Human Machine Interaction: The Special Role for Human Unconscious Emotional Information Processing

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Abstract. The nature of (un)conscious human emotional information processing remains a great mystery. On the one hand, classical models view human conscious emotional information processing as computation among the brain's neurons but fail to address its enigmatic features. On the other hand, quantum processes (superposition of states, nonlocality, entanglement,) also remain mysterious, yet are being harnessed in revolutionary information technologies like quantum computation, quantum cryptography, and quantum teleportation. In this paper, we would like to discuss several experiments that suggest a special role for unconscious emotional information processing in the human-computer interaction. What are its consequences and could this be the missing link between quantum information theory and conscious human emotional information processing?

1 Quantum Information Theory

Einstein proposed his revolutionary hypothesis of the light-quantum 100 years ago. Later, Einstein took his light-quantum hypothesis a stage further and he formulated the probability laws governing the emission and absorption of radiation by an atom [6], [13]. Many scientists did not accept Einstein's hypothesis due to several reasons.

From the beginning of quantum mechanics, the concept of measurement and the possible role of consciousness in the solution to the measurement problem have been important issues. Despite of these controversies, quantum theory has further developed and describes the bizarre properties of matter and energy at near-atomic scales. These properties include: 1) quantum coherence, in which individual particles yield identity to a collective, unifying wave function (exemplified in Bose-Einstein condensates). 2) non-local quantum entanglement, in which spatially separated particle states are nonetheless connected or related. 3) quantum superposition, in which particles exist in two or more states or locations simultaneously. 4) quantum state reduction or 'collapse of the wave function', in which superpositioned particles reduce or collapse to specific choices [31].

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According to some scientists, all four quantum properties can be applied to the seemingly inexplicable features of consciousness. First, quantum coherence (e.g. Bose-Einstein condensation) is a possible physical basis for 'binding' or unity of consciousness [17]. Second, non-local entanglements (e.g. 'Einstein-Podolsky-Rosen correlations') serve as a potential basis for associative memory and non-local emotional interpersonal connection. Third, quantum superposition of information provides a basis for preconscious and subconscious processes, dreams and altered states. Finally, quantum state reduction (quantum computation) serves as a possible physical mechanism for the transition from preconscious processes to consciousness [23], [24].

In the quantum, real time is uncertain and events may run in a non-linear way. Quantum state reductions such as objective reduction events may send quantum information "backwards in time", for example according to the Aharonov "dual vector" theory. Time may simply be indeterminate in the quantum superposition phase [10].

In addition to non-linear information processing, information can exist in quantum superposition, for example, as quantum bits or 'qubits' of both 1 and 0 in contrast to the classical information theories. Qubits interact or compute by entanglement and then reduce or collapse to a solution expressed in classical bits (either 1 or 0).

In the Orch OR model, quantum computation occurs in microtubules within the brain's neurons. Microtubules are polymers of the protein tubulin, which in the Orch OR model transiently exist in quantum superposition of two or more conformational states. Following periods of preconscious quantum computation (e.g. on the order of tens to hundreds of milliseconds) tubulin superpositions reduce or 'self-collapse' at an objective threshold due to a quantum gravity mechanism proposed by Penrose [23], [24]. Microtubule-associated protein (MAP-2) connections provide input during classical phases. Each Orch OR quantum computation determines classical output states of tubulin, which govern neurophysiological events, such as initiating spikes at the axon hillock, regulating synaptic strengths, forming new MAP-2 attachment sites and gap-junction connections, and establishing starting conditions for the next conscious event [9], [11], [25].

However, most cognitive- and neuroscientists are skeptical. How could the human brain process information in a non-linear way? Quantum physics and Neuroscience have nothing to do with each other. Moreover, this is simply against our experiences in daily life, in which time is completely linear! There is a hot debate going on between physicists and cognitive neuroscientists. In this paper, we would like to present two neuroimaging studies on emotions, in which non-linear information processing was found. Moreover, we would like to suggest that the solution in this debate lies in human unconscious information processing. At the higher (conscious) level, information is processed in a linear way. However, at the unconscious level, human information processing is similar to what quantum information theory would predict. As a result, non-linear information processing at this level is possible. Before discussing this more into detail, we would like to briefly discuss some of the main findings of human information processing. The focus will be on emotional information processing, since the neuroimaging studies that we will discuss later in this paper to support our theory are also studies on emotions.

2 Human Information Processing

If we want to understand the human machine interaction with respect to emotional information processing, it is essential to understand normal human emotional information processing. In the late seventies, the cognitive approach to emotions was more or less the only approach [8], [19]. This started to change with the publication of the paper *"Feeling and Thinking: Preferences Need No Inferences"* by Robert Zajonc [31]. He argued, on the basis of logic and clever experiments, that emotion can exist before and without cognition.

