Consciousness as an Alternate Interpretation of Corollary Discharges

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Contents

1 Abstract

The mechanism of thought initiation in the brain to its execution as a motor action is a complex process that is still in the process of being understood.

I would like to hint closer towards a materialistic concept of consciousness using the help of schizophrenic patients. Their corollary discharge functioning is affected, hence malfunctioning, leading to their inability to distinguish between self and other. I investigated if these patients with hindered corollary discharge functionality had problems with consciousness.

I studied their reaction times towards simple button press actions (both active and passive button presses) where they had to signal the instant when they consciously felt like pressing the button and then press the button. In a significant number of active button presses it happened that the conscious realization of the activity occurred only after the activity was performed whereas the passive button press actions had results similar to that of normal humans (performing the same experiment) where the subjects were fully aware of what they were doing (in case of humans) and forced to be aware of their actions (in Schizophrenic subjects). Contradicting the above results were also few unexpected situations where consciousness was hindered between thought initiation and motor action.

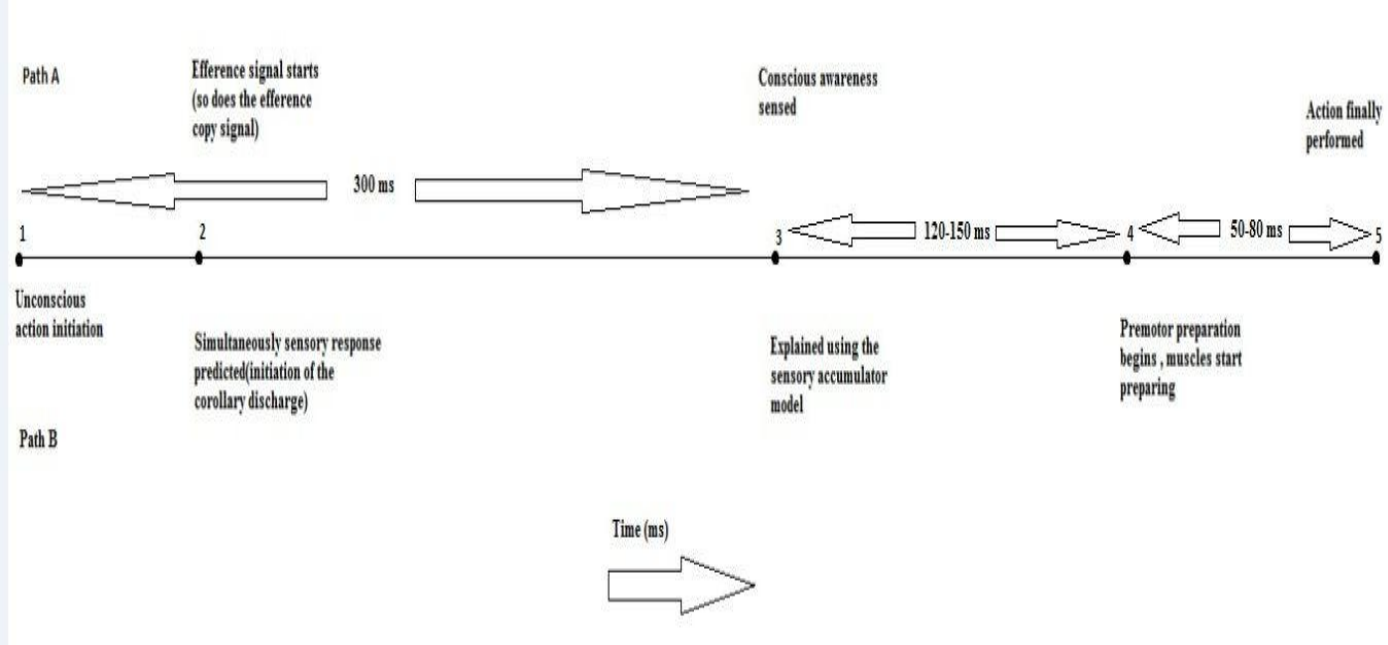
2 Introduction

The nature of consciousness has always intrigued mankind since ages. It's been under attack by philosophers, neuroscientists, psychologists leading to a lot of theories like dualism, logical behaviourism, functionalism etc. It has not convincingly been mapped either to the physical domain or the mental domain. Consciousness could either be materialistic neural signals in the brain or non-physical entity that exists independent of the brain. It is highly peculiar that it stubbornly resists an attempt at explanation. Jean Paul Stare often said 'consciousness is what I am not, and is not what it is.'

