

Network Science and Crowd Behavior Metrics

Target Behavioral Response Laboratory

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Report Documentation Page

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14. ABSTRACT ARDEC's Target Behavioral Response Laboratory is currently conducting research on methods for crowd laboratory experiments, specifically crowd behavior metrics. Crowd metrics based on topological data were derived using motion capture methods. Sociometrics were based on coded videotaped communications. The preliminary results suggest that these crowd metrics, including those produced by network science methods, should be considered for further study. The results also suggest that crowd metrics, rather than only weapon characteristics, should be used to compare effectiveness of non-lethal weapons from different technologies.					
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The Problem

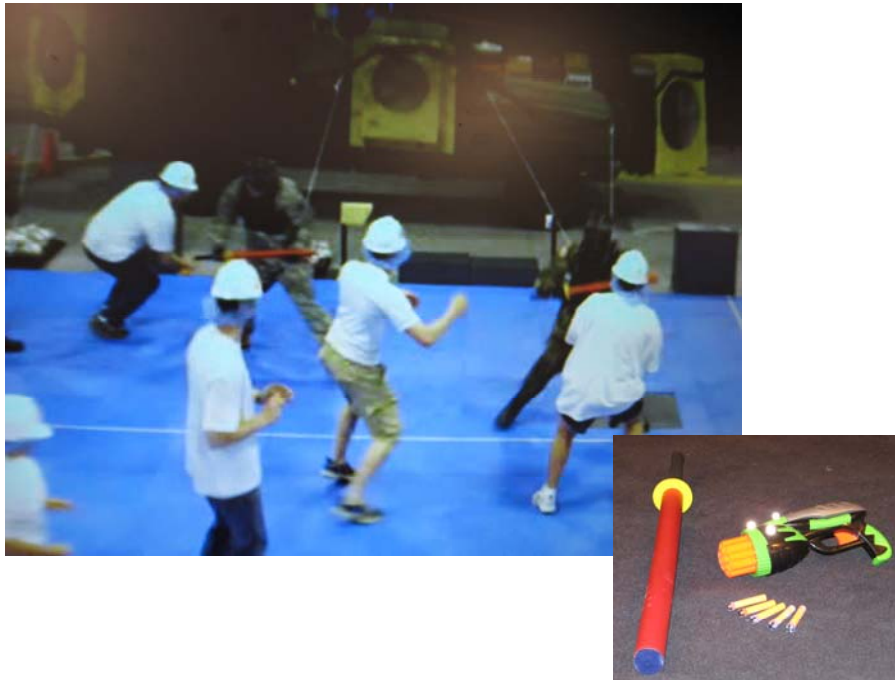
- Large numbers
- Heterogeneous
- Individual Actors
- Interdependence
- Language Barriers



- Empirical testing is difficult
- Social behavioral research has been lacking
- Simulations require models based on real data, otherwise they are fiction.



Method



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

- Groups of 12 individuals
- Controlled motivations toward goal & away from control force with money
- Manipulated type of weapon, size of control force and the ROE.
- Two tactical constructs
 - Approach / Keep away
 - Occupy / Go Away
- Recorded spatial data
- Video recording



Test Setup

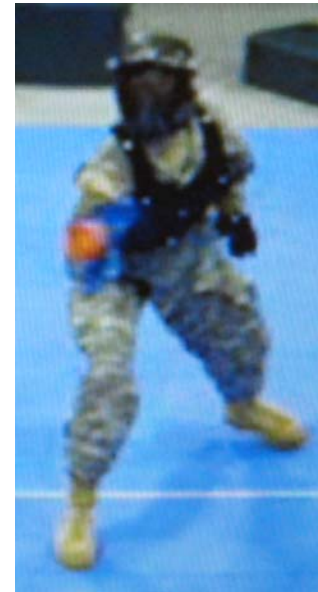




Data Measurement



- Vicon V8i system
- 24 cameras
- 120 fps
- Optical tracking of retro reflective markers ($\varnothing 14\text{mm}$)
- Marker error $< 10\text{mm}$
- Subjects
 - Unique Helmets
 - XYZ location + 3DOF orientation of head
- Control Force
 - Head & Torso
 - Capability for weapon

