A Biometric for Neurobiology of Influence with Social Informatics Using Game Theory

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Abstract: This paper is constructed on the premise that human belief dependent emotions can be triggered by story-telling or narratives. With recent technological advancements to measure neurobiological measurements of the brain, such as functional magnetic resonance imaging (fMRI) and non-invasive brain computing interface (BCI) equipment, these technologies can allow for visualization and data collection of brain activation patterns showing unconsciously controlled responses to narratives or stories. Current game theory application to belief networks has been modeled to help explain observed behavior when material payoffs of others matters to the individual. We discuss a method of how game theory, utilizing communication packet theory, can now be modeled to belief dependent emotions and intentions measured through a new biometric tool correlating neurobiological emotional states and responses.

***Index Terms*—**Neurobiology, Social Informatics, Game Theory, Storytelling, Biometrics, Narratives, Decision Making, Marketing, Entertainment, Communication Packet Theory

I. INTRODUCTION

A new interdisciplinary field called social neuroscience has emerged from a union between classical cognitive neuroscience and social psychology. In general, social neuroscience seeks to understand phenomena in terms of the complex interactions between social factors and their influence on behavior, the cognitive processes underlying behavior, and finally the neural and hormonal mechanisms subserving cognitive processes. Another important line of research focuses on our ability to understand other people's minds – that is, their beliefs, intentions, and feelings. Social neuroscientists have used social games to investigate the neural underpinnings of social exchange and mutual cooperation. In studies employing these tasks, people play games for monetary payoffs using different playing strategies, some selfish and some cooperative, which allows for the investigation of social reasoning. Economic decision-making, for example, frequently takes place in the context of social interactions. Game theory, founded within economics, has come to provide a very effective quantitative framework for studying how different pieces of information, incentives, and social knowledge influence strategies optimal for social interaction. [11]. It is interesting to note that when one player knew that the other player was a computer rather than a person, any offer given in an Ultimatum Game (UG) was accepted more often [6].

Stories can alter beliefs, values, and behaviors and exhort influence; they have been around since the caveman and are handed down from generation to generation. However, the listener does not remember or internalize the vast majority of "stories" – the stories have no lasting impact on the listener. Effective stories share a specific core architecture that uniquely defines this small subset of all narratives. This paper defines story to be synonymous with this small subset of "effective story". Stories are differentiated from all other narrative materials because they adhere to the structural mandates of that specific core narrative architecture. Stories convey influence which narratives somewhat do not. Stories are constructed around an architectural framework of the following specific design elements: character, character traits, goal, motive, conflicts & problems, risk and danger, struggles, and sensory details [3].

We conjecture that one's measure of emotional responses is correlated to an individual's belief system through stories. Our proposed system processing flow diagram as shown below in Figure 1 contains a tuning process between the story-teller and reward matrix to be performed during a training session which measures two responses from a player during the process. One response method is the measurement of the internal unconscious responses through fMRI or BCI sensor equipment. The other response mechanism is obtained through an interactive response hand held device between the listener and the story teller. A Turing machine framework is used to efficiently look at complex response information in order to calculate the emotional values for eight different belief driven emotions based upon the responses collected. The output from the response calculated through the Turing machine is a new biometric in the form of a spider chart. Game theory analysis can then be performed on the biometric to help determine the belief system of the player, specifically whether a red or blue player. Combined, these capabilities allow for a feasible way to correlate emotional states based upon belief networks for a multitude of applications.