3 Motivation

Nadia Chernyak et al[1] in their paper analysed and observed the concepts of free will in Nepalese and American children. They studied if decisions made were either done consciously i.e. totally an independent decision of the individual or were the decisions influenced by societal constraints. While Sukhvinder S.Obhi in his paper [2] studied the sources of conscious awareness of action and differences between anticipatory judgement times in active and passive key press movements. Keeping an overall view of both the papers I wanted to study if consciousness can be materialistic using the methodologies used in [2] and differing from the ideas of free will proposed in [1].

4 Fundamental concepts involved



Based on the studies of Benjamin Libet et al[3], Irwin Feinberg[4], the concepts of efference copy and the forward internal model of motor control I have summarised the entire thought flow process concerning the execution of a motor action. From the unconscious initiation signals in the brain till the final performance of the action. Here is a brief description of the thought flow mechanism:

1. The first signs of any intention to perform an action are observed in the pre supplementary motor area of the brain using Electroencephalography (EEG).This is an unconsciousness process, the subject is unaware of his future actions at this stage.

2. After a very negligible amount of time (~few milliseconds) an efferent signal originates from the complex Central Nervous System (CNS) that intends to stimulate motor signals at a later stage. Simultaneously an efference copy is generated that is an exact replica of the efference signal .This efference signal is fed as the input into the forward internal

model (a black box).This black box reads, analyses, manipulates the continuously increasing efference copy signal and weaves out another continuously increasing afference signal (called the corollary discharge) which is actually the slowly growing sensory output that is expected when the action is finally executed. In short this system is predicting the sensory output of the would be executed efferent signal.

3. As the main efference signal builds so does the corollary discharge and when a certain signal threshold is crossed by the accumulation of predicted sensory outputs, the subject becomes aware of his will to perform the action. Consciousness is first felt at this instant. The time gap between (1) and (3) is approximately 300 ms, Libet et al (1983) [5].The sensory accumulator model (Aschersleben et al, 2004) predicts the onset of consciousness through sensory information accumulation. Ideally at this instant the subject has performed the action mentally but a certain preparation time is required for muscle adjustment for the action to be performed physically.

4. After a gap of 120-150 ms from (3) (Libet, 1985) [3] the subject's muscles start preparing for action execution, premotor responses are induced.

5. Finally, after a gap of 80 to 50 ms from (4) the action is performed. Just when the action is performed the efference signal would have completed its journey and a predicted outcome of the above mentioned efference signal would be kept ready. This is then compared with the actual reafferent signal to determine if the afferent signal is because of a self- generated efferent signal or if the afferent signal was caused due to any other external stimulus. This process of comparison is the mechanism to differentiate self from other.

5 Experimental Procedure

*Experiments were conducted on 10 Schizophrenic patients whose condition was confirmed by Dr.Sanjay Mahendru (Psychiatrist).These were patients with various levels of damages to their corollary discharge pathway.

*A .csv file was run using DirectRT [6] which generated a series of stimuluses which prompted the subject to take an action.

*The subjects were shown a red circle on the laptop screen which was their stimulus to press the keyboard button A.

*They were asked to say yes when they felt conscious of their action initiation and press the button.

*The time instant of 'YES' was noted by me through a mouse click on the Xnote desktop stopwatch[8] and the button press time instant was noted using the DirectRT software[6] .

*Five active trials were performed where the subject himself pressed the button and five passive trials where I pushed the participant's finger onto the button. In the active event the subject's finger hitting the button was the first tactile event whereas in the passive case the 1st was that of me pushing the subject's finger and the 2nd was that of the subject hitting the button.

*Two trials in each category were performed before each category was started.

*The time gap was calculated in each case which is the difference between the time instant of button press and that of telling 'YES'.

*My auditory time lag (time taken for me to mouse click after I hear 'YES') was measured using the auditory reaction time test available at[7] , the average and standard deviation was found to be 225 ms and 33 ms respectively.

A similar experimental setup was proposed by Obhi[2] with additional EMG setups. His main motive was to study the differences in judgemental errors (difference between actual and judged time of motor actions) between active and passive movements which were carried out in a forceful as well as soft manner. And he found out that conscious perception of forceful movements were less anticipatory compared with their soft counterparts , while there was not much difference amongst soft and amongst forceful movement judgemental errors .

