A review on IPC in Autism and related theories from relevant experiments.

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Abstract

The impaired response of Autistic patients in interpersonal environment is attributed to lack of capability of prediction or use of information. It was also observed that the perception of information is comparative to the control group. Similar facts are also verified to indicate the same lack of use of information in circumstances involving similar predictive coding behaviour. The fact also brings light to some theories derived from various such experiments to explain the phenomenon. The report below discusses such theories in light of the experiments performed in [7] and [3]. These theories emerged from different experiments, checking the behaviour of autistic patients in various social situations. The problem is that the theories are too specific to observations in a particular experiment and do not qualify for generalisation. Hence while on one hand none of them is guaranteed to be causal, close correspondence of theories in terms of explanations, focus on study of common behaviour and region of interest in brain, qualify them for discussion from an overall perspective.

Keywords: Autism, Action perception, Interpersonal Predictive Coding, High Functioning Autism, Social Motivation Theory, Underconnectivity Theory

1 Introduction

The Human Response in an Interpersonal Environment is an outcome of a complex mix of cognitive processes, control of dynamical systems and optimisation processes. It starts with perception of environment followed by a prediction of best response based on the perceived environment. The response is usually executed in a feedback loop, resulting in adaptation of existing learned model-parameters and meta-parameters. The patients suffering from Autism are reported to show impaired behaviour in such an environment. Studies also reveal that out of the above sequence of processes, the predictive coding is impaired

while the action perception seems intact [7]. Experiments also give theories such as lack of rule learning [2], intensive resource requirement for integrative processing in interpersonal environment [5] etc. The coding in this context is called Interpersonal Predictive Coding(IPC). Above Observation is supported by the experimental evidence where it was seen that the usage of correctly perceived information into generating a response or building interpretation is missing. We will discuss the experimental setup and mathematical approach to derive such qualitative inferences from data captured during cognitive experiments performed with Healthy Control Individuals Group(HC) and High Functioning Autism Individuals Group(HFA).

There are many different daily routing areas where Autistic patients are reported to face problems. This can be prediction of behaviour of self as an actor or others as observer. This includes action perception in interpersonal environment [7], comprehension of a special kind of sentence structure [5] and many more. A similar process is correction of the perceived data in light of new experiences such as violation of some previously known fact, change in ground rules etc [2]. They all can be seen as prediction of data points. However, this would follow in further discussion that the task of prediction which we discuss is a complex upper level abstraction of different small tasks which themselves could be predictions, but simple in nature and resource requirement such as implicit actions [3]. Or in another way the response in an interpersonal environment does not only perceive information from different senses but also processes information from different context to get an inference. For example, to predict if two people are working in synchronisation, we need to understand the state of mind of both the actors to see if they are oriented toward a common goal. In sentence comprehension for passive structure, one has to explicitly visualise in some way the two parts of the sentence as subject and object and then establish the relationship signified by the verb.

The experiment in [7] is a comparative study of HC and HFA for the task of discrimination between an individual versus a joint action. The question was investigated to establish the fact that patients with HFA are impaired with the Interpersonal Predictive Coding and not Action Perception. The experiment was in two steps. First, to check if the perception of joint action vs individual action works. This is proven by the fact that in both the groups the action perception in case of individualistic actions is decently good. Second, if the usage of the perceived information is done to predict an actions category and caption. This acts as a discriminant of the behaviour of two groups where it was shown that while on one hand HC group improve their predictive behaviour in interpersonal environment, the HFA group still show the same level of accuracy in the results in interpersonal environment. The results indicate HFA group is comparative to HC group in perception of the information. While they did not show a tendency to use the perceived information to predict expected values in interpersonal environment. This was a user response based evaluation applied with mathematical approach to derive the inferences. This points towards the possibility that the predictive behaviour is the key factor impaired in HFA as they do not use the interpersonal cues for improving prediction.