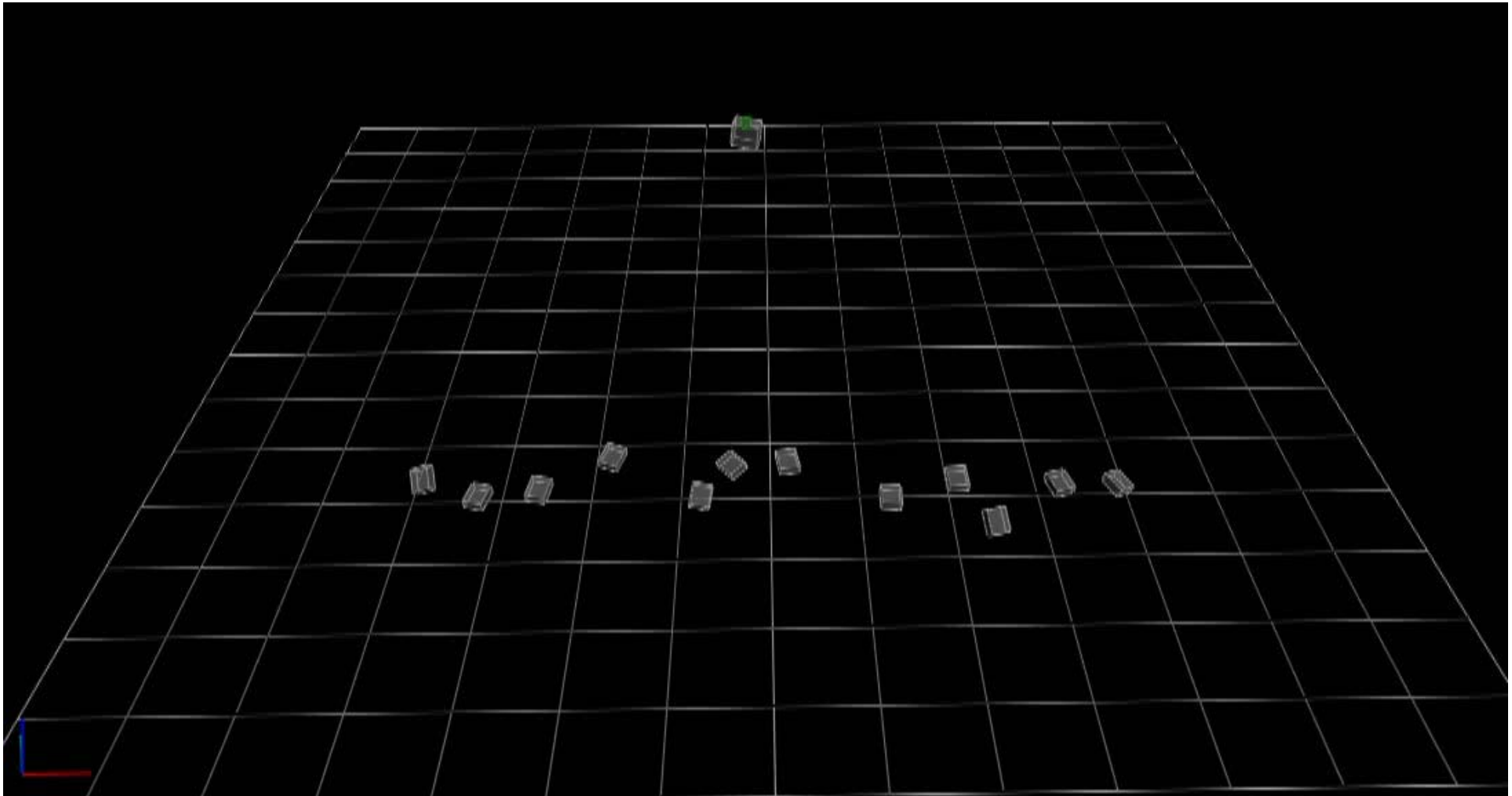


Courtesy Vicon





Example





Individual Metrics



$S_{t,Sa}$	Distance covered in interval
$V_{t,Sa}$	Instantaneous Velocity
$ID_{t,Sa,Sb}$	Interpersonal Distance between any pair of subjects
$CD_{t,c,Sa}$	Distance between control force-subject pairs
$CID_{t,c,c}$	Interpersonal Distance between any pair of control force