Table 1 – Mean judgment errors and standard deviations for all experimental conditions across subjects (in ms)

Condition	Active-soft	Active-forceful	Passive-soft	Passive-forceful
Mean judgment error (SD) in ms	−135 (47)	−81 (49)	−138 (74)	−81 (67)

Note that there were significant differences between mean judgment errors between forceful and soft movements but not between active and passive movements (see text for statistics).

Obhi(Brain research , 2002) [2]

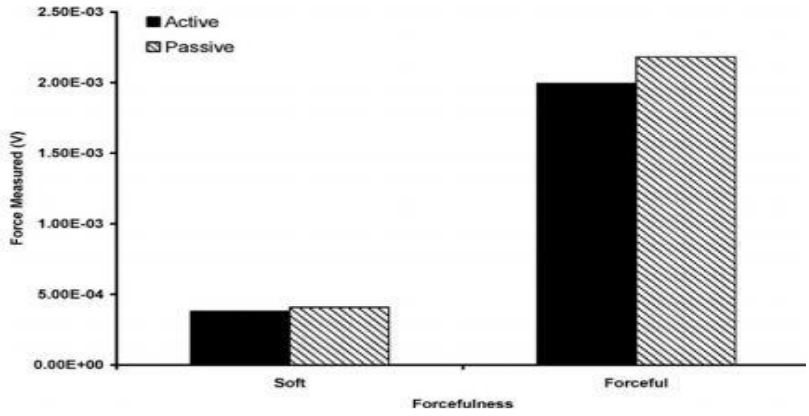


Fig. 2 – FSR data (volts) for active and passive conditions in the case of forceful and soft movements. Note that there are no significant differences between active and passive FSR signals and that forceful movements produce greater amplitude FSR signals than soft movements.

Obhi(Brain research , 2002) [2]

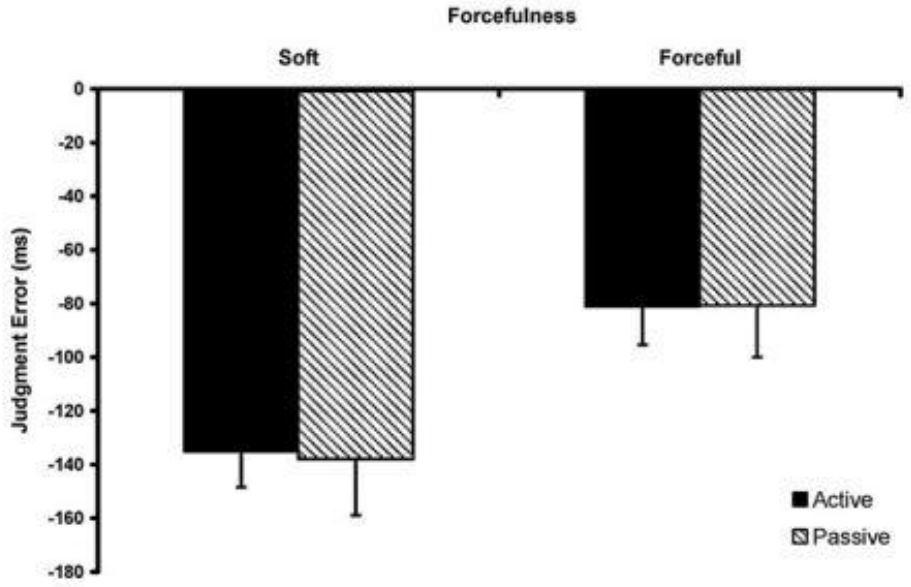


Fig. 1 – Judgment errors (ms) for active and passive conditions in the case of forceful and soft movements. Errors represent the difference between recorded time of a key press and conscious awareness of initiation of the movement. Error bars are SEM.

Obhi(Brain research , 2002) [2]

I used the same experimental methodology of Obhi[2] but performed the test not in normal subjects but on Schizophrenics. Malfunctions in their corollary discharge were a known fact [4]. All I wanted to know that whether their affected corollary discharge had any repercussions on their consciousness.