The study in [3] also, investigated a comparison between HFA and HC (Referred to as ASD and TC in original Text) to see their brain behaviour in an interpersonal environment using fMRI of the whole brain. An area of brain referred to as superior temporal sulcus region (STS) is found to be significantly involved in the biological motion processing. An additional task which STS is identified to be taking care of is social information processing. It acts as a hub to facilitate connections between distant brain areas required to co-ordinate in case of social information processing. In fact the STS is suggested to be involved in multiple aspects of social perception, including mentalizing, face processing, and social reward processes. Further, the posterior STS is also known to provide the main visual input to other regions of the action observation network which is suggested to provide a direct motor matching mechanism for understanding other peoples actions and emotions, thereby proving themselves to be the key aspects of embodied cognition.

The rest of the article is organised as an initial discussion over the experiments in [7] and [3] followed by discussing the theories from [5] and [3] in context of [7].

2 Related Work

The experiments of [7] and [3], both involve two groups HFA and HC, with 16 and 15 participants respectively, closely matched for IQ and demographics. Special care is taken in the selection of HFA participants to make sure that they do not have any special disability relevant to the task apart from Autism Spectrum Disorder. The technique selected actions or sentences from standard databases.

2.1 An experiment for IPC in Interpersonal Environment: Statistical Analysis

In [7] the participants were shown two videos (Point Light Display)(PLD) in a sequence separated by a fixation. Both the videos have at least one intact motion by an agent A. For another Agent B, in one of the video we have an actual actor acting (COM Condition) while in the other we have a scrambled image which is not acting in tune with agent A, but still remains in bounds to deceive for an actual agent (IND Condition). These two videos are shown separated by a fixation interval. The participants were asked to tell which window contained a joint action considering scrambled motion is not doing anything in one of the two videos. The experiment gave another task to (i) check if the participants remember the video from previous task (ii) The task is of which category (COM Vs. IND) (iii) And selection of descriptive caption for task from five give options.

While a cross-validation over the data itself reveals that the selection of parameters was good, repeated-measures ANOVA was performed over data and it was found that there is a significant main effect of condition. Where higher value of sensitivity is for COM condition and lower IND condition. There was

a significant interaction between the condition and group and hence the effect was moderated. To break this moderation effect, a simple effects analysis was performed and it was found that while there is a significant effect of condition in HC group. There was no such effect in HFA group which indicates that the information was used for evaluating the behaviour in HC but not in HFA.

Beck's Depression Inventory(BDI) and Autism Quotient(AQ) was correlated with Measures of sensitivity d'. While BDI did not show any correlation, AQ has a significant negative correlation in COM condition. This shows that while the Autism has an effect on capability of participants in communicative condition than IND, any sort of environmental influence does not vary between the condition despite give equal effect. Variants like visual inspection, number of fixations or gaze shifts from one ROI to the other, pupil size etc. are compared from eye-tracking data across all experimental conditions and participant groups and no difference was found. Also no significant difference was found between HFA and HC participants in the ability to correctly identify which COM and IND actions had been presented in the previous detection task. No difference between groups was found in the ability to classify the stimuli employed in the detection task as communicative versus non-communicative. The same was true for the actions not presented in the detection task. No difference between HFA group and HC group was found in selecting which of the five response alternatives best described the observed actions. Hence it proves that while HFA patients perceive comparative to HC, they do not use that information to relate things in an inter personal environment.

2.2 An experiment with HFA for Biological Motion: fMRI and Statistical Analysis

In [3], authors support the claim that STS is causal for impaired behaviour in HFA, by experimental evidences both in the form of brain imaging and statistical analysis. Both of them show a particular difference on the results which can be attributed to the lack of social cognition in HFA. Importantly, above techniques are state of the art for experiments related to HFA behaviour.

The behaviour of participants was evaluated on tasks involving biological motions where a discrimination of biologically intact versus scrambled movement is to be done. For the other type of task, we asked participants to point out colour change of moving point lights (in PLD) as and when it appears. The detection of intact Vs. scrambled motion is an explicit task while the change of colour is an implicit task. The response was in tune with other studies, as while HFA and HC show no significant group to condition interaction for implicit task, they do have some interaction in case of explicit task with HC producing significant and HFA producing insignificant interaction.