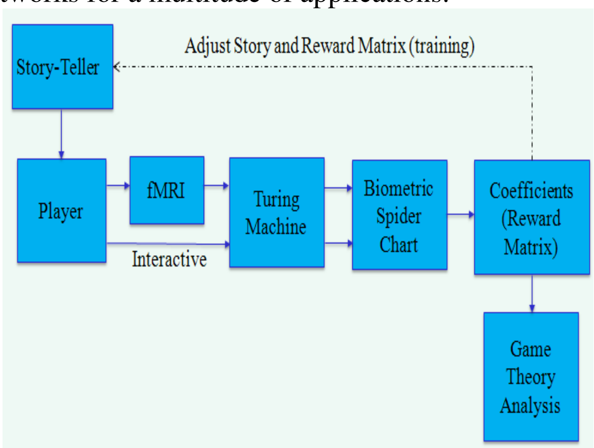

Figure 1. System Processing Flow Diagram

II. NEUROBIOLOGY OF NARRATIVE COMPREHENSION AND INFLUENCE

Agent-based modeling to represent detailed intra- and inter-personal interactions, as well as a system dynamics model to integrate societal-level influences via reciprocating functions has been performed. Cognitive Network Model as a method of quantitatively characterizing cognitive mechanisms at the intra-individual level to capture the rich dynamics of interpersonal communication for the propagation of beliefs and attitudes has been presented. Socio-cognitive network models tie strength to regulate how agents influence and are influenced by beliefs during social interactions [5].

In addition to the ability to understand action intentions or more abstract mental states such as other people's beliefs or wishes, humans can also empathize with others. Current fMRI studies have provided evidence for a role of such shared neural networks that enable one to feel – by merely perceiving or imagining another person feeling pain, touch, or disgust in the absence of any stimulation to one's own body – what it feels like for the other person to be in pain, touched, or disgusted [11].

The Anterior Insula (AI) and Lateral Prefrontal Cortex (LPFC) and Visual Cortex (VC) are parts of the brain shown in Figure 2 that are involved in human decision-making processes. Signals from the AI and LPFC serve as supporting disagreement while the signals from the VC serve as supporting agreement.

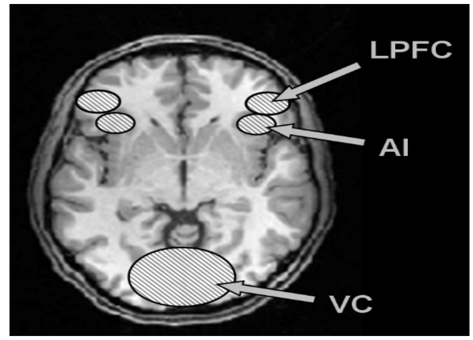

Figure 2. Emotion Generating Parts of Brain [6]

The AI and LPFC regions are activated when an unfair situation occurs [6]. Results from current fMRI studies have demonstrated on empathy for taste, disgust, and pain suggest that AI cortices play a crucial role in empathy, feelings, and automatic feedback [11].

III. COMMUNICATION PACKET THEORY

Previous imaging studies have used content oriented boundaries to explore associated brain activity [12][13][20]. Interactive storytelling is not characterized by a continuous flow of information from teller to listener and back from listener to teller rather information exchange proceeds in discrete packets. The teller conveys a small chunk of the story through words, voice, and gesture. The teller pauses—even momentarily—in his/her delivery to receive and assess listener feedback. The teller uses the visual, auditory or kinesthetic feedback as a guide for constructing and delivering the next small block of the story. For our revolutionary bridging concepts, we call these small story blocks, "packets." Story packets can last from a few seconds up to half a minute or more. Packets demarcate communicative epochs of brain activity for story transmission and comprehension. The teller decomposes the delivery of the story into packets on the basis of an audience model; the audience reintegrates the packets into a story that can be influential. The efficacy of the cumulative packets ('story') depends upon the fidelity of the teller's audience model to the audience [4].

The construction of story architectures to persuade and to influence is based on a well-established skill set that has been tested and validated extensively through the compilation of anecdotal data from literally millions of storytelling performances, modern marketing effort, and story publishing experiences. Story inputs have been dissected and cataloged in excruciating detail. Outward listener responses to story material have been observed carefully and related back to story structural elements. This approach has been attempted in previous imaging studies that used content oriented boundaries to explore associated brain activity [13] [20]. The associated functional imaging has been triggered by boundaries of event structure perception of content features related to story comprehension [19]. This approach has yet to yield neural response templates that are sufficiently robust to identify prospectively key boundaries and comprehension.

Our approach is fundamentally different from existing research. We base our analysis on the more fundamental and central concept of communication packets. This approach is based upon the observations that content features, meaning, and influence are embedded in the bi-directional flow of packets delivered by a storyteller and by the audience as responsive feedback packets to the storyteller. The comprehension of the content and influence are internal, underlying processes in the audience members. The storyteller uses an audience model for constructing and organizing content and for dividing that content into packets. The success of stories of influence depends upon the fidelity of the model to the audience member(s) and in the storyteller's ability to recognize and effectively use the response packets received from the audience during the telling. The packet structure, therefore, becomes the target (or key) for detecting associated brain activity. Stated simply, packet demarcators are the brain-generated markers of engagement, comprehension and influence [4].

