Laboratory Crowd Behavior

Laboratory Crowd Behavior at the Army’s Target Behavioral Response Laboratory.
Crowd Research

- Large numbers
- Heterogeneous
- Individual Actors
- Interdependence
- Language Barriers
- Empirical testing is difficult
Methods

Gather empirical data on real people and real groups in tactically relevant situations.
Conceptual Framework

• Based on the work of Kurt Lewin

• Field Theory in Social Science (1948)

• Principles of Topological Psychology (1936)
Indoor Crowd Behavior Testbed Layout
Video Cameras on Trusses
Method

- Groups of 12-19 individuals
- Controlled motivations toward goal & away from control force with money
- Manipulated type of weapon and the ROE
- Approach / Keep away
  - (“Deny access into/out of an area to individuals” JNLE/CBA)
- Recorded spatial data
- Video recording
Data Measurement

- Vicon V8i system
- 24 cameras
- 120 fps
- Optical tracking of retro reflective markers (ø14mm)
- Marker error <10mm
- Subjects
  - Unique Helmets
  - XYZ location + 3DOF orientation of head
- Control Force
  - Head & Torso
  - Capability for weapon control
TBRL Crowd
Few - Hand - Threat
### Individual Metrics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{t,sa}$</td>
<td>Distance covered in interval</td>
</tr>
<tr>
<td>$V_{t,sa}$</td>
<td>Instantaneous Velocity</td>
</tr>
<tr>
<td>$ID_{t,sa,SB}$</td>
<td>Interpersonal Distance between any pair of subjects</td>
</tr>
<tr>
<td>$CD_{t,c,sa}$</td>
<td>Distance between control force-subject pairs</td>
</tr>
<tr>
<td>$CID_{t,c,c}$</td>
<td>Interpersonal Distance between any pair of control force</td>
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</table>
## Crowd Metrics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cgt</td>
<td>Geometric Center - middle of extrema</td>
</tr>
<tr>
<td>Cd_t</td>
<td>Centroid - mean of subject positions</td>
</tr>
<tr>
<td>Dt</td>
<td>Dispersion - mean subject radii from centroid</td>
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<tr>
<td>LE_t</td>
<td>Leading Edge - max along the approach axis</td>
</tr>
<tr>
<td>TE_t</td>
<td>Trailing Edge - min along the approach axis</td>
</tr>
<tr>
<td>ρ_t</td>
<td>Density - $\rho_t = \frac{N}{\pi D_t^2}$</td>
</tr>
<tr>
<td>CDmin_t</td>
<td>Minimum distance between any subject-control force pair</td>
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<tr>
<td>σOt</td>
<td>Deviation of Orientation</td>
</tr>
<tr>
<td>σVt</td>
<td>Deviation of Velocity</td>
</tr>
<tr>
<td>Vct</td>
<td>Bulk velocity of crowd - rate of change of centroid</td>
</tr>
</tbody>
</table>

Defined time periods based on events dependent on the construct or scenario used.

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**Goal**

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Metrics for Weapon Performance

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Average Leading Edge

Frame (30/s)

Location (meters)

No Control Force Present

No Threat

Threat

Baseline

Standoff Weapon Threat

Hand Weapon Threat

Standoff Weapon No-Threat

Hand Weapon No-Threat

TECHNOWGY DRIVEN. WARFIGHTER FOCUSED.
Vector Fields

- Each subject's path of movement considered separately.
- Coordinate conversion so Control Force is origin.
- Subject locations grouped into cells.
- Resulting vector for a cell is the average vector from all data in that cell.
- Stream lines built from Vector Field.
Baseline Vector Field

Baseline: Streamlines

Goal End

Streamline View

Start End
Crowd Metrics for Effectiveness

Standoff Weapon Threat: Streamlines

Hand Weapon Threat: Streamlines
Importance of Social Factors

• Response to non-lethal weapons fire depends on social relationships among crowd members
  – Pre-existing Personal Relationships
  – Ongoing Real Time Social Interactions
  – Formal/Informal Hierarchies

• Therefore need method to assess social factors
• Social Network Analysis
Data Measurement

- Social Bonds
  - Self-Report
- Crowd Social Interactions
  - Observed on Video
- Leader Nomination
  - Questionnaire
Social Network Analysis

- 19 x 19 matrix submitted to networking analysis software
- ORA Version 1.9.5.4.3, Dr. Kathleen M. Carley, Center for Computational Analysis of Social and Organizational Systems (CASOS), Institute for Software Research International (ISRI) School of Computer Science (SCS) Carnegie Mellon University
- Visualization for insight
- Numerical Sociometrics outputted for formal analyses: density, isolates, linkages among nodes
Social Bonds

Do you know anyone else who is participating in the study today?