For explicit biological motion task, sensitivity and criterion was also calculated. The difference in sensitivity and criterion among groups is insignificant with HC performing slightly better marking both the groups similar in terms of these two factors. They calculated two indices to measure performance across the task conditions. A Similar repeated-measure Anova analysis revealed a

significant group to task interaction. The performance was higher in HC in comparison to HFA for explicit task. In contrast for the implicit task the performance of HC and HFA was comparable. This observation itself is in tune with previous observations as explicit condition needs a higher level of processing of the perceived data as in interpersonal environment.

For evaluating the effective connectivity of right STS during biological motion processing, a psycho-physiological interaction (PPI) analysis was conducted to assess group differences in effective connectivity of right STS during explicit biological motion processing versus fixation. At a whole-brain level, the HFA has shown stronger coupling between right STS and a cluster in the medial prefrontal cortex (mPFC), than HC group. Inspection of the differential coupling pattern showed that in the HC group, right STS-mPFC coupling was relatively diminished during explicit biological motion processing (compared to fixation), whereas in the HFA group, right STS-mPFC coupling was enhanced during explicit biological motion processing, compared to fixation.

3 Discussion

The phenomenon of lack of coding and its generalised nature is testified by many experiments and it is safe to say, in general, that the predictive coding is impaired in case of HFA. Attribution of this problem to the core reason is still not clear. There are several theories which are candidate for discussion in this context as they emerged from one or another experiment with HFA and HC over tasks requiring a higher level abstraction of a multilevel predictive coding.

The study in [7] also involves a scenario as the one discussed above and there are clearly two different levels of information processing. The first is to perceive the individual action and for that some area of brain is responsible. We will consider these as a trivial predictive coding module of human brain. This process is then followed by joining the perception from both the agents to figure out if they are doing one part each of the same task or coordinating in some way. This involves a more complex high level inference process. An example could be processing environment with an approach like "theory of mind" to see if a movement from an agent "A" be somehow causing the movement performed by other agent "B". This sort of processing clearly does not work in HFA patients and is proved by this experiment. However, it lacked an direct analysis of brain state such as by fMRI. Thus, let us discuss results from different experiments as well as the relevant theories explaining results. Since it cannot be said if the impaired behaviour is because, the excitation was not enough to employ another area of brain, or the excitation did not reach the destined area due to under-connection.

3.1 Underconnectivity theory

We see brain as a collection of specialised areas for different types of processing, memorising etc. Since not every area is self sufficient and a collaborative pro-

cessing of environment corresponding to different sensory as well as memorised inputs is to be done to draw inference in a complex environment, we also imagine these areas connected by an integrative underlying network of excitation. It is also evident that if this integrative network is not properly connected for the feed of information from one region to another, the prediction in complex environment would be affected while the simple mechanisms might work. This above philosophy is considered to be key factor in explaining the behaviour of HFA in emergent cognitive, perceptual, and/or motor abilities.

Importantly, this might be regarded as the reason for HFA behaviour in any task requiring integration of information at the neural and cognitive levels where an integrative processing of emergent nature at a high level is required. Particularly in case of complex social interaction, it certainly places a lot of resource demand on the human brain, to collaborate different information coming from different sources, like vision and sound to name a few. It might also be required to integrate perception with historical experience etc. Having a theory of someone elses mind requires a high level abstraction, which could impose a large demand on high level integration processes on its own. The rapid changes in the scenario and multilevel processing to derive inference demands a lot of simultaneous integration of quickly arriving inputs and such a strain cause a compromise in the quality of interaction of HFA with environment. Hence, the under-connectivity theory by [5] is formulated and verified by experimental evidences.

3.2 Social Motivation Theory

The social motivation theory of HFA as in [1] suggests that impaired social behaviour is caused by lack of capability to attend the corresponding inputs from environment. The further investigation in the form of the whole-brain analysis in [3] revealed some important facts. The results as interpreted for this theory indicate that while the basic (implicit) neural processing of biological motion seems intact, patients with HFA may show a reduced ability to process the explicit motion. This is then attributed to the inadequate employment of neural resources or inadequate excitation of a brain region when explicitly prompted to draw inferences from the biological motion.

