Neurobiology of technological addiction : Impulsive compulsive spectrum

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INTRODUCTION

For the last two decades we are witnessing a change, an advancement of technology leading to communication revolution. People are coming closer in a virtual world. Smart phone, computer, internet, social networking sites like facebook, whatsapp are now household names. Another person from the farthest part of the globe can access anything happening at another part of the globe. Information of different spheres is now at our fingertips. Many commercial activities like banking, shopping, entertainment etc are routinely done through internet. Many social networking sites are very much active. Any sort of information sharing, or protest on a social cause can be done through these sites instantaneously. But all good things come with a vice. This is also no exception. There are lots of people who are hooked to facebook, games etc neglecting their normal activities with a negative impact on their school, social or occupational life (Young, 1998). It is almost like addiction to a substance. Internet addiction is a new rubric added to the group of behavioural addiction like pathological gambling. Though in DSM 5 only the internet game addiction has been included in the appendix (DSM 5), the similarities between substance use and technological addiction has influenced many researchers to study to find out the common brain correlates between these two disorders. Most of the research in this area has been done in Asian countries like China and Korea. These findings are not only important from understanding the scientific underpinning of addiction but also important from the point of intervention. It also determines whether it should be approached medically or socially or both.

ADDICTION AND BRAIN : SOME GENERAL COMMENTS

Drug addiction is now considered to be a chronic, relapsing brain disorder. One of the most intriguing questions of drug addiction is that why people continue to take drug even when the pleasure associated with the drug is gradually diminished, with so many negative consequences in family life, occupational life, financial situation and physical health. In the last two or three decades there is a paradigm shift in understanding drug addiction. Two of the persons who are instrumental in bringing this change are George Koob and Nora Volkow. According to Koob, apart from getting back the hedonic pleasure when off drug, there are other mechanisms responsible like allostasis and anti reward mechanism (Koob and Le Moal, 2008). As per Volkow, loss of control of the prefrontal cortex over the reward circuitry, i.e. Ventral Tegmental Area (VTA) and Ventral Striatum (VS) is one of the main reasons why people continue to take drugs even when there are lots of negative features. It is like driving a car without brake (Volkow et al, 2003). It has been found that people with impulsivity and sensation seeking traits often indulge in using drugs or other high-risk behavior. Among them some get hooked to drug while others can lead a normal life. In the next part, I will discuss the reasons behind that.

IMPULSIVITY, COMPULSIVITY AND LOSS OF CONTROL : EXTERNALIZING BEHAVIOR

Impulsivity has many definitions. The basic feature of impulsivity is to undertake an action without thinking about the consequences. It is poorly

conceived, premature, in appropriate and frequently results in some deleterious effect (Chamberlain and Sahakian, 2007). Compulsivity refers to repetitive acts or behavior, which is performed as a rigid rule or to avoid negative consequence (DSM 5). So the constructs can be viewed as diametrically opposite; impulsivity is associated with risk taking and compulsivity is associated with harm avoidance (Fineberg et al, 2014). But interestingly both impulsivity and compulsivity has been implicated in explaining addictive behavior including behavioural addiction. In the DSM 5 gambling disorder has been put under substance related and addictive disorders, while in DSMIV it was under impulse control disorder. So a compulsive behavior like gambling has a strong relationship with impulsivity, and many behaviors start initially as an impulsive behavior, but later transforms into a compulsive habit forming behavior.

There are different types of impulsivity with different significance and different cerebral correlates. Potenza and Wit (2010) have suggested two different dimensions of impulsivity, choice impulsivity and response impulsivity. Fineberg (2014) has elaborated the concept and has given four different types of impulsivity. Motor impulsivity is inability to stop motor responses. Go/no go test and stop signal reaction time (SSRT) are the tests used to evaluate it and right inferior frontal gyrus (IFG) with subcortical connections is the brain region involved. Decision-making impulsivity is inability to take decision on the basis of risks involved. Neuropsychological test is the Gambling task and orbitofrontal (OFC) connection is the cerebral correlate. Choice impulsivity is where one cannot delay gratification and opts for immediate reward with negative consequences. Delay discounting task is the test and ventromedial prefrontal cortex (VMPFC), OFC with ventral striatum (evaluation) and anterior cingulate cortex (ACC) (cognitive control) are the brain areas involved. Reflection impulsivity is the action based on insufficient information. The cerebral correlate is not clear; information sampling task is the test.

