulating effect on this capture, as described by Ruz & Lupienaz (2002). People are thus not entirely subject to involuntarily switches in attention, but actively modulate the saliency of stimuli with top

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down settings.

To investigate whether or not attentional capture is impaired in psychosis, Ducato et al., (2008) designed three experiments where participants had to locate a target square that either appeared above or below a fixation dot. A distractor was added alongside the presentation of the target square, and was either a moving object or a static distractor that changed colour. They found that schizophrenic patients showed more involuntary attentional capture than nonpsychotic subjects. However, this effect was only present for the motion, and not for colour distractors, which hints towards a role for physical saliency. Congruent results were obtained by Leonard, Robinson, Hahn, Gold, & Luck (2014) who used a similar visual search paradigm.

Since both experiments used low-load cognitive tasks, it might be that attentional capture was only present due to left over attentional resources in the patients. To test for this theory, Ducato, Thomas, Monestes, Desprez & Boucart (2008) designed another experiment where they used a task load paradigm with incrementally complex visual scenes. They assumed in advance that schizophrenic patients would show less attentional capture in higher load conditions, as their attentional resources would already be depleted. The results confirmed that patients were indeed better than healthy controls in resisting interference in medium and high load tasks. The authors suggest that this effect is not due to an ability to better filter out irrelevant information, but more so stems from a limitation in attentional resources. This reduced processing capacity leads to heightened selectivity and seemingly strong sustained attention, characterized by a neglect of distracting stimuli if presented in a high load scene.

Selectivity and sustained attention

Based on these studies, it seems that attentional capture for visual stimuli is abnormal in psychosis. Both the load of a visual scene and saliency of visual distractors are able to

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modulate the orienting of attention, but its mechanism remain unclear. To find out, Carter et al., (2010) used a visual selective attention task in a recent fMRI study. The goal was to dissociate between transient and sustained attentional deficits in psychosis. A mixed block and event related design was used in order to test both sustained attention (block) and transient attention (event-related). Participants had to press distinct buttons for the targets and none targets. They found significantly slower mean response time and correct responses for the psychosis group. Furthermore, fMRI results revealed more brain activity in regions of interest for psychosis than controls during the sustained attention task. However, they found reduced brain activity in the regions of interest compared to controls for the transient periods within the task. The authors suggest that this diminished brain activity as a response to transient attention demanding stimuli shows that psychosis is not characterized by deficits in sustained, but rather in transient attention.

The results of an experiment conducted by Williams, Wellman, & Geaney (2005) are congruent with these findings. They rated clinical distractibility in patients with acute schizophrenia alongside a range of other metrics. The experiment consisted of a single trial colour-naming Stroop task where participants were asked to vocalize the ink colour of words that were always written in a conflicting colour. Such tasks are known to measure attentional control, with more interference indicating decreased attentional control. Stroop task interference was very low for patients who scored high on 'clinical distractibility', which is similar to the results found on high load tasks by Ducato et al., (2008). In support, they also found that patients with low Stroop interference scored higher on the metrics of Reality Distortion and Disorganisation. The authors state that while it is often thought that strong selective attention is a good thing, too much selective attention, interpreted as a resistance to attentional capture, can severely impair functioning

Although Williams et al., (2005) found decreased distractibility during a high load

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attentional Stroop task, Tang, Wong & Chen (2016) did find attentional capture, albeit in the auditory sensory system. They used a similar Stroop paradigm, but throughout the task also randomly played the name of the subject binaurally. This auditory distractor significantly captured the attention for psychotic patients who had ideas and delusions of reference, but not for psychotic patients without such delusions. These findings indicate intergroup differences in the attribution of salience to stimuli, in this case, the auditory sensation of hearing one's own name.

Based on the studies described above, it seems that visual attentional capture in psychosis is altered and is modulated by the load of the task. Specifically, the results suggest that psychosis is characterized by strong selectivity on stimuli when the load is high, which is indeed incompatible with the distractibility proposed by the low LI theory. This also implies that exogenous attentional capture based on physical saliency would be reduced in real life situations, as these are almost always high load situations and thus could not be an explanation for the distractibility found in psychosis. However, the findings by Tang et al., (2015) hint towards attentional capture that is based not only on physical salience, but on learnt inappropriate attribution of salience. The dopamine hypothesis predicts that attentional deficits primarily occur due to aberrant saliency processing, not due to the initial physical saliency of stimuli. The ambiguous findings on selectivity might thus be explained by the use of primarily visually physical salient stimuli within very controlled experimental settings, instead of value based or learnt stimuli that are saliently enhanced through training or experience.

Value-driven attentional capture

Typically, humans do not only pay attention to exogenous, physically salient visual stimuli, but to all the sensory modalities. Furthermore, attention is also required for our appreciation of internally generated representations such as thoughts, ideas and beliefs (such

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as the representation of your own name). This has been described as value-driven attentional capture. Like Tang et al., (2015), Anderson, Laurent & Yantis (2011) show that high-value but contextually inconsequential stimuli can capture attention as a consequence of reward learning. In their experiment on healthy participants, they showed that the search for a salient target was slowed through the presentation of a task-irrelevant item which was imbued with the idea of monetary award through a training session. The authors argue that arbitrary, neutral stimuli that are imbued with value or salience via basic associative learning mechanisms are able to capture attention, regardless of contingent goals or physical salience. Congruent with these findings, Munneke, Hoppenbrouwers & Theeuwes (2015) found that reward can modulate attentional capture in healthy individuals regardless of the activated top down set. This mechanism has been described as 'selection history' and is supposedly a third category of attentional capture that was first elaborated on by Belopolsky, Schreij & Theeuwes (2010). The theory states that top down control can be reduced to mere monitoring of the attentional process and does not control the attentional selection process itself. Thus, involuntary shifts of attention that can be behaviourally interpreted as distractibility might occur primarily on the presence of previously rewarded stimuli or associations of stimuli.