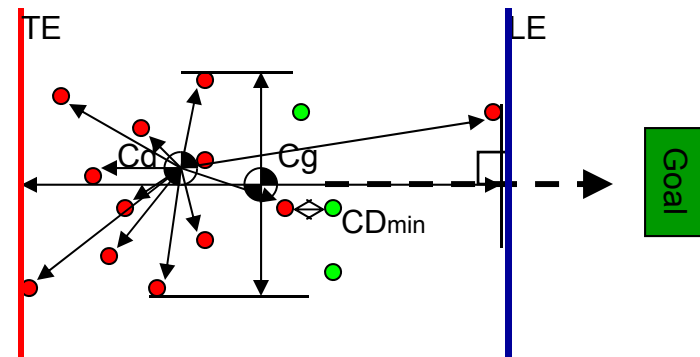


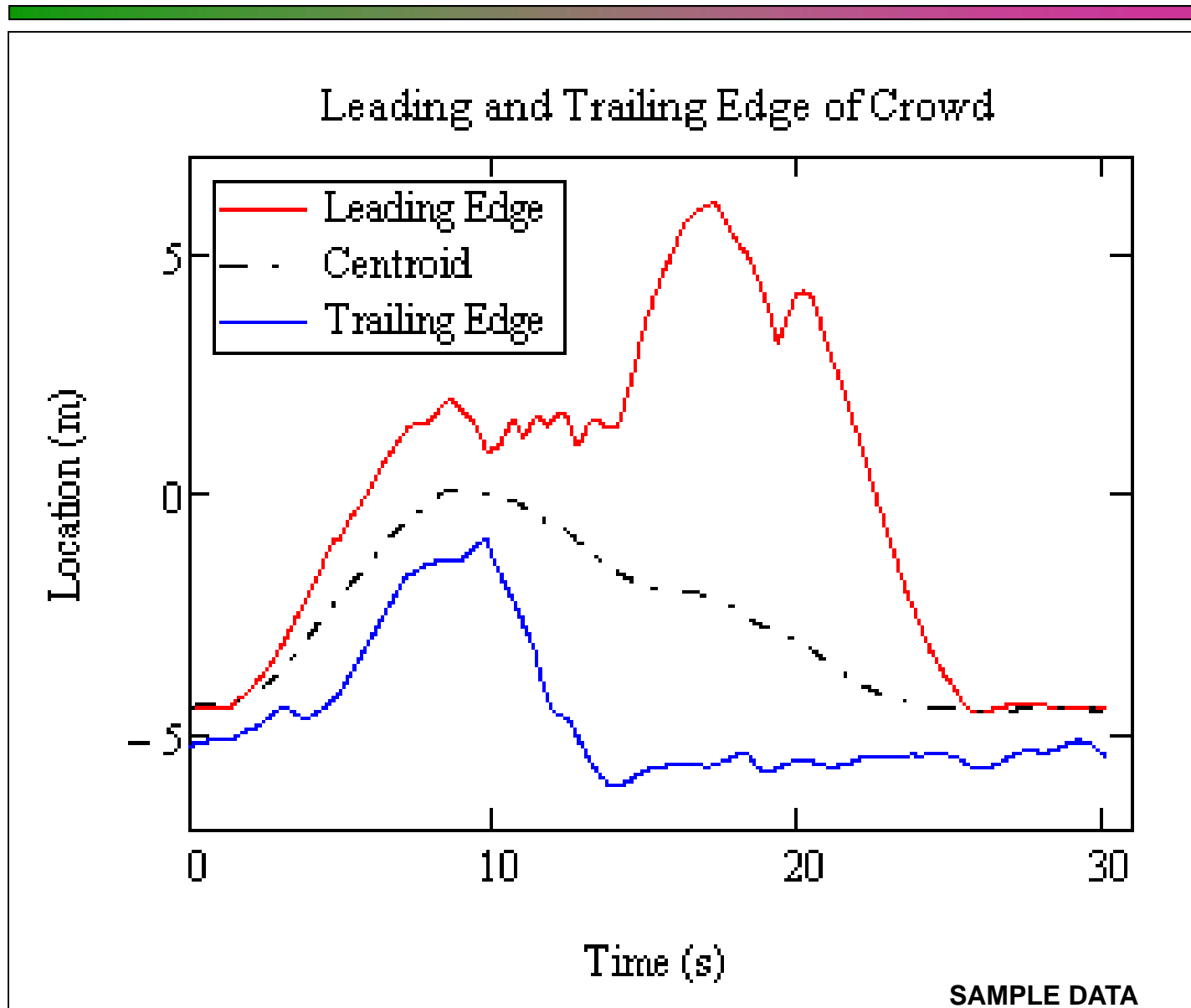
Crowd Metrics

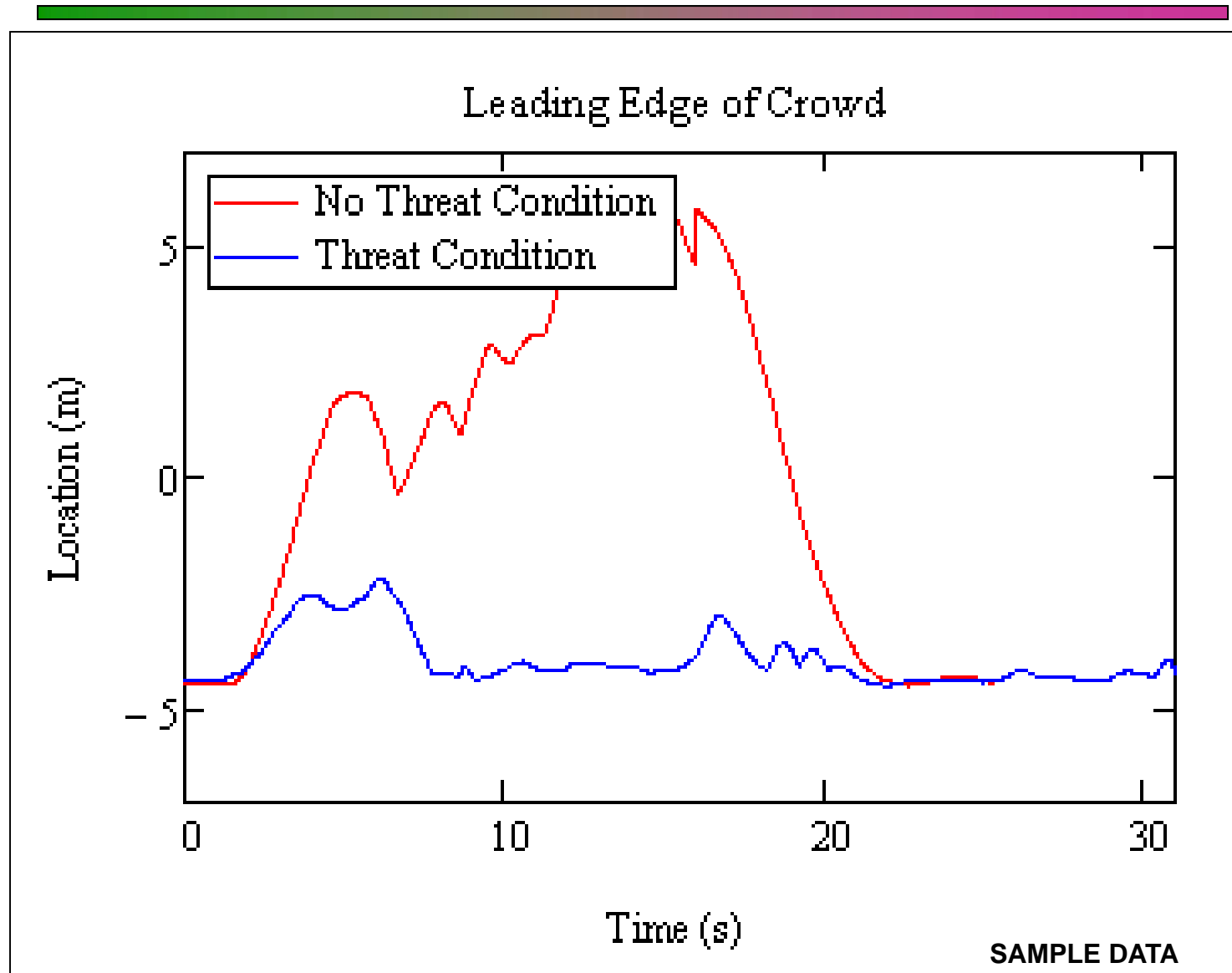


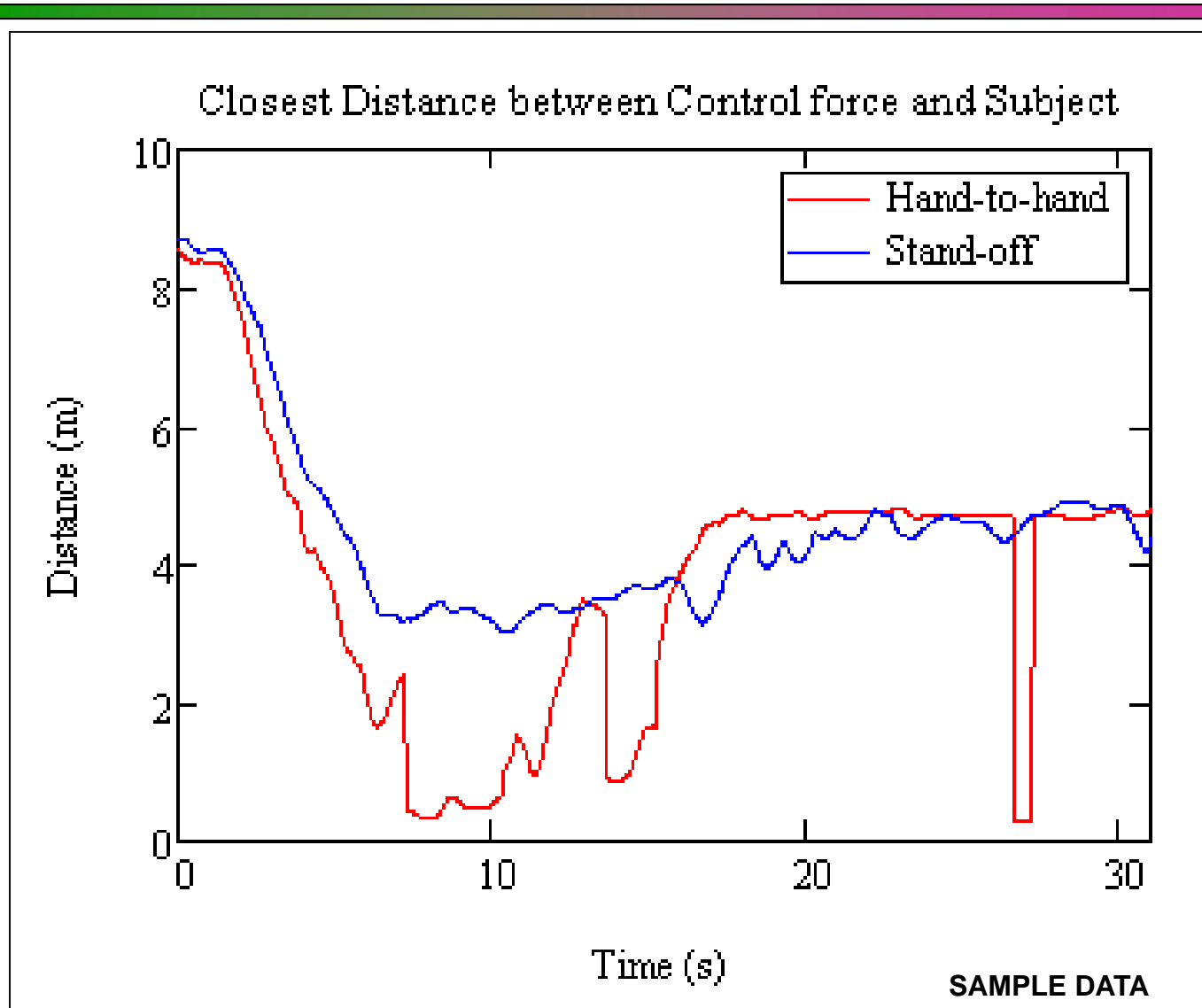
Cg_t	Geometric Center- middle of extrema
Cd_t	Centroid- mean of subject positions
D_t	Dispersion- mean subject radii from centroid
LE_t TE_t	Leading/Trailing edge- max/min along the approach axis
ρ_t	Density- $\rho_t = N / \pi D_t^2$
$CDmin_t$	Minimum distance between any subject-control force pair
σO_t σV_t	Deviation of Orientation/Velocity- StDev of all subjects head orientation or velocity
Vc_t	Bulk velocity of crowd- rate of change of centroid

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











Outcome



- Probability Distributions
 - Identify the distribution & parameters
 - To be used in Stochastic models of both the aggregate (crowd) level or at the individual level
- Regression Equation
 - $y = (\beta_1 x_1) + (\beta_2 x_2) + (\beta_3 x_3) + \dots + (\beta_{12} x_1 x_2) + \dots + \varepsilon$
 - Identify covariates (interacting & confounding)
 - Determine distributions for coefficients to use in stochastic models
 - Determine coefficients to use in deterministic models



Social Network Analyses



- Videotapes coded for pairwise social interaction among crowd members
 - Verbal communication, physical contact, gestures, non-verbal auditory signaling
 - 30-sec epochs at beginning and end for two groups
- 12 x 12 matrix submitted to networking analysis software (ORA Version 1.9.5.2.9)
- Sociometric Data outputted
 - #subgroups, isolates, linkages among nodes