IV. INFLUENCE MODELS

Understanding influence processes necessarily requires viewing the phenomenon at various scales, primarily at individual, inter-personal levels and societal levels. Modeling these processes traditionally follows a single-scaled paradigm such as the use of social networks for understanding information diffusion and the occurrence of outbreaks. Social network analysis primarily attacks these types of problems by concentrating on finding the most 'influential' or informative nodes within a network, using, for example, linear threshold or cascade models to capture specific types of spreading behavior.

Understanding behavior at the individual level as it relates to interpersonal communication is frequently represented through the use of agent-based models, where 'emergence' of social phenomena is an important component of understanding the larger-scaled results of influence. These types of models are often chosen for information operations within the military as they allow for exploration of cognitive architectures in conjunction with inter-personal information transmission to aid in the interpretation of message content [2].

The influence process can be modeled at multiple levels using a comprehensive network approach that is able to both take into account the social networks of individuals as well as their existing cognitive structure to allow for the consideration of the content of the message (as composed of *packets*) at multiple scales - within an individual (how a communicated message is reconciled with the recipients' existing beliefs), between individuals (how various aspects of the sender affect message reception), and at the societal level (how emergence and cultural variables interact to create top-down effects) – all of which utilize both existing and novel social and psychological theory as applicable to population structure and message content [4].

A story packet is a block of story information delivered by the teller without pausing to receive and assess listener feedback. Hence, in neuroscientific terms, a packet is a ballistic or pre-programmed communicative act. A story packet engenders verbal and/or nonverbal responses in the listener accompanied by unconscious and autonomic activity reflecting factors that include emotion, intent and arousal. This listener response "packet" guides the teller's formation and launching of the next story packet. Thus, story packets (rather than plot stages, character, words, or seconds) becomes the true meaningful unit of measure for marking progress through a story against which the dependent variable, listener response can be measured and plotted [4].

From a neurocognitive perspective, story packets and response packets are the discrete, outward manifestations of continuous neural processes of story transmission and comprehension. The audience makes sense of the story lines and meanings during reception of the story packets. Intuition and experience suggest that responses differ markedly when one is listening to new information, as opposed to comparing new information to anticipated information from a sense-making hypothesis or story line [4].

V. MEASURING PROGRESS THROUGH A STORY

As a basic unit of measure of the progress through a story, packets allow us to bridge between neural, neurocognitive, and social sciences as we assess a story's ability to engage and to deliver influence. Figure 3 illustrates application of story packet structure to a sample story segment (with packets separated by "/" marks) [4]: "*John shook his fist/ and laugh at the burning sun./ Wind swirled as he stretched out a trembling hand/, breathed deep,/ and eased open the big double doors./ He gulped/ and stepped inside!"*

Each packet is of equal size in center of the diagram, with an expected response at the packet boundary illustrated above. The actual response of the listener, indicated below, are outward manifestations of engagement that mark the processes of sense-making, comprehension and influence [4].