6 Results analysed

6.1

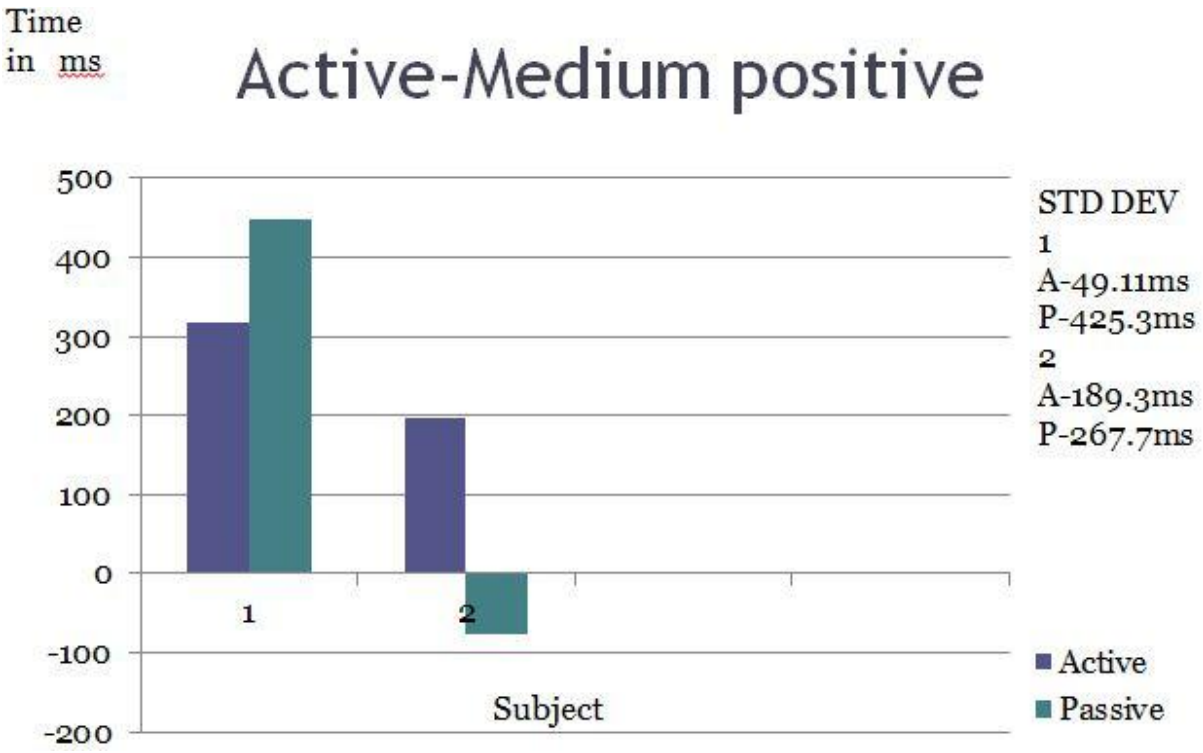


Chart 1 – Data of those patients who were cured of Schizophrenia to a certain extent and were currently being treated as outpatients. Their active time gaps were tending towards to those of normal humans so were their passive time gaps. Except in case 2 where there was an abnormal unexpected negative time gap seen. Physically in both cases the growing corollary discharge signal might be playing the role of consciousness.