Adjacency Matrix

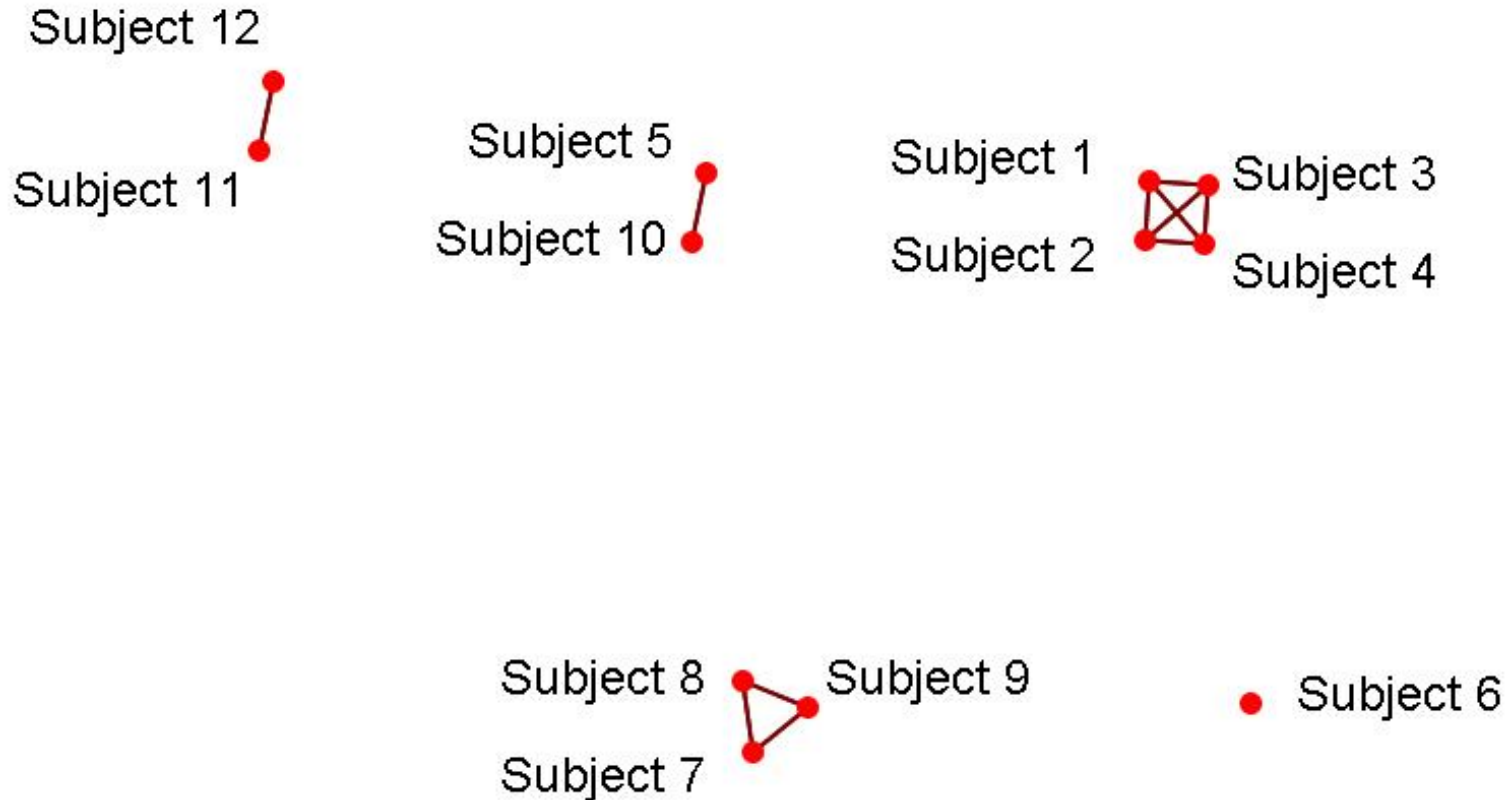


Intercommunications among Crowd Members

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7	Subject 8	Subject 9	Subject 10	Subject 11	Subject 12
2	Subject 1		1	1	1	0	0	0	0	0	0	0	0
3	Subject 2	1		1	1	0	0	0	0	0	0	0	0
4	Subject 3	1	1		1	0	0	0	0	0	0	0	0
5	Subject 4	1	1	1		0	0	0	0	0	0	0	0
6	Subject 5	0	0	0	0		0	0	0	0	1	0	0
7	Subject 6	0	0	0	0	0		0	0	0	0	0	0
8	Subject 7	0	0	0	0	0	0		1	1	0	0	0
9	Subject 8	0	0	0	0	0	0	1		1	0	0	0
10	Subject 9	0	0	0	0	0	0	1	1		0	0	0
11	Subject 10	0	0	0	0	1	0	0	0	0		0	0
12	Subject 11	0	0	0	0	0	0	0	0	0	0		1
13	Subject 12	0	0	0	0	0	0	0	0	0	0	1	

