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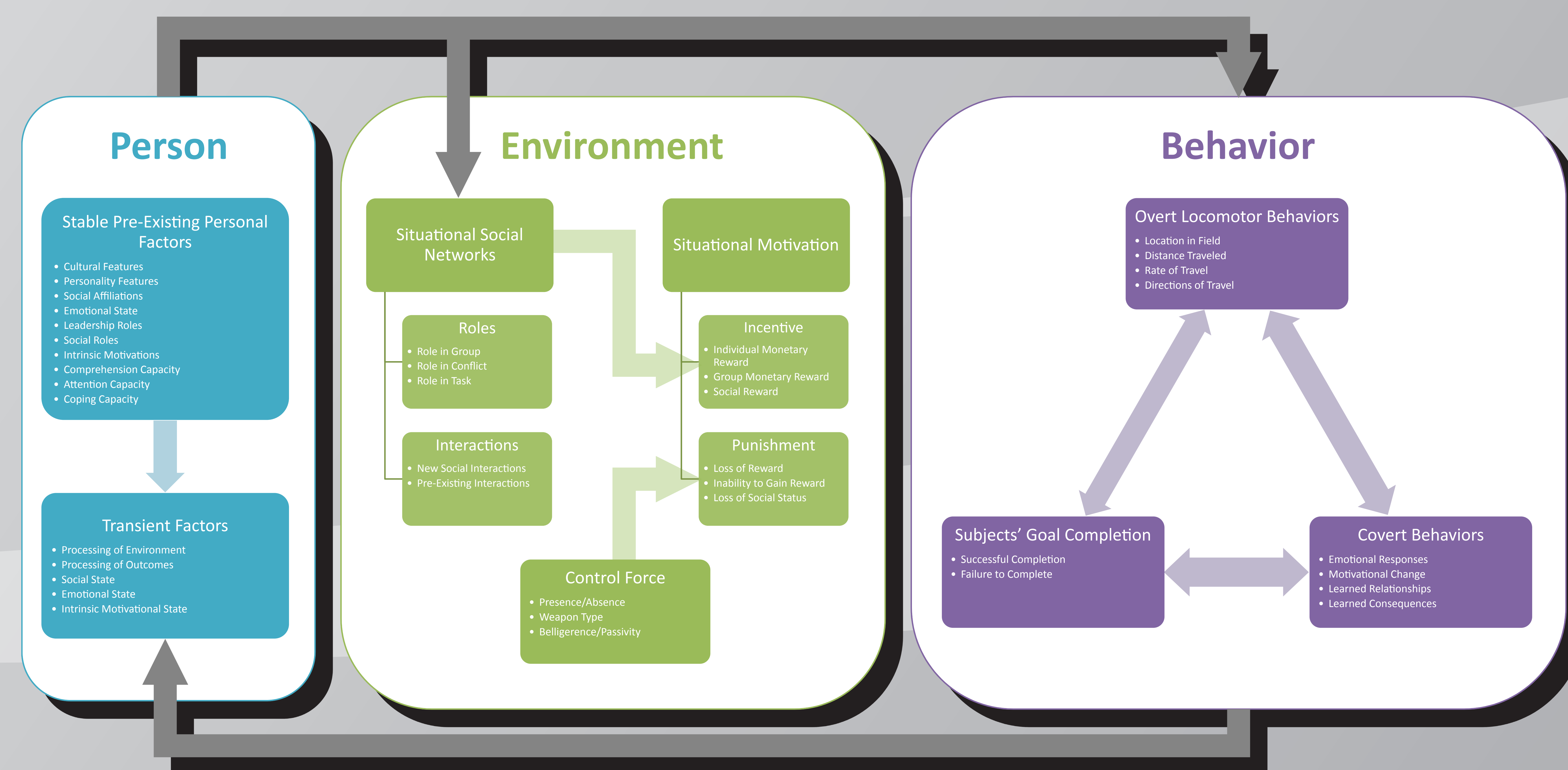
## MATHEMATICAL AND COMPUTATIONAL MODELING OF CROWD BEHAVIOR

Robert M. Demarco, Gladstone Reid, Gordon Cooke, Kevin Tevis, Charlie Sheridan, Elizabeth Mezzacappa, John Riedener

*Target Behavioral Response Laboratory*

This poster describes how these empirical methods of data collection are used to derive computational models that drive models that drive efforts at modeling and simulating crowd response to stimuli (non-lethal weapons) in a virtual environment. This approach of conducting future research and analysis on simulated crowds based on empirical data is important given the logistical constraints precluding testing of crowds with hundreds of members.

### Conceptual Model



### Mathematical Model

Currently, almost all modeling and simulation of human behavior relies on mathematical construction solely based on theory or subject matter expert opinion. Utilizing the conceptual model shown, this work uses the behavior of real persons in tactically relevant scenarios as the analytical link to modeling and simulation. Empirical data was collected via a motion capture system in a lab paradigm based off of the conceptual model. The conceptual model is translated into a theoretical mathematical model for data analysis.

$$\vec{B} = f(p, e)$$

$$\vec{B} = \vec{G}_1 + \vec{G}_2 + \dots + \vec{G}_n$$

$$\vec{B} = \vec{G}_1 + \vec{G}_2 = \vec{G}_{Target} + \vec{G}_{Weapon}$$

$$\vec{G}_{Target} = \begin{bmatrix} \Delta X \\ \Delta Y \end{bmatrix} = [\alpha] \begin{bmatrix} p \\ e \end{bmatrix} = [\alpha] \begin{bmatrix} x_i \\ y_i \\ x_G \\ y_G \\ \vdots \\ M \end{bmatrix}$$

$$\vec{G}_{Weapon} = \begin{bmatrix} \Delta X \\ \Delta Y \end{bmatrix} = [\beta] \begin{bmatrix} p \\ e \end{bmatrix} = [\beta] \begin{bmatrix} x_i \\ y_i \\ x_G \\ y_G \\ \vdots \\ M \end{bmatrix}$$

$$[\beta] \begin{bmatrix} a_1 \\ b \end{bmatrix} = \beta_1 a + \beta_2 b + \beta_3 ab + \dots$$

- Behavior (B) is a function of the person (p) and the environment (e).
- Behavior is the sum of goal (G) influences.
- Our simplification has two goals, the target and the weapon.
- The behavior caused by the target is a change in location which is based on the current states of the person and the environment. The p and e can be expressed by particular variables on which we collect data such as location of the individual and location of the goal.
- Likewise, the behavior caused by the weapon is also dependent on the current state of the input variables.
- The matrices,  $\alpha$  and  $\beta$ , are the coefficients of the model.

Custom-developed software can use recorded empirical data from several subjects in various scenarios to develop a model. A best-fit model is developed by deriving the coefficients of the theoretical mathematical model. The model developed can be used to simulate crowd behavior of hundreds of subjects.