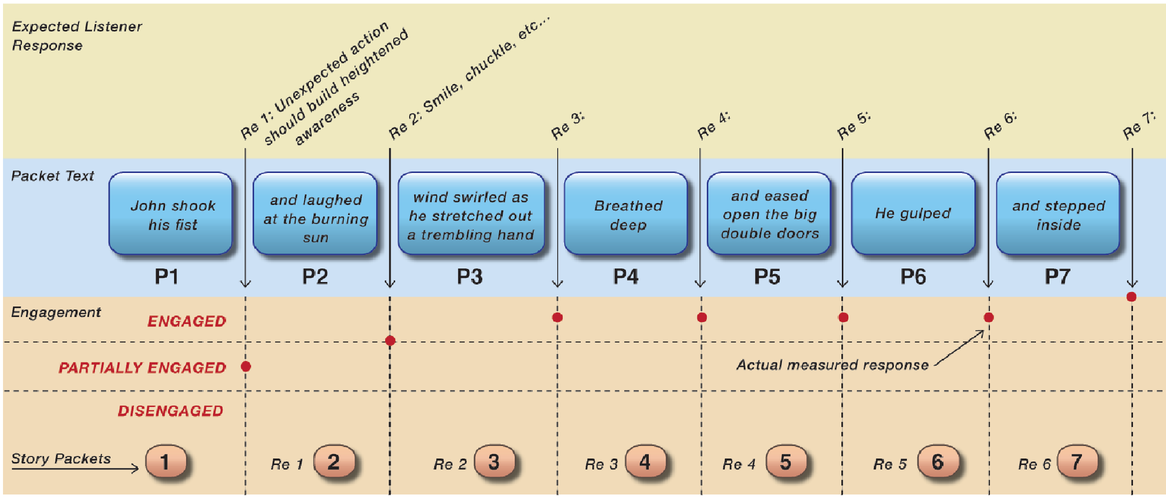

Figure 3. Application of Story Packet Structure to a Sample Story Segment

We posit that both engagement and influence are and can be transmitted via story packets. Our guiding suppositions are that: 1) influence through story requires engagement, 2) when effectively structured, story engages the listener and the teller in a dance of rapport, whereby, the story will facilitate the exertion of influence on the listener, and 3) that the neurological, physiological, and behavioral indicators of engagement and influence can be detected by a sensor system. Three primary measures for tracing the effects of story on engagement and influence: *Engagement Index* (EI), *Meme Reception* (MR), and *Sentiment Shift* (SS) [5].

The Engagement Index (EI) is intended to be a quantification of engagement as a mathematical function of multiple variables, based on neurophysiological signals (EEG, heart rate, respiration rate, perspiration, pupillary reactions, etc.) and neurocognitive behavioral responses (eye gaze, facial expressions, postures, gestures) or brain wave patterns as detected and calculated by the sensor system. These metrics will provide the means by which we will establish a baseline of how the listener(s) mentally process information. EI is measured according to story packets as the liminal units – thus an engagement index is the quantitative measure associated with a single story packet, and can be plotted to illustrate near real time measure of audience engagement in the story as told by the narrator. [5].

Meme Reception (MR) refers to a quantified measure of acceptance or rejection of the influence memes (delivered as part of selected packets) resulting from the story as presented by the narrator. As noted above, the system is capable of detecting and classifying listener responses to narrator delivered story packets through both external and internal triggers. It is possible to use these response signals to automatically mark moments of listener recognition of core messages, and to quantitatively indicate either a positive or negative reception of the influence memes associated with selected story packets. This measure will be correlated to the mental processing baseline of the individual(s). [5]

Sentiment Shift (SS) can be observed after the presentation of the stimulus story, based upon a simple pretest and posttest of attitudes towards themes using a continuous attitude/sentiment scale between two dichotomous endpoints. The SS measure will provide both magnitude and direction of sentiment shift for specific themes and this too may be correlated to the target's preferred mental processing cognitive pattern strategy for processing information. The SS measure is calculated using custom designed measures of attitude toward domain-related themes of story, collection of self-report of pre and post stimulus attitudes, and a numeric value calculation of sentiment shift (SS) for themes. Once this measure is acquired, the value is then compared to sentiment for theme-related memes in the story as expressed by the narrator, as well as audience expressed sentiment for the meme (i.e., meme reception (MR)) [5].

VI. NEW BIOMETRIC BEHAVIORAL MODEL

Emotions are an important belief dependent motivation. Anxiety, disappointment, elation, frustration, guilt, joy, regret, and shame, among other emotions, can all be conceived of as belief-dependent incentives or motivations and incorporated into models of behavior using tools from psychological game theory [1]. Given a story and the many responses of the brain one method for recording these fMRI or BCI responses is through the use of a Turing machine framework. This method allows efficient storing of data as well as the ability to do pattern recognition. The concept of a Turing machine provides a way to make a concept of computational complexity precise and efficient [9]. The measured and interactive responses from the player are recorded in real time and utilized to create a new biometric in the form of a spider chart which contains the characteristics of having each node represent a behavior induced emotion.

A spider chart is a graphical method of displaying multivariate data as shown in Figure 4. Each of the values of the recorded emotions is represented starting from the center of the 2D plot. An example using fMRI data is shown in blue and the interactive responses are shown in black to create the biometric based upon a story.

