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Research article

Emotional simulations and depression diagnostics

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ABSTRACT

In this work we propose the following hypothesis: the neuromodulatory mechanisms that control the emotional states of mammals can be translated and re-implemented in a computer by controlling the computational performance of a hosted computational system. In our specific implementation, we represent the simulation of the 'fear-like' state based on the three dimensional neuromodulatory model of affects, in this paper 'affects' refer to the basic emotional inborn states, inherited from works of Hugo Lövheim. Whilst dopamine controls attention, serotonin is the key for inhibition, and fear is a elicitator for inhibitory and protective processes. This inhibition can promote [in a cognitive system] to blocking behaviour which can be labelled as 'depression'. Therefore, our interest is how to reimplement biomimetically both action-regulators without the computational system to resulting in a 'failed' scenario. We have simulated 1000 ms of the dopamine system using NEST Neural Simulation Tool with the rat brain as the model. The results of the simulation experiments are reported with an evaluation to demonstrate the correctness of our hypothesis.

1. Introduction

The current rapid developments in neurocognitive sciences and new discoveries related to the core mechanisms of natural intelligence have triggered new insights and opportunities in the field of biologically inspired cognitive systems. There are new and reliable data related to a key aspect [previously undervalued or hidden] which builds the entire cognitive processes architecture: emotions (Minsky, 2007).

Research has shown that emotions play a significant role in natural intelligence and adaptive behaviour (Damasio, 1999; Picard, Vyzas, & Healey, 2001). Additionally, the intrinsic value of emotions in cognitive processes remains undervalued by researchers who take a behaviourist approach to artificial emotions based on basic observable actions; we term this: *the 'skinnerian' approach to emotions*. This approach basically considers the emotional performance as *epiphenomenalist* without considering the deep mechanisms that are hidden under this black box. This view can be somehow useful for 'real-time' emotional detection during Human-Robot Interactions or Human-Computer Interactions.

Attempts to design computer emotional architectures have been proposed, consider for example *CogAff* (Sloman, 1994) or *LIDA* (Franklin, Madl, D'Mello, & Snaider, 2014) which are architectonically modulatory and whilst they simulate the homeostatic role of emotional mechanisms, they fail to provide an integrative way to implement emotional design into all areas of computational activity.

As a departure point of our model, we consider a simple "fear", which is necessary to evaluate "fly-or-fight" actions (Stevenson & Rillich, 2012). Our study focuses on two opposing and complimentary neuromodulators: dopamine and serotonin (Daw, Kakade, & Dayan, 2002). Dopamine is related to brain reward processes, whilst serotonin is implied into aversive or inhibitory processes; used in combination we may design a system that manages 'fly-or-fight' actions in which several learning procedures could be easily implemented.

We argue that our proposal represents a milestone in the creation of a new generation AI intelligence incorporating the capability to create neuromodulatory architectures which can run over several conceptual models, languages and systems. The posited

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approach is designed to model human cognitive processes such as: creating unique and plastic cognitive identities. This is a basic, but solid, first step towards grounded cognitive systems that share across the whole cognitive multi-heuristic architecture the same controlling mechanisms: synthetic neuromodulators.

2. The problem

Dating from the seminal work of Rosalind Picard in the mid 1990s (Picard, 1997), interest in emotion(s) has gained significant traction; this is particulary evident where the understanding of the connection between cognition and thinking is concerned (Ahn & Picard, 2006; Damasio, 1999; Picard, 2003). We have indicated the cognitive perspectives which seem to offer the most promise in the context of the reimplementation of emotions in a computised machine (Bridges et al., 2015). Based on these cognitive perspectives, we propose an approach for a neurobiologically plausible model to represent the influence of emotions over neurobiological processes of thinking mapped to the emotional influence over computational processes using neuromodulation.

Research, for exmple see: Arbib and Fellous (2004), Picard (1997), Kort, Reilly, and Picard (2001), Ahn and Picard (2006), and Damasio (1994, 1998), has identified that emotions form a fundamental part of human cognition and are important in cognitive processes which include: *attention*, *motivation*, *strategy selection*, *mood disposal*, and *reaction*, *invention*. In this paper we have paid special attention to mental disorders (see Section 3.1 for a detailed discussion). It is clear that emotions and neuromodulators play a crucial role in the diagnosis and management of depression, schizophrenia and addictive personalities which includes drug addition. Once explained, the crucial role of grounded and emotional aspects in cognitive architectures, we have adopted the Lövheim model as a reference for our own architecture.