The experiment conducted by Le Pelley, Pearson, Griffiths & Beesley (2015) provides further evidence that saliently enhanced stimuli can produce the counterproductive behaviour that we see in psychosis. They used a visual search task which contained distractor stimuli of which the participants knew if they either signalled low or high reward. However, whether or not the reward was actually paid was not contingent on actually responding to said stimuli, as attending to the distractors always led to a reduction of reward. The results showed that the distractors which signalled large reward produced heightened attentional and oculomotor capture compared to those who signalled a small reward. The authors argue that

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such capture by task-irrelevant but saliently enhanced stimuli is important, as it could model the counterproductive behaviour that is seen in many problematic real world situations.

From functional to dysfunctional.

The experiments described above all used healthy participants and monetary value as a means to imbue artificial reward to certain stimuli. However, one can now readily imagine how the psychotic hyperdopaminergic brain could effectively be doing the same thing. In order to investigate the plausibility of this theory, Roiser, Howes, Chaddock, Joyce, & McGuire (2013) conducted an fMRI experiment where individuals who were 'at high risk for psychosis' (ARMS) and controls performed the Salience Attribution Test which provides behavioural measures of adaptive salience. Results showed that ARMS were significantly more likely to attribute motivational salience to stimulus features that were irrelevant. Furthermore, their likelihood to do this positively correlated with the severity of their delusions. To see if these results are generalizable, Reininghaus et al., (2016) used an experience sampling questionnaire to gauge how individuals with first-episode psychosis, 'at risk for psychosis' status and controls scored on the categories elevated stress sensitivity, experiences of aberrant novelty and salience, and enhanced anticipation of threat. Their results showed that individuals who were classified as 'at risk for psychosis' scored the highest on experiencing aberrant salience and novelty with regards to their subjective experiences. Mishara, & Fusar-Poli (2013) further elaborate on a novel framework which incorporates these experiences as an explanation for delusion formation.

Although there exists a lack in experimental results concerning patients, the findings in healthy individuals hint towards the possibility of dysfunctional attention in psychosis caused by attentional capture by specific irrelevant stimuli. Unbeknownst to the observer, the brain is imbuing certain stimuli, objects and associations with too much saliency and novelty, as if someone was literally assigning money to them. Although this mechanism helps healthy

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people to engage and disengage attention to relevant or irrelevant objects, there might be an initial coding error in psychosis. As this selection process operates partly under the hood of consciousness and is based on an accumulation of past experiences and learned patterns of reward and associations, deficits in attention might not always univocally present themselves in experimental settings. This could be an explanation for the lack of attentional capture and somewhat intact sustained attention seen in the studies discussed.

Conclusion & Discussion

The scope of this paper was to investigate the role of aberrant attentional capture as an explanation for distractibility and attentional deficits seen in psychosis. Through convergence of literature, it has become clear that attentional capture in psychosis depends not so much on the often tested physical saliency of stimuli (excluding motion), but more on the attributed learnt saliency towards irrelevant stimuli. Value-driven attentional capture and reward learning in healthy participants show how involuntary shifts of attention can arise primarily on the presence of previously rewarded stimuli or associations of stimuli. These findings correspond with the dopamine hypothesis of schizophrenia.

However, psychosis is an incredibly broad term and an equally broad field of interest for many scientific disciplines. As many neurophysiological mechanisms interact to form the full-fledged state of psychosis, it is rather naïve to expect all understanding to come from aberrant dopamine signalling, and research on the role of serotonin and glutamate are warranted. However, based on the current findings, it seems that distractibility and attention deficits in psychosis are likely to stem from the functionally normal selection history mechanisms of attentional capture. In psychosis, dopaminergic hyper activation makes it more difficult to establish why previous stimuli or associations were selected to be as salient as they are. Since selection of attention can be completely independent of top down goals, it can result in the phenomenology of psychosis, where involuntary violations of attention

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occur. As heightened motivational salience is attributed to actual irrelevant stimuli, delusions will form over time based on associations that do not make sense to outsiders.

Kapur et al., (2005) describe this delusion formation as a top-down cognitive explanation constructed by the observer in order to make sense of the aberrant saliency of stimuli, objects or events. This framework can explain how strong interpersonal and intercultural differences exist in delusional content. Although the underlying mechanism might be disrupted in a similar fashion, the observer uses his personal life and cultural history to give exact form to the delusions. Thus, it is possible for the same theory to explain how someone in Japan might think that the Yakuza is following his every move, whereas a Christian Evangelist in a Southern state of America might come to believe himself to be Jesus.

If the proposed theory holds any truth, future researchers will have to find new paradigms in order to test attentional deficits in psychosis, as regular attentional capture tasks are unable to highlight the deficits in attention and do not generalize well to real life problems or clinical practice. This might prove to be too cumbersome as distractors that do possibly capture attention might be highly personal and can be content of a patients delusion. However, as Tang et al., (2016) showed, there might be certain stimuli such as self-referential stimuli, that could serve as standardized means of evoking significant attentional capture.

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