6.2

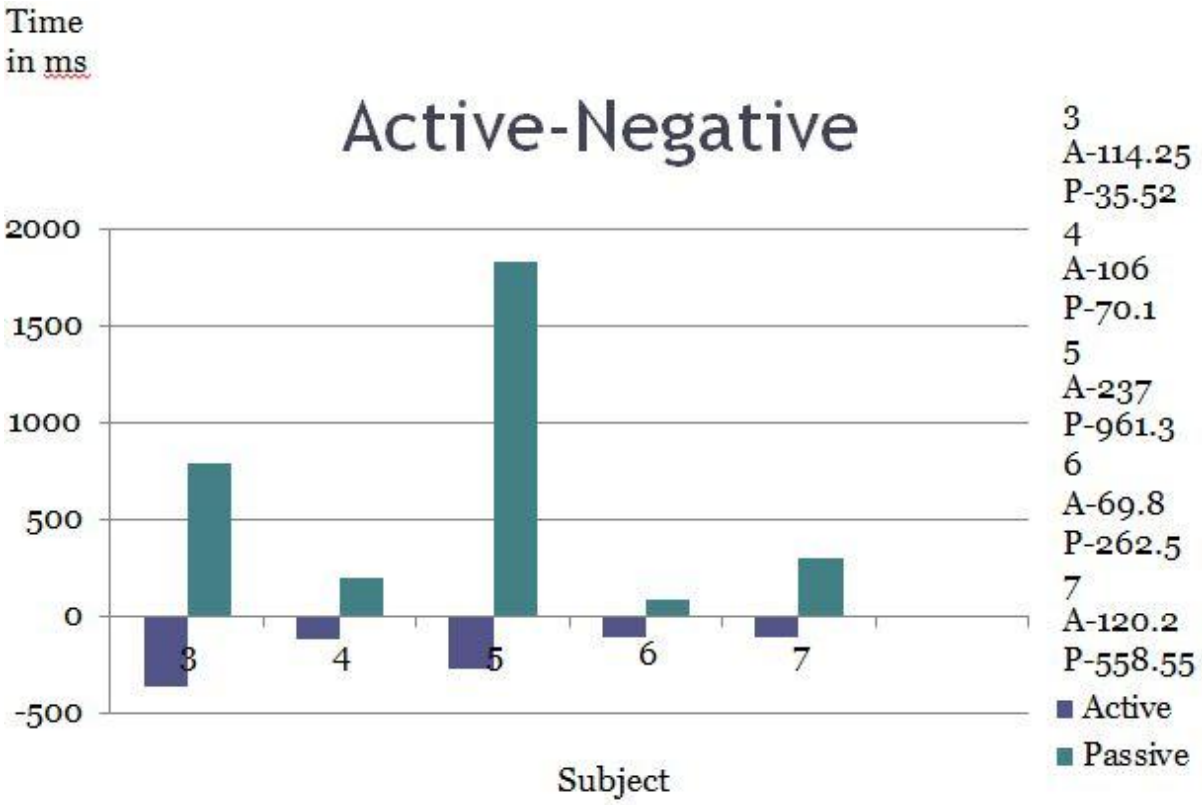


Chart 2 – Data from those patients who were in the advanced stages of Schizophrenia and were hospitalised. The active time gaps were as predicted , negative i.e. the patient first pressed the button and then after a few milliseconds of time lag said ‘YES’ indicating that the conscious awareness of action happened only after the actual action was performed. Passive cases 3,4,6,7 are acceptable while 5 are unusual.

In these cases it can be argued that conscious realization is happening not because of the growing corollary discharge signal (which I feel is the source of consciousness) but because of the reafferent signal that arises after the action is performed, therefore there being a loss of conscious realization of action before it is performed.

The passive cases here are used like test cases and they turn out to be positive as expected. By default the schizophrenic subject tends to deviate from normalcy and produce a negative time gap but our interference reinforces in him, his awareness of performing the action, putting him back on track (i.e. positive time gap).Physically the supposedly diminishing corollary discharge signal is strengthened by my push. A lot of things happen between me pushing his finger(1st tactile event) and his subsequent touch of the button(2nd tactile event) .The 'YES' which would ideally have come after the button press (like in the active cases) now comes just before the button press because I forcibly make him realise his actions by my interference.