One of the challenges neuroscientists face is that how the impulsive drug taking is transformed into compulsive use. Everitt and Robbins (2013) have hypothesized that, this may be due to shift of loci of control from ventral striatum to dorsal striatum, and progressive loss of control over drug related behavior (Everitt and Robbins, 2013). Volkow et al (2003) in an article earlier had named several brain circuits which are important from the point of view of drug addiction. They are reward (NA), motivation (OFC), memory (amygdala and hippocampus), and cognitive control (ACC). In a model postulated by them during exposure to drug and related cues the memory of the expected reward results in overactivation of the reward and motivational circuits and deactivation of cognitive control.

Recently the role of insula has also been postulated in addictive behavior. The insula is important for understanding the interoceptive state of the body and through its connection to VMPFC, ACC and VS maintains the adaptive behavior. In case of insular dysfunction the deficit in self-awareness during intoxication results in failure to recognize the pathological state and leads to denial. So this may be another explanation from initial voluntary drug use to pathological compulsive use (Volkow et al, 2013)

Another important area of research for the predictors of substance abuse is the externalizing behavior. As the basic impairment in addiction is the loss of control and impulsivity, so externalizing behavior is thought to be a risk factor for substance use. A recent study has shown that externalizing behavior in the absence of internalizing problem has the strongest association with alcohol, cigarette and marijuana use (Colder et al, 2013). So rule breaking and aggression may be a forerunner of different types of addiction. Also those with externalizing behavior have shown poor outcome including poorer treatment retention and greater drug use in follow up treatment (Winters et al, 2008). In a study conducted in NIMHANS, India, Benegal et al (2007) found that high risk subjects for alcoholism show significant smaller volume of superior frontal,

cingulate, parahippocampalgyrus, amygdala, thalamus and cerebellum. The gray matter volume also correlated negatively with externalizing symptoms. They proposed that the implicated brain region may be a part of causal pathway of generalized disinhibitory complex. This results in compromised impulse control, high novelty seeking, increased reward dependence and unconcern about long term negative consequences. All these may be causal to increased vulnerability to alcoholism. Also it has been found that increased impulsivity coupled with increased sensation seeking behavior is the reason why some people with impulsive behavior are more prone to develop addictive behavior, than those with either impulsivity or sensation seeking (Ersche et al, 2013)

So a behavior, which usually starts in some persons with a certain kind of personality traits, results in some changes in the brain with the transformation of a voluntary impulse driven behavior to a compulsive habitual behavior. I will try to explain the technological addiction with the same brain circuits in the later part of the review.

DEFAULT MODE NETWORK

Recently it has been found that brain at rest is not actually in rest truly. Most of the functional imaging studies of brain have been done in response to some task and cognitive subtraction method is used to find out the region important for the particular task. But recently it has been found that brain is very active even in the absence of explicit input or output. One of the networks which is active in resting state is default mode network (DMN) consisting of PCC, precuneus, medial prefrontal cortex and bilateral temporoparietaljunction (Utevsky et al, 2014). The DMN exhibits low frequency oscillation during resting state and deactivates during a task performance (Fox and Raichle, 2007). There is still controversy regarding the function of the network. Greicius et al (2003) postulated that retrieval and manipulation of episodic memories and semantic knowledge may be the likely candidate. Cavanna and Trimble (2006) are of the opinion that precuneus,