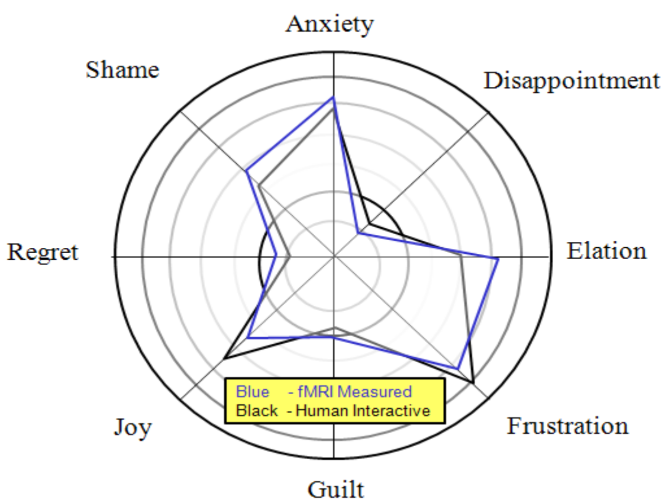

Figure 4. Example of Spider Chart of Belief Dependent Emotions

VII. Game Theory Analysis

Game theory considers the effect of a player's decision on other decision makers. Two or more decision makers choose an action and that action affects the rewards earned by the players [14]. Our paper looks at an example of using linear program game theory to analyze scores given a reward matrix for possible actions. In our case, the story-teller sets up an emotional situation and tests the player's emotional response to the story. Therefore, the row of a reward matrix is chosen by the story-teller and represents the expected emotion to be measured. The player's emotional response then determines the column of the reward matrix and the score. This determination of the column is done by the player's interactive responses and also by the fMRI responses of the story-teller's asking of binary questions to determine the column of the player's response. Current measuring techniques limit the questions to binary responses. The fMRI sensing system achieves a 70% accuracy based on binary agree/disagree or yes/no questions [6].

In many situations, the opponents know the strategy that they are following and what actions are available. The maximin equilibrium often is the strategy and is called the Nash theory application of zero or constant sum strategy game. This threshold can be used to determine if the player is on the blue or red team. For example, if a reward matrix exists, then the equilibrium point is the one where the reward is the smallest value in its row and the largest number in its column. This equilibrium point is also called a saddle point since it is like the center point in a horse's saddle. This equilibrium is also known as the Nash Equilibrium [7]. The saddle point is the local minimum in one direction (row) and a local maximum in another direction (column) [14] such as:

$$\max_{\text{all rows}} (\text{row min}) = \min_{\text{all columns}} (\text{column max}) \quad (1)$$

This left half of (1) presents the basic applied theory to decision making of our model under uncertainty. For a possible action, one consideration is to choose the "best" worst outcome [14]. The maximin criterion suggests that the decision-maker should choose the alternative which maximizes the minimum payoff he can get. This pessimistic approach implies that the decision-maker should expect the worst to happen. The maximin criterion is concerned with making the worst possible outcome as pleasant as possible.

The right half of (1) represents minimax regret criterion which uses the concept of opportunity cost to arrive at a decision. The regret of an outcome is the difference between the value of that outcome and the maximum value of all the possible outcomes. For any action and state, there is opportunity of loss or regret. The decision-maker should choose the alternative that minimizes the maximum regret he/she could suffer. Although these decision-making criteria discussed may seem reasonable, many decisions are made without using any analysis [14].

An emotional couple is a duo of two emotions that belong to the same group but contradict each other. For example, the two emotions of Joy and Distress will make an emotional couple. The value of an emotional couple is a real number that varies between -1 and +1 inclusively [10]. In order to compute every element a_{ij}, we can create a reward matrix which collects all emotional states of interest. This reward matrix has the elements a_{ij} which will determine the weight of how much each constituent affects the emotional couple. The choice of the values of a_{ij} is a very critical issue since it is basically the core of the whole emotional paradigm.

Linear programming is useful for solving game theory problems and finding optimal strategies. We can define: x_i = probability that the player's emotion is one of the eight emotions. Game theory can be used to determine a threshold of an average response to determine if you are a blue or red player. An example reward matrix shown in Table 1 contains values similar to [8]. The example matrix may have sparse values since some emotions are not expected and would not make sense. These emotions with values of zero would be considered irrelevant outliers.