Much of contemporary psychology has come to recognize that a great deal of human emotional functioning is rooted in unconscious processes. During the last two decades, a lot of behavioral studies were conducted in this field. These studies, for example, showed that humans pick up the emotional content of facial expressions outside conscious awareness and intent to influence perceptions of the target individual [1], [20], [21], [22]. Other studies showed that humans evaluate objects (as for example "good" or "bad") at an unconscious level [2], [3], [5].

Current theories of emotion suggest that stimuli are first processed via an automatically engaged neural mechanism, which occurs outside conscious awareness. This mechanism operates in conjunction with a slower and more comprehensive process that allows a detailed evaluation of the potentially harmful stimulus [15], [16]. Evidence comes from neuroimaging studies. Event-related potential (ERP) data revealed a double dissociation for the conscious versus unconscious perception of negative stimuli. In the unconscious condition, responses to the perception of negative stimuli were enhanced relative to neutral for the N2 "excitatory" component (a negative potential at +/-200 milliseconds), which is thought to represent orienting and automatic aspects of information processing. By contrast, conscious perception of negative stimuli was associated with relatively enhanced responses for the late P3 "inhibitory" component (a positive potential at +/-300 milliseconds), implicated in the integration of emotional processes [16].

The conclusion can be drawn that unconscious emotional information processing happens all the time and has direct behavioral consequences [27]. Until now, these unconscious processes remain a great mystery. Although we are beginning to understand some of the mechanisms behind unconscious emotional information processing, a lot remains unanswered. For example, do humans process emotional information at the unconscious level in exactly the same way as at the conscious level and what are its implications for the human machine interaction? Moreover, could this perhaps be the missing link between quantum information theory and conscious human emotional information processing? [28]

3 Non-linear Emotional Information Processing

To answer these questions, data will be presented from two neuroimaging studies. It is important to note that both in the fMRI-study and in the ERP-study highly emotional versus more neutral stimuli were used and all stimuli were randomized with replacement. This is important because these results could otherwise be contributed completely to an expectancy effect of the participant.

3.1 FMRI Study

Bierman and Scholte conducted an fMRI-study on emotions [4], [29], [30]. In the experiment, a 1.5 Tesla Siemens system was used. Ten participants (6 male, 4 female) entered the study. The experiment started with an instruction that was given outside the scanner. The participants were instructed to relax while passively looking at the pictures that were randomly presented by a computer connected to a video projector onto a screen. Then, an MPRAGE high resolution scan which lasted for about 20 minutes was conducted. Moreover, a position localizer scan of about 2 minutes was conducted after which the experimental task of about 13 minutes was presented. The participants were able to watch the screen by looking at a mirror inside the scan. They were requested to try to forget any emotional material right after exposure finished so that the next presentation would be influenced as little as possible by the previous one. The stimulus material consisted of a picture pool of 36 emotional (18 erotic, 18 violent) and 48 neutral stimuli. The neutral and violent stimuli were taken from the International Affective Picture System [12] while the erotic material was taken from a previous study on sexuality by Laan [14]. For each stimulus presentation, the stimulus condition was determined randomly with a priori chance of 2 neutral versus 1 emotional. Each stimulus sequence started with the 4.2 second presentation of a fixation point during which the anticipation was measured. After the exposure of the stimulus picture, which also lasted 4.2 seconds, there was a period of 8.4 seconds during which the participant was supposed to recover from the stimulus presentation. Data were analyzed using Brainvoyager. The main hypothesis of the study was, whether a significant prestimulus difference in BOLD signal for the different stimuli could be found [27]. This non-linear information processing would be indirect evidence for quantum information processing in the human brain.

The poststimulus results showed whole visual cortex activation, which could be expected because visual stimuli were used. Interestingly, all the regions of interest resulting from the contrast analysis, showed a response for all stimuli (including the calm pictures). An exception to this was the subcortical region close to the amygdala. Both erotic and violent pictures showed a response there. This is in line with previous findings [7], [15].

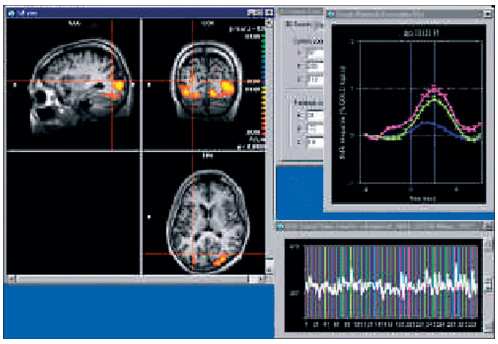

Fig. 1. Results from an fMRI experiment. There is a significant difference in the prestimulus phase between highly emotional (pink curve) and neutral stimuli (blue curve) 4 seconds before stimulus presentation.