one of the important brain regions of the DMN, is important for integrating internally and externally driven information. When one does any cognitively demanding task the DMN is deactivated with activation of cognitive executive network (CEN) whose main functioning area is DLPFC. The right fronto insular cortex (rFIC) and ACC network play a critical and switching role between DMN and CEN. (Sridharan et al, 2008). Sutherland et al (2012) have postulated that insular dysfunction can result in some problem in this circuit connectivity, giving rise to some change in cognitive circuitry resulting in addictive behavior. In another study done among pathological gamblers the network properties of resting state functional MRI data was analysed and alteration of integration and segregation of medial frontal regions was found, which may be causally related to the behavioural alteration of pathological gamblers (Tscherneegg et al, 2013). So DMN is a new area of research for understanding addictive behavior.

TECHNOLOGICAL ADDICTION

We use modern technologies like mobile phone, computer, internet etc everyday. So much so that it is now almost unthinkable to live without these facilities. Many of us have account in Facebook or WhatsApp. And it is so easy to communicate or keep in touch with someone living at a distant place, or finding out old friends. But as all who drink alcohol do not become addict, so also a minority of people using these become hooked to it. It is important to know the psychological and biological vulnerabilities of these people. The first time when Young (1999) introduced the concept of internet addiction, it sparked a huge controversy. People used to debate that addiction is a term which should be used only with drugs. But over the years there is some change in the concept and pathological gambling which was an impulse control disorder in DSM IV has been included under addictive disorders in DSM 5. Internet gaming disorder has still not found any place in the main text of DSM 5 but has been included in the appendix. But many of the symptoms of this group is similar to drug

addiction. They are unable to stop this activity even when it interferes with other important activities of life or harmful to the person. Internet, mobile, video games are the most significant technological addictions. The psychological processes involved in the development of dependence are 1) sense of playfulness and experience of absorption provided by the games 2) opportunities for social interaction provided by the internet and 3) accessibility and availability of mobile phone. (Choliz et al 2012). Wilson et al (2010) have predicted that extraverted and unconscientious individuals reported higher levels of both social networking sites use and addictive tendencies. The most important factor for diagnosis of internet addiction is the unsuccessful attempt to control the behavior or in other words the loss of control (Brand et al, 2014). There are two types of internet users, general and specific. The neuropsychology and the neurobiology of these different groups will be discussed in the next section

RESEARCH FINDINGS ON TECHNOLOGICAL ADDICTION

Most of these researches have been done on internet related addiction. So my review will be confined to those aspects only.

The basic problem in internet addiction is the loss of control over the use of internet. So the model proposed by Volkow et al (2003) is also applicable here. They proposed a network of four circuits, reward, motivation/drive, memory and cognitive control. Here the enhanced value of the process of reward, motivation and memory circuits overcome the control exerted by prefrontal cortex. Therefore one cannot control his behavior in spite of the negative consequences. To prove the hypothesis two types of research approaches have been taken. One is through the neuropsychological testing, the other is through the different functional neuroimaging.

One of the tests, which have been used quite commonly to find out the loss of control, is the "Iowa gambling task" (Bechara et al, 2000). Here decision-

making is being done in ambiguous conditions. Here participants are instructed to choose from four deck of cards. There are some bad decks and some good decks. Choosing the bad deck will result in losing money but choosing the opposite will result in gain. The whole procedure of selection of decks is blind. So trial and error method is applied. Normal people choose the better decks after several trials. But people who use excessive internet have deficit in Iowa gambling task (Sun et al, 2009). The problem in decision making of Iowa gambling tasks has been attributed to the defective functioning of ventromedial prefrontal cortex, which is further explained by somatic marker hypothesis (Damasio 1994, Bechara et al, 2006). This is a part of the reward circuit. So here the impulsivity in taking a decision is the driving force behind. The other test, which has been used frequently, is the Go/no go test, which is a test of response inhibition. Sun et al in the same experiment as depicted above have found that excessive internet users fared better in the Go/no go test. But Zhou et al (2012) in a study of 46 persons with internet addiction disorder tried to find the cognitive bias, mental flexibility and response inhibition of internet gaming addiction. They found that the persons with internet gaming disorder had cognitive bias towards information related to internet gaming and also had lower mental flexibility and response prevention. So this is a pointer towards placing internet addiction in the impulsive compulsive spectra. In another recent study by Snagowski and Brand (2015), 123 heterosexual males were given an Approach Avoidance task modified with pornographic pictures. It was found that individuals with high sexual excitation and problematic behavior and with high approach/avoidance tendencies reported higher symptoms of Cybersex addiction. This study provides empirical evidence link between cybersex addiction and substance dependence. Zhou et al (2014) in another study compared Internet addiction disorder patients with alcohol addiction patients by using Barrat impulsive scale 11, go/no go tasks, Wisconsin card sorting test and digit span task. The findings showed similarity in the impulsivity,