We can solve this linear program using several manual techniques such as the simplex method, the dual simplex method, or the artificial basis technique. We can also use a computer with LINDO software from www.lindo.com to solve for the mixed strategies as well as the value of the responses.

	Anxiety	Disappointment	Elation	Frustration	Guilt	Joy	Regret	Shame
Anxiety	1000	0	-400	600	200	-600	0	0
Disappointment	0	1000	0	600	200	-400	0	0
Elation	-400	0	600	0	0	600	-400	-1000
Frustration	600	600	0	400	0	-200	600	0
Guilt	200	200	0	0	1000	0	0	600
Joy	-600	-400	600	-200	0	1000	0	0
Regret	0	0	-400	600	0	0	1000	400
Shame	0	0	-1000	0	600	0	400	1000

Table 1. Example Reward Matrix

Equation (2) is used to determine which expected emotions in the story will get the highest score. It turns out that the best strategy for the player is to do the dual of the story-teller to obtain the highest score. The dual is computed in (3).

$$\begin{aligned}
&\max v' \\
&s.t.\ (a)\ v'-1000x_1+400x_3-600x_4-200x_5+600x_6\le 0 \\
&(b)\ v'-1000x_2-600x_4-200x_5+400x_6\le 0 \\
&(c)\ v'+400x_1-600x_3-600x_6+400x_7+1000x_8\le 0 \\
&(d)\ v'-600x_1-600x_2-400x_4+200x_6-600x_7\le 0 \\
&(e)\ v'-200x_1-200x_2-1000x_5-600x_8\le 0 \\
&(f)\ v'+600x_1+400x_2-600x_3+200x_4-1000x_6\le 0 \\
&(g)\ v'+400x_3-600x_4-1000x_7-400x_8\le 0 \\
&(h)\ v'+1000x_3-600x_5-400x_7-1000x_8\le 0 \\
&x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8=1 \\
&x_1,x_2,x_3,x_4,x_5,x_6,x_7,x_8,v'\ge 0
\end{aligned} \tag{2}$$

$$\begin{aligned}
&\min w' \\
&s.t.\ (a)\ w'-1000x_1+400x_3-600x_4-200x_5+600x_6\ge 0 \\
&(b)\ w'-1000x_2-600x_4-200x_5+400x_6\ge 0 \\
&(c)\ w'+400x_1-600x_3-600x_6+400x_7+1000x_8\ge 0 \\
&(d)\ w'-600x_1-600x_2-400x_4+200x_6-600x_7\ge 0 \\
&(e)\ w'-200x_1-200x_2-1000x_5-600x_8\ge 0 \\
&(f)\ w'+600x_1+400x_2-600x_3+200x_4-1000x_6\ge 0 \\
&(g)\ w'+400x_3-600x_4-1000x_7-400x_8\ge 0 \\
&(h)\ w'+1000x_3-600x_5-400x_7-1000x_8\ge 0 \\
&x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8=1 \\
&x_1,x_2,x_3,x_4,x_5,x_6,x_7,x_8,w'\ge 0
\end{aligned} \tag{3}$$

Using the Lindo software, the resulting value of the story is 153. We let the vector **x** correspond to the eight emotions in the order listed in Table 1. The solution for the story-teller is **x** = (0.00, 0.05, 0.00, 0.43, 0.25, 0.26, 0.01, 0.00) meaning the story expects a frustration response most often to obtain the highest score. The solution for the player is **x** = (0.08, 0.00, 0.31, 0.31, 0.00, 0.07, 0.00, 0.23) means the player selects elation or frustration most often to get highest score for the story. The player's score is then compared with equilibrium value of the responses. If the player's score is above the threshold, then the player is of the blue team's beliefs. If the score is below the threshold, then the player is of the red team's beliefs.

VIII. REAL WORLD APPLICATIONS

Today companies are increasingly using emotional intelligence (EQ) to evaluate job candidates using self report questionnaires. Not only do they buy into the value of emotionally intelligent employees, the incredibly competitive job market has given them large pools of candidates. Being emotionally intelligent can help break down stereotypes such as entitlement, need for constant encouragement, and inflated self-worth. Insight to emotional responses can provide information regarding emotional states and can help predict what kind of decisions will be made, what kind of behavior will occur, and what types of relationships will be formed [15].