First evidence for the lack of attention orientation is different excitation in STS in case of HC and explicit task condition than implicit, but no such pattern in HFA. Further the evidence shows modulation of STS activity by the virtue of STS-mPFC connectivity. In the experiment, we already saw that for HFA in explicit condition, the connectivity becomes stronger while the excitation in STS does not change much. The observation for HC in similar conditions was augmentation of right-STS activity and decreased right STS-mPFC connectivity. Also mPFC is an identified key region in top-down attention regulation. This modulates the recruitment of STS during explicit task in HFA. It is also in tune with the previous studies that reported the difference between HC and HFA in terms of excitation in STS during explicit task.

3.3 HFA and Building Inferences

We have seen from many experiments that the implicit task condition does not produce much group difference for HFA and HC; the generalisation of a learned rule to adapt to a particular environment is found lacking in HFA. The generalisation of environment is again a higher level abstract task as discussed in Social Motivation Theory. The complexity can be understood in terms of the model and meta parameters which can come as a data feed from many other perception and prediction systems. It can also be seen as a flow of information through connectivity tracts as in Underconnectivity Theory. It is such an integrative environment, which leaves enough room for above theories to fit.

The Study in [6] support the intensive resource requirement reason to a more fine grained level with the help of ROTE learning and inducing a requirement of model adaptation in later stage. The strategy adopted in the experiment is to give a visual feedback of status(Correct or Incorrect), while the input stimulus is partially overlapping for building a generalised rule. It is also suggested by the experiment, that, while learning simple explicit rule is relatively strong in HFA, the ability of negotiation, in view of demand of current environment, between the use of "trail and error with rapidly changing reward" and "rules of thumb" is lacking.

This lays foundation for the fact that while a learning with exact details works in HFA, they show relatively low tendency to adapt to some changed environment. Hence, the impaired behaviour in HFA can also be attributed to the fact that the process of reward based learning to derive abstract rules is impaired.

3.4 Implicit versus Explicit Task

We have seen that the explicit task across groups shows all the difference in behaviour, and implicit responses are almost intact with insignificantly different performance in HFA. The under and over specialisation of a brain region as seen in [5], can also affect the implicit task, as a region dedicated to an implicit task may under or over specialise. Now, talking from the perspective of [3], the explanation of impaired behaviour is heavy resource requirement. We also know that in case of integrative processing, an already learnt rule has to be adapted in interpersonal environment quickly to support the requirement of current situation. Hence above task with a previously known rule also qualifies to be falling under integrative processing. This can be a potential area where the HFA behaviour can get hampered. Implicit task or behaviour is free from all these adaptations (such as observing colour change). It was also found that the capability of implicit retrieval of information is also intact with no effect of age as seen in the cued recall but the explicit retrieval and processing such as in priming, show age related deterioration [4]. This deterioration can be worse in HFA and can also account for their impaired behaviour. This is further supported by the observation that implicit retrieval showed decreased activity during priming relative to baseline. If this is the case then we can say that

the behaviour in implicit tasks could not be impaired in HFA, at least in the light of above evidences. However, explicit tasks do have complex processing requirements for information retrieval also and can cause impaired behaviour in HFA.

3.5 Relationship among above theories

The similarities in the above experiments which made them a candidate for comparison in this report are: Both the experiments discussed above involve experiments with HFA and HC groups comparative in size and demographics. The experiments were using same kind of PLD as stimulus. They also analysed the data with the same statistical techniques. As a whole the theories built above are mainly based on the statistical analysis to find correlations, cause-effect and modulation interaction of responses across groups and conditions. Also fMRI has been used to analyse the brain for task related activation as the statistical analysis can be explained with the help of neurobiological evidences. Also the analysis is generally done at two levels. The whole brain analysis was used to identify the key regions of interest's. The Region of Interest analysis was to find a detailed report of a particular region of brain or a pair of some regions to find some correlation.