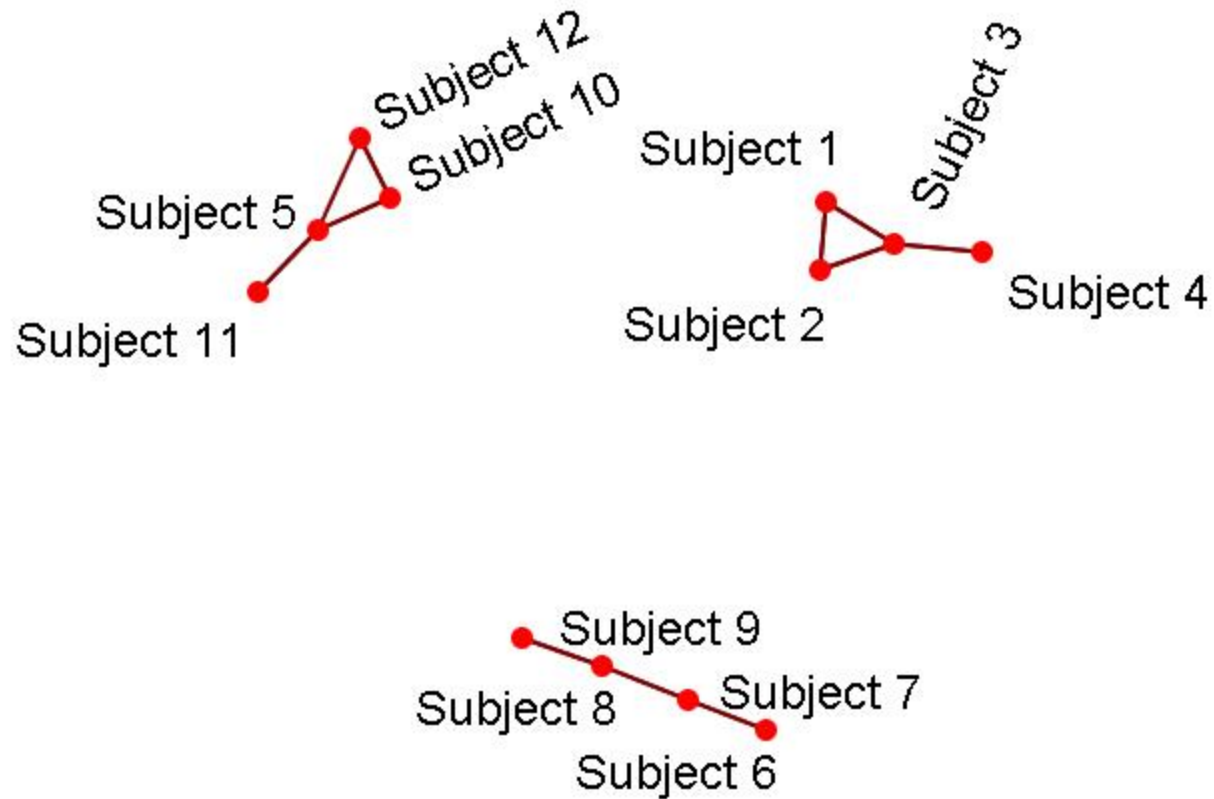


TBRL → Crowd A at Beginning of Experiment



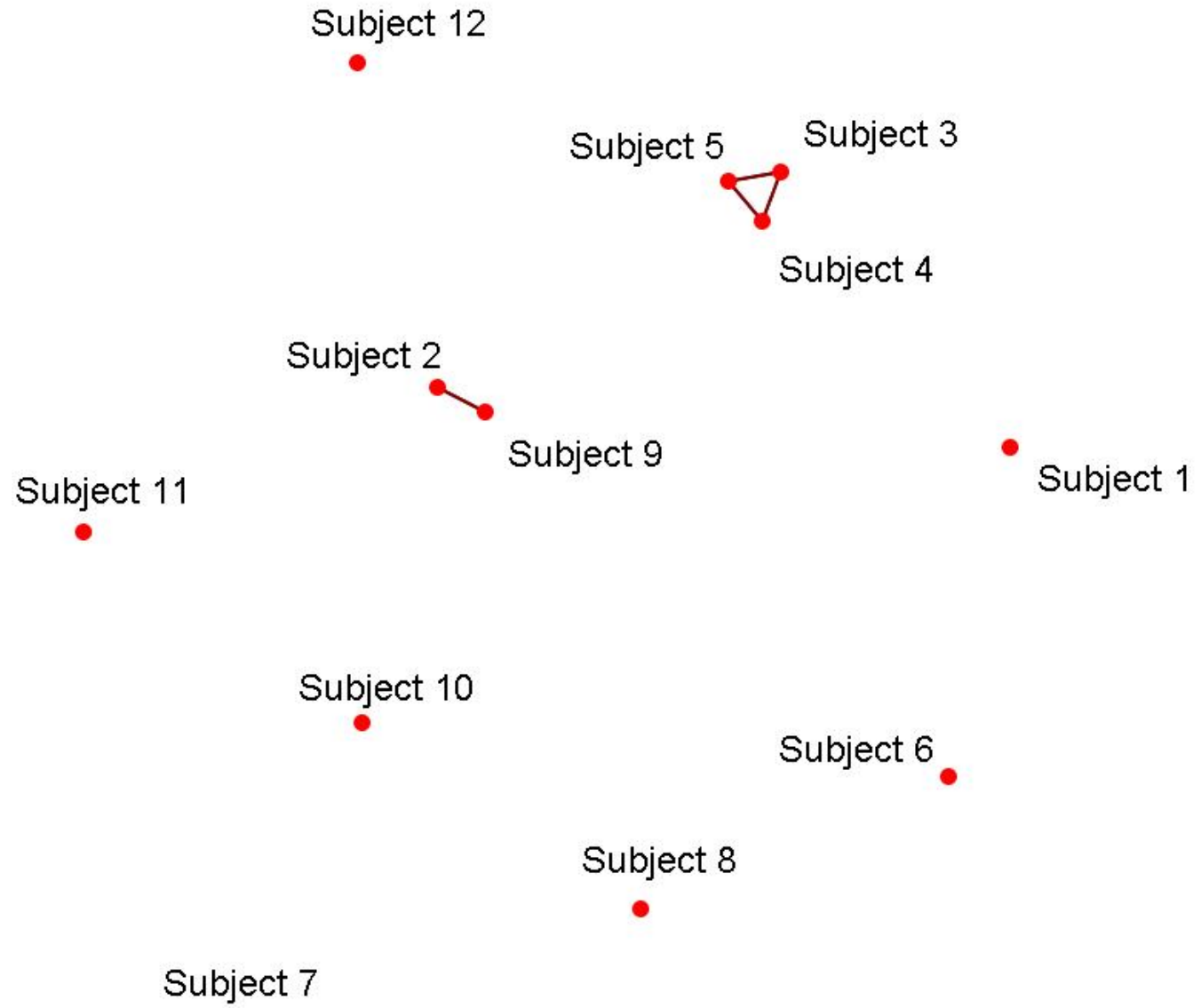