defective executive functions and working memory between the two groups. So it can be postulated from neuropsychological evidence that a person with internet addiction has similar problem of defective cognitive control when they are exposed to addiction related cues and therefore can be grouped under the addictive disorder group.

NEUROIMAGING FINDINGS IN INTERNET ADDICTION

Internet addiction is associated with poor impulse control, and the people with internet addiction disorder (IAD) use it compulsively despite adverse consequences. Areas responsive for impulse control like orbitofrontal cortex (OFC) has been found to be thinner in IAD (Hong et al, 2013). In another study Dong et al (2012) compared IAD and healthy control (HC) using Stroop task and fMRI. They found that IAD group demonstrated greater Stroop effect related activity in the ACC and PCC which showed diminished response inhibition among IAD group. Li et al (2014) have found that IAD subjects fail to recruit the indirect frontal basal ganglia pathway in response inhibition tasks like Go/no go. They postulated IAD as a behavioural disorder and aberrant connectivity in the response inhibition network is the cause. Some of the earlier studies have looked into the persons who play excessively the World of Warcraft (WoW) games. It was found that during playing of the game they show stronger activation of the reward circuits including nucleus accumbens, OFC and caudate (Brand et al, 2014). In a recently published study Wang and his colleagues (2015) have compared 28 IAD with 28 HC. They found that gray matter of the bilateral ACC, precuneus, supplementary motor area (SMA), superior parietal cortex, left DLPFC, left insula and bilateral cerebellum is decreased in IAD. The gray matter volume of ACC was found to be negatively correlated with incongruent response errors of the Stroop task. In a study between 35 internet gaming disorder and 36 HC, where resting state functional connectivity was observed, it was found that the functional connectivity in reward circuitry was

stronger than the executive control circuitry (Dong et al, 2015). So impairment in executive control network is unable to control the excessive time spent in internet gaming. In another study by Hong et al (2013), resting state functional MRI image was compared between 12 IAD and 11 HC. It was found that functional connectivity in cortico striatal circuit was impaired in IAD group. Ding et al (2014) in a study using fMRI and Go/no go test also found that the prefrontal circuit which is important for modulating impulsivity is impaired in case of IGA, which leads to high impulsivity among them. In another study it was speculated that abnormal development in the long range and interhemispheric connectivity may be the reason of IAD (Wee et al, 2014)

So both when given some tasks like response inhibition or impulsivity as well as in resting state the circuit imposing cognitive control is weaker than the impulsivity and reward circuit resulting in excessive use of internet even when there is negative consequence.

CONCLUSION

So the internet addiction and other forms of technological addiction is a rapidly growing field for the study of human behavior. Both neuropsychological and neuroimaging studies have opened a new vista for understanding of brain behavior relationship. There are still many controversies over the adoption of internet addiction as an addictive behavior but many of the similarities between these two types of behavior is gradually emerging. DMN is a new area of research for understanding myriad brain activities. Still we have to go a long way to understand a behavior, which starts as an impulsive behavior but over the time gradually, turns into a compulsive habitual behavior resulting in many negative consequences.

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