Yes  No

If yes, please indicate who you know based on the subject number assigned to them (on their tee shirt or folder). Please circle their numbers below:

1  2  3  4  5  6  7  8  9  10
11 12 13 14 15 16 17 18 19 20
Pre-existing Social Bonds
Social Interactions

- Videotapes coded for pair-wise social interaction among crowd members:
  - Verbal communication, physical contact, gestures, non-verbal auditory signaling
  - Scored three 2-minute epochs before/during crowd-control force interaction
  - Inter-rater reliability .94
<table>
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<th>Sub 2</th>
<th>Sub 3</th>
<th>Sub 4</th>
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</tbody>
</table>
Social Interaction Early
Social Interaction Later
Was there a person (or people) in your group that you considered to be a leader (or leaders)?

Yes  No

If yes, please indicate all the people that you thought were leaders.

Please circle their numbers below:

1  2  3  4  5  6  7  8  9  10
11 12 13 14 15 16 17 18 19 20
Leadership Nominations
### Numerical Sociometrics

<table>
<thead>
<tr>
<th></th>
<th>Social Bonds</th>
<th>Early Interactions</th>
<th>Late Interactions</th>
<th>Leadership</th>
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<tbody>
<tr>
<td><strong>Node Count</strong></td>
<td>19</td>
<td>19</td>
<td>19</td>
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<td><strong>Density</strong></td>
<td>0.0117</td>
<td>0.1257</td>
<td>0.0936</td>
<td>0.0526</td>
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<td><strong>Fragmentation</strong></td>
<td>0.9883</td>
<td>0</td>
<td>0.7485</td>
<td>0.4678</td>
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<td><strong>Isolate Count</strong></td>
<td>15</td>
<td>0</td>
<td>4</td>
<td>5</td>
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<tr>
<td><strong>Link Count</strong></td>
<td>4</td>
<td>43</td>
<td>32</td>
<td>18</td>
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<tr>
<td><strong>Centralization</strong></td>
<td>0.049</td>
<td>0.5114</td>
<td>0.2059</td>
<td>0.1585</td>
</tr>
</tbody>
</table>

**TECHNOWGY DRIVEN. WARFIGHTER FOCUSED.**
Conceptualization of Behavior

- \( B = f(P, E) \) Behavior is a function of the Person and the Environment
- Behavior can be expressed in mathematical terms
  - Easily imported into modeling and simulation exercises
- The challenge to researchers is to identify the totality of relevant factors and the elimination of extraneous factors
Factors in Crowd Response to Non-lethal Weapons and Systems

- **Weapon Variables:**
  - Visibility (can you see it)
  - Predictability (can you tell where it’s going to hit)
  - Controllability (can do something to avoid being hit)
  - Ability (“Effects” damage to persons)

- **Environmental Factors:**
  - Cover
  - Escape Routes
  - Barriers

- **Individual Psychological Factors:**
  - Motivation toward forbidden goal
  - Competing motivations

- **Crowd Social Factors:**
  - Organizational Hierarchy
  - Interpersonal Attraction
  - Alignment of motivations (do they all want the same thing)
  - Communication Ability
- \( y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots \beta_{12} x_1 x_2 \ldots + \epsilon \)

- “Behavior is a weighted function of variable \( x_1, x_2, x_3 \) their interactions, and error.”

- \( y \) is Output

- \( x \) are Inputs (Weapons, Environment, Individual, and Crowd Social Factors)
Validation

Need to make/use against real world observations

• Challenge is to measure
• Challenge is to find recorded measures
• Beware of circularity
  – Can’t use same data that you’ve built the model for validation
• Requires control over factors
• Quantitative Crowd Metrics allow algorithms to be made
• Algorithms can be used for to build models
• Output and Predictions of applications can be compared to data recorded in lab
• Visualization alone is helpful
• Comparison of VICON data with computer simulation with same parameters
• MAICE Station™
  Crowd Modeling Application Version 1
  Southwest Research Institute
  www.tspi.swri.org
Critical Elements for Data Feed into Modeling Efforts

- Common Conceptualization of Crowd Behaviors
  *Lewinian Field Theory*
- Common Metrics
- Common Data Formats
- Common Inputs
- Common Outputs
- Common Statistical Analyses
Using Data for Model Validation

- Build model around a scenario with one level of a parameter using real human data
- Run model with a different level of a parameter and record output metrics and predictions
  - Real human data must exist at this level of the parameter
- Compare output of model to analyses of laboratory data of real humans
Model Validation: Examples

Build Model On

- One Control Force
- Hand-to-hand Combat Weapon
- 10 in crowd

Validate Against

- Three Control Force
- Stand-off Weapon
- 20 in crowd
Comparison of Data and Output

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Average Leading Edge

Location (meters)

Frame (30/s)

Notional Model Results

Baseline
Standoff Weapon Threat
Hand Weapon Threat
Standoff Weapon No-Threat
Hand Weapon No-Threat