The analysis of the prestimulus phase showed a significant prestimulus effect that was widely distributed over many brain regions, including hippocampus, pallidum, amygdala, and caudate nucleum. Most brain regions did not show striking differences in anticipation before emotional and neutral stimuli. However, larger anticipatory activation preceding emotional stimuli compared to neutral stimuli was found in the right amygdala and in the nucleus caudatus. For the male participants, as can be seen in Fig. 1, this appeared before the erotic stimuli while for the female both erotic and violent stimuli produced this prestimulus effect [27], [28]. These results suggest the existence of unconscious non-linear information processing in the human brain, which could be expected according to the quantum information theory.

3.2 ERP Study

However, the temporal resolution of fMRI is not good enough and therefore a replication study was conducted with the same experimental set-up while using ERP [18]. 26 adult participants, 11 males, 15 females, participated in the experiment. Each participant was fitted with an EEG electrode cap according to the International 10-20 system. An additional electrode for recording the electrooculogram (EOG) was placed above the right eye to monitor eye blinks and movement. Data editing was blind to stimulus category (calm or emotional targets). To reduce the possibility of false-positive findings, statistically conservative procedures were chosen for data analysis. Because it controls for autocorrelations inherent in physiologic signals and their underlying non-normal distributions, randomized permutation analysis was used to determine statistical significance of the differences between emotional and calm curves during the prestimulus period. Results for the group as a whole showed a significant difference in ERPs in the prestimulus period for future calm versus emotional pictures at both FP1 (left frontopolar; t_{sum} = -28.82, $p < .05$) and FP2 (right frontopolar; t_{sum} = -27.27, $p < .05$) EEG sites. The ERPs for a future emotional stimulus were more negative, with the point of maximum negativity occurring slightly before that of the ERPs for the future calm pictures. In addition, there was a positive shift with a steep slope observed approximately 4 seconds before the emotional stimuli. In both locations, this positive shift in the emotional trial ERP occurred approximately a second before the shift occurred in the calm trial ERPs. There was a significant t_{sum} difference between the prestimulus ERPs for calm versus emotional trials at midline EEG site Pz (t_{sum} = -13.24, $p < .05$). Because of the significant findings at FP1 and FP2, an additional RPA of the EOG channel was conducted, which revealed that eye movement artifacts did not contribute to this result [29]. These results are in line with unconscious non-linear emotional information processing in the human brain, which could be expected according to quantum information theory.

4 Human Machine Interaction

In this paper, data was presented that support the quantum information theory of human emotional information processing. Evidence for unconscious non-linear human information processing was found, however, more research on this topic is needed. This is in particular necessary with respect to the direct human computer

emotional interaction. So far we do know from studies with random generators, for example, that non-linear information-processing is possible up to longer time distances [30]. In these studies, evidence for consciousness-related anomalies in random physical systems was found [26]. Before, during, and after powerful engaging events, the measurement system was affected. This was, for instance, the case before, during, and after the September 11 attacks. Significant trends in the data were found that can normally not be expected in the data produced by random generators [27]. However, one should be critical with these data since alternative explanations, like methodological problems with the random generators, can not be completely excluded [29]. In addition, it is unknown whether non-linear information processing as observed in random generator data is the same mechanism underlying biological organisms. Therefore, more (brain) research in the direct human computer emotional interaction is needed.

5 General Discussion

The results that were presented in this paper might surprise scientists, who have a more conservative view on quantum physics and cognitive neuroscience. It is obvious that we are only beginning to understand quantum information processing in the human brain and the mechanisms behind human machine interaction. Scientists often do not like the idea that unconscious emotional information processing plays an important role in human beings. We wish to emphasize that we are not saying that consciousness is not important for human beings, on the contrary, it is of great importance, but human consciousness is also restricted. Therefore, for optimal functioning, it is vital that consciousness is only used for some higher mental processes, whereas unconscious information processing is needed when the conscious mind is otherwise occupied.

In physics, nature is normally described in particles, molecules, waves etc., which is very useful from a mathematical point of view, but from a strict physical point of view: it is wrong. In fact particles, molecules, waves etc. do not *exist* but are only used to *describe* nature. It is the opinion of the authors that we can use these concepts in our calculations, but perhaps it is time to redefine nature and describe it not in particles, molecules, waves etc., but as a very large information processor, of which human beings are only a small part. If we describe nature as a very large information processor we can also better describe human computer interaction and understand unconscious non-linear emotional information processing. Then, at the unconscious level in sharp contrast to the conscious level people are able to process emotional information in a non-linear way. Since humans process information not only unconsciously but also at a conscious level there seems to be an inconsistency. In reality, however, this is only an illusion. Or to say it in Einstein's words:

"People like us, who believe in physics, know that the distinction between past, present, and future is only a stubbornly persistent illusion." - Albert Einstein

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