While the underconnectivity mainly mean lack of enough capacity to transmit excitation to other region, this concept can be extended to abnormal connectivity. The argument is as under and over excitement both can be causal to impaired behaviour in Autism, resulting in under and over specialisation. The experiment in [3] shows, there is an increased coupling of right-STS to mPFC for HFA, which is otherwise reduced in case of HC. The excitation propagation from an overspecialised region would cause an over strengthened connectivity which might excite this region more strongly than others and have more influence. Since the general pattern seen in case of HFA is abnormal excitation and coupling, and not only decreased excitation and coupling so a general framework with both positive and negative growth taken into consideration might orient the actual cause-effect relationship in the brain for any abnormal behaviour.

The Social Motivation Theory, gives evidence of lack of differential recruitment of the brain regions for explicit task processing and tries to attribute this as cause for the lack of integrative processing. This differential recruitment is seen in observation of STS activation pattern for HC between implicit and explicit conditions. The same was insignificant in case of HFA, and hence while the implicit task condition performance is comparable, explicit task shows impaired behaviour in HFA. The incapability to differentially recruit the brain is seen as the cause of impaired behaviour in HFA as per this theory.

It is also evident that while in case of explicit task with HC the activation of right-STS is more, the coupling with mPFC is weakened and hence a possible explanation is that while the task is identified as explicit, more focus is on integrative processing and less connection to mPFA which is known for many tasks such as mentalizing etc. On the other hand, HFA show a tendency to strengthen the coupling of right-STS to mPFC area, which could be explained

as request of information retrieval while the task is considered to be implicit as a result of lack of discriminate between explicit and implicit, shown by differential recruitment of right-STS in HC and not in HFA.

3.6 HFA and training for explicit task

As a normal behaviour, HFA participant do perform the above discussed experiments and follow instructions given in it. Hence it is safe to say that the HFA can follow verbal instructions explicitly given, to a comparative level to HC. It is also seen as in [2] that the learning of rules is itself hampered in HFA. With above two arguments we can say that, while a rule can be explained to HFA, and they show a tendency to understand and follow them, we cannot expect them to infer and adapt it by themselves. Hence a possible approach could be to give the abstract rules in as clear instructions. However, the space of all such instructions is impossible to exhaust during any training.

There are many advancements of technology which can be used in building a support system for such patients. The main field we want to discuss is virtual reality. It is easy to provide an online simulation of the current environment. We can also classify the environment into types of objects. Now while in a social environment, the exact rule might not be applied, an automated generalisation of the environment with possible task types can be done. This can further be augmented by a clue to help in generalisation. An added advantage is that now the task on HFA is not to learn acting in interpersonal environment but to follow the limited types of clues (can be learned as implicit rules after certain repetitions) which could be given in the target environment thereby reducing the space of training for HFA and still supporting them better in the target environment. We could also research on the localisation of information in time and space to its most appropriated use so that HFA has relevant information as and when required. A simple example is showing a video of "people waiting in the queue for some food in the cafeteria before the lunchtime".

4 Conclusion

We can conclude by saying that the attribution of neural cause to the HFA behaviour is still not clear, but it is evident that the behaviour of HFA in complex task is more prone to be hampered than a simple task. This can also be supported by the requirements, the implicit versus explicit tasks put on human brain, where implicit task can be seen as a trivial function, explicit task is an upper level abstraction of many trivial calculations. Also the Underconnectivity Theory takes into account, the lack of connectivity to propagate excitation. From experiments in this field, we observed that the areas can also be under or over specialised, the changed coupling pattern in HFA between right STS-mPFC can also be attributed to differently specialised network. Also it can be the case that the required population of neural activity is not created and cause wrong prediction to happen. Also the implicit tasks are driven usually by

one specialised area in brain and they can also be differently specialised. The inference building capacity of HFA is also tested and found to be good in light of specific fix stimulus, however, adaptation and generalisation of model is lacking. The cause of HFA being impaired in interpersonal environment might be that they do not get enough ROTE based training on every single environment and the adaptation does not work.

While on one hand above reasoning does not lead to a concrete conclusion and more study is required in this direction, it is satisfying to see that the information coming from all these experiments serve as a good base to device techniques for training Autism patients. An example is the fact that verbal instructions are well processed by HFA, and hence for the most important things simple instructions can be given instead of leaving them to learn it by themselves.

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