6.3

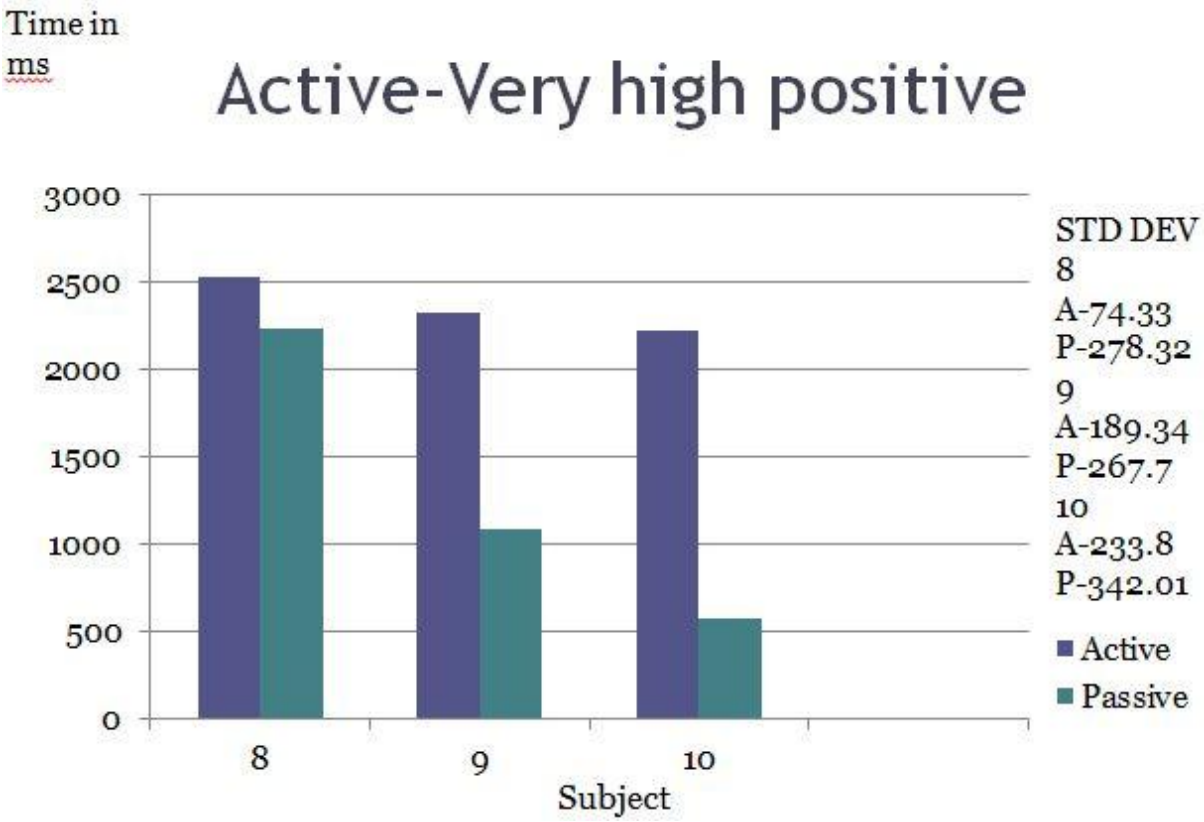


Chart 3 – This represents data from patients who were also sufficiently Schizophrenic .But their active and passive time gaps were unusually high. I could not find any rational explanation for this observation.

In the active case the patient said ‘YES’ and then after approximately 2000ms pressed the button. After observing a large time gap in the active case I touched the subject’s finger rather than pushing it, in the passive case. i.e. in the passive case I touch the subject’s finger , after a few milliseconds he says ‘YES’ but again like in the active case the button press happened after a considerably long amount of time. Mostly there might be a conscious signal loss once the corollary discharge signal has crossed the consciousness threshold and then reappeared later causing the subject to press the button.

This wide variety of results indicates that at different stages of the illness the extent to which corollary discharge is affected also varies, the signal tending to normalcy, in cases 1 and 2, malfunctioning as expected, in cases 3, 4,5,6,7 and in an unexpected manner in cases 8,9,10.

7 Inferences

From the analysis above I can definitely say that there is a correlation between corollary discharges and consciousness. Subjects with impaired corollary discharges showed evidence of impairments in their conscious realization of actions. But the complete mapping of conscious awareness to physical corollary discharge neural signals is currently still inconclusive.

8 Scope for improvement

There were a few drawbacks of my experimentation process, which could have been overcome provided a greater set of relevant resources.

*Other than EEG (Electroencephalography) there were no practically feasible methods available to measure the real time instant at which a subject makes a decision. Therefore I had to resort to a ‘YES’ utterance of the subject , which also required me to intervene as part of the timing process, leading to an error correction of approximately 200ms.

*Technically, tests on a larger number of subjects could have given more conclusive results. As it is being observed that in certain cases the standard deviations in time gaps are larger than their corresponding mean.

9 Conclusions

I feel that if this concept can be carried out on a much larger scale with the usage of the best available timing detection systems, resources and methodologies then there are very high chances that we could end up unravelling many hidden truths of the mind .Possibly put to rest many age old theories that say consciousness is non-physical. But for now consciousness still remains a hard nut to crack.

10 Acknowledgements

I would like to thank Prof.Amitabh Mukherjee for letting me go ahead with the project and for his constant support and guidance. I am extremely thankful to Dr.Sanjay Mahendru , Mahendru Psychiatric Centre(http://mahendrupsychiatry.org/) for his guidance, patience, time and for permitting me to test his patients. I would also like to thank Prof.Venkatesh K.S for willing to help me out. I am grateful to all the hospital attendants for co-operating with me throughout the experimentation process.

11 References

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[8]XNote Stopwatch, Version 1.65, 2011, Dmitry Niktin, **http://www.xnotestopwatch.com/ .**