Lövheim (2012) has developed a three-dimensional model of emotions based on monoamine neurotransmitters: *serotonin*, *dopamine*, and *noradrenaline*. The vertexes of the model are affects as defined in the Tomkins "Theory of affects" (Kelly, 2009). Tomkins (1962, 1963, 1991) referres to basic emotions as "innate affects", where affect in his theory, stands for the "strictly biological portion of emotion". Basic affects are: *enjoyment/joy*, *interest/excitement*, *surprise*, *anger/rage*, *disgust*, *distress/anguish*, *fear/terror*, and *shame/humiliation*. There are basic affects which are managed soley by the internal cognitive processes of an individual, other basic affects are intrinsically related to social interactions; however in all cases "fly-or-fight" or even neutral states are hormonally controlled.

In our previous publications we have demonstrated the attention regulation of dopamine (Vallverdú et al., 2015); in the studu presented in this paper we have extend our implementation with a second monoamine neuromodulator: *serotonin* (Meltzer, 1998). The serotonin (5-HT) neurotransmitter is main actor in how a body prepares to deal with some perceived danger. Additionally the serotonin neurotransmitter acts as a bridge channel for an action regulation: it controls sexual *satiation* (Arnone et al., 1995). There is a final aspect related to the serotonin: loss is also related to ageing and several neuropsychiatric diseases (Pfaff, 2002); for this reason we explore the possible outcomes of an implemented bioinspired architecture which uses serotonin.

There is extensive evidence which implicates a deficit in serotonergic neurotransmission in the development of stress or major depression; this is related to the combination of disturbances in cholinergic and serotonergic functions. We use a naturalistically inspired model of cognition where the management of a selec tion/suppression/reinforcement actions are neuromodulatory managed following a complex flow of hormonal interactions.

3. Illustrative scenario

The aim of intelligent systems is to realise set goals in dynamic environments such as the healthcare domain. The concept of *self* has been identified along with the *internalised* and *externalised* concepts in respect of self forms an important component in cognitive modelling and emotive response; this has synergies with the two types of stimuli which are: (1) *internal* stimuli (events triggered by an individual with a response from their external environment) and (2) *external* stimuli (events triggered in their external environment which prompt an emotional response.

In this paper we are addressing emotive response to events (stimuli) with a particular focus on the healthcare domain and mental disorders. In the following illustrative scenarios we discuss two specific areas in relation to mental disorders: (1) depressive states and (2) Schizophrenia; the concept of *self* forms an important element in such mental disorders in terms of the diagnosis and management in terms of short, medium, and long term time scales. We argue that emotive responses are central to this process.

3.1. Depression and depressive states

Depression is a prototypical mental disorder and we argue that cognitive factors, taken with physical symptoms, forms a pivotal feature is the diagnosis and treatment of the condition. Depression is a feature of a number of mental disorders (American Psychiatric Association, 2013) we may however view depression on a spectrum as, whilst it may be clinical depression, it may also be a normal reaction to life events or side effects as a result of drugs and medical treatments. Recent evidence has suggested that recurrent episodes of severe depression are associated with changes in brain function that further heighten vulnerability and functional impairment. It is argued in Thase (1999) that an: "integrated approach" to diagnosis and management imbues profound beneficial effects for all stakeholders in the treatment of depression.

There is a very large (and growing) body of of documented research in the literature addressing depression and depressive states, for example see: Dyrbye, Thomas, and Shanafelt (2006), Lawlor and Hopker (2001), Blatt (2004), Joiner, Coyne, and Blalock (1999), Blanchard, Waterreus, and Mann (1994), Thase (1999), Greenberg and Watson (2006), Spitzer, Md, and Williams (1980), and Sandra (1997). Depression is a highly variable condition that impacts individuals across demographics and gender (Blanchard et al., 1994; Thase, 1999) and Greenberg in Greenberg and Watson (2006) introduces the emotional component into the treatment of depression.

Depression is a highly variable condition that impacts individuals across demographics and gender (Blanchard et al., 1994; Thase, 1999); Greenberg in Greenberg and Watson (2006) introduces the emotional component into the treatment of depression. We have considered the concept of *self self* in both *internalised* and *externalised* forms and this forms an important element in such mental disorders in terms of the diagnosis and management (both short and long term) of the conditions and we argue that emotive responses are central to this process.

Depression and depressive states reflect an individuals low mood and aversion to activity such that there can be significant affects in terms of an individuals thoughts, behaviour, feelings and sense of well-being (American Psychiatric Association, 2013; Sandra, 1997; Spitzer et al., 1980). Depression may trigger mood swings including feeling: *sad*, *anxious*, *empty*, *hopeless*, *helpless*, *worthless*, *guilty*, *irritable*, *ashamed* or *restless*. Additionally, interest in activities (that were previously enjoyed) along with eating disorders, problems in concentration, remembering details or making decisions. In extreme cases, individuals suffering from depression