For example, our proposed solution could be used as a screening tool for reducing insider threat by generating a list of questions where there are known red or blue player strategies for a particular situation or event based upon a particular set of script responses. For example, on 2 September 2012, American special operations forces had suspended the training of new recruits to an Afghan village militia until the entire 16,000-member force can be rescreened for possible links to the insurgency. The move is the latest repercussion from a series of "insider" shootings carried out by members of the Afghan police and army against Western troops. Forty-five NATO service members have been killed in such attacks this year with the U.S. toll in August 2012 alone totaling to 12 [16].

Another example of insider threat occurred on 20 July 2012 where James Holmes was arrested without resistance minutes after police say he unleashed a barrage of gunfire inside a packed Colorado Century 16 movie theater. Twelve people were killed and 58 were injured. Holmes' defense has been quoted stating Holmes is mentally ill [17]. The suspect had threatened a professor before the shooting, leading the university to ban him from campus [18]. The school could have used a form of EQ to identify early possibilities of mental health and initiate counseling.

IX. Conclusion and Future Work

Cognitive neuroscience investigates neuronal correlations of the human decision-making processes associated with brain responses. Economic behavioral research has proven emotional influences on human decision making. Decision making theory provides a method for measuring desired outcome calculating both maximum and minimum scores. A neurobiological based foundation of narrative and story-telling is a critical enabling technology for understanding human responses to narratives or stories for many purposes.

During any narrative or story, a player can be given binary interactive choices throughout the story or narrative. Players hear same story, but beliefs (religious, political, etc.) generate different individual emotions with decisions made upon the emotions or beliefs experienced by the player. Our premise is that sensed brain measurements versus interactive choices indicate beliefs of the player and what the player would like to believe respectively; these choices can be algorithmically scored with elections weighted by a reward matrix. Stories which contain neutral emotion can be injected between important choices with emotional states recorded with Turing machine for both sensed and chosen responses. The resulting output is a spider chart can be used as a new biometric tool to understand human response and decision making correlating to narratives or stories.

We have defined a solution for determining strategies based on game theory. We described an example using linear programming and resource allocation as it applies to influence based upon human emotional responses mapping to brain activation patterns. Automated game theory is promising for automatically solving real world strategies and help make decisions based on measurable emotional attributes. The Nash Equilibrium value in game theory can serve as a threshold between if a player has red or blue player beliefs by comparing the average score with the equilibrium value. Different cultural beliefs can use same reward matrix; however, different scores would result for same story. Additionally, different stories may require a different reward matrix.

We have considered a unique and innovative approach to enable neurobiological analysis of narratives that influence an audience. This approach bridges research in the social, computational cognitive and neurosciences to provide an integrated, quantitative roadmap for experimental analysis. The interplay of units of communication provides targets for detecting underlying brain activity in both the narrator and player. Our method can be used for psychological purposes, marketing, entertainment, game immersion context, hiring or screening process, etc., for use within these narrative domains.

These considerations are implicit in the audience model used by a narrator to translate a story into packets; these considerations may be modeled to determine an optimal message composition relative to the narrator's goals. Therefore, the behavioral and neurobiological correlates of the packet structure provide a 'Rosetta stone' for unlocking the neurobiology of influence. Analysis of the specific packet structure selected by a narrator can illuminate the evolving audience model and the efficacy of the narrative (or story). Conversely, audience responses to the story can illuminate the transition from simple engagement to recruitment of influence. Emotions occur as a result of how people understand a story or event of influence based upon their belief structures. These emotional responses, both controlled and uncontrolled, can be measured through a game theory technique.

Future work in this domain includes, but is not limited to, laboratory experimentation of the tool utilizing non-invasive methods mapping to individual and cultural belief networks, ability to influence and propagate messages or stories based upon refined models, more challenging models including imperfect knowledge, unknown, dominant strategies, non-rational players, asymmetric, and cooperative models, messages at multiple scales to include within a individual, between individuals, and at societal levels, cultural and anthropological effects, expansion of belief dependent emotions with decision making at both conscious and unconscious levels, influence models, effects of competing elements, decision making, neuropsychology and testing within longitudinal and real world applications.

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