Crowd A at End of Experiment



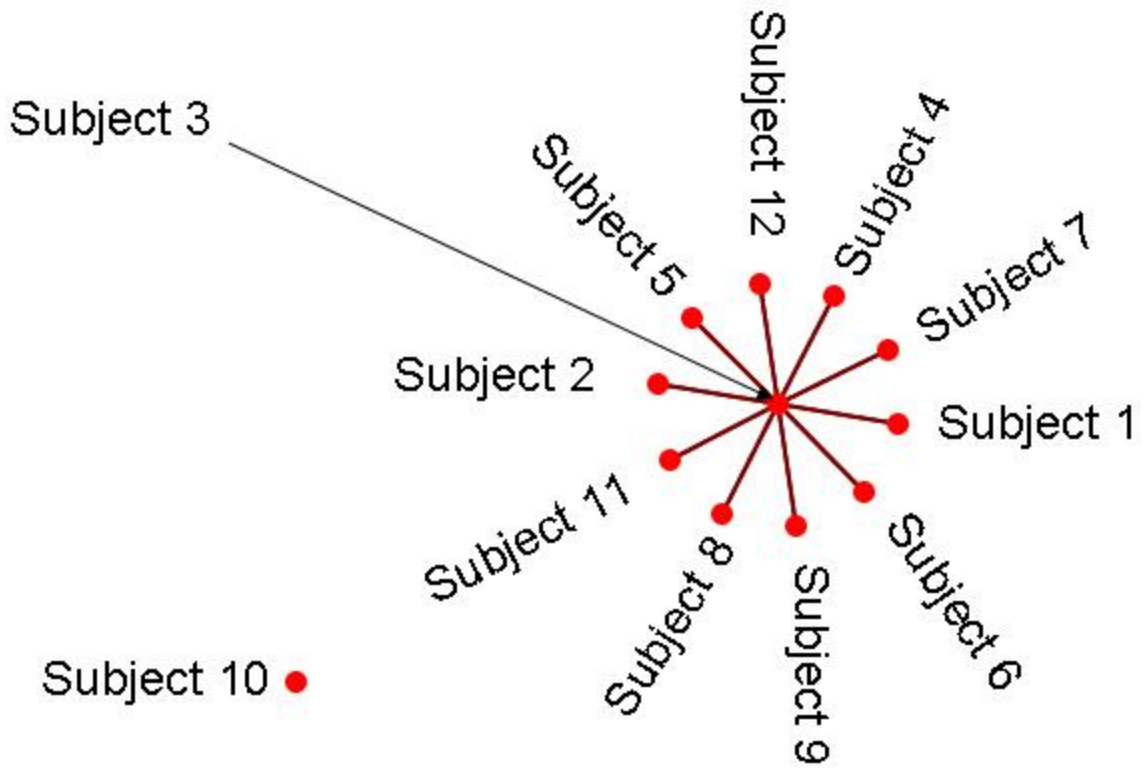


Crowd B at Beginning of Experiment





Crowd B at End of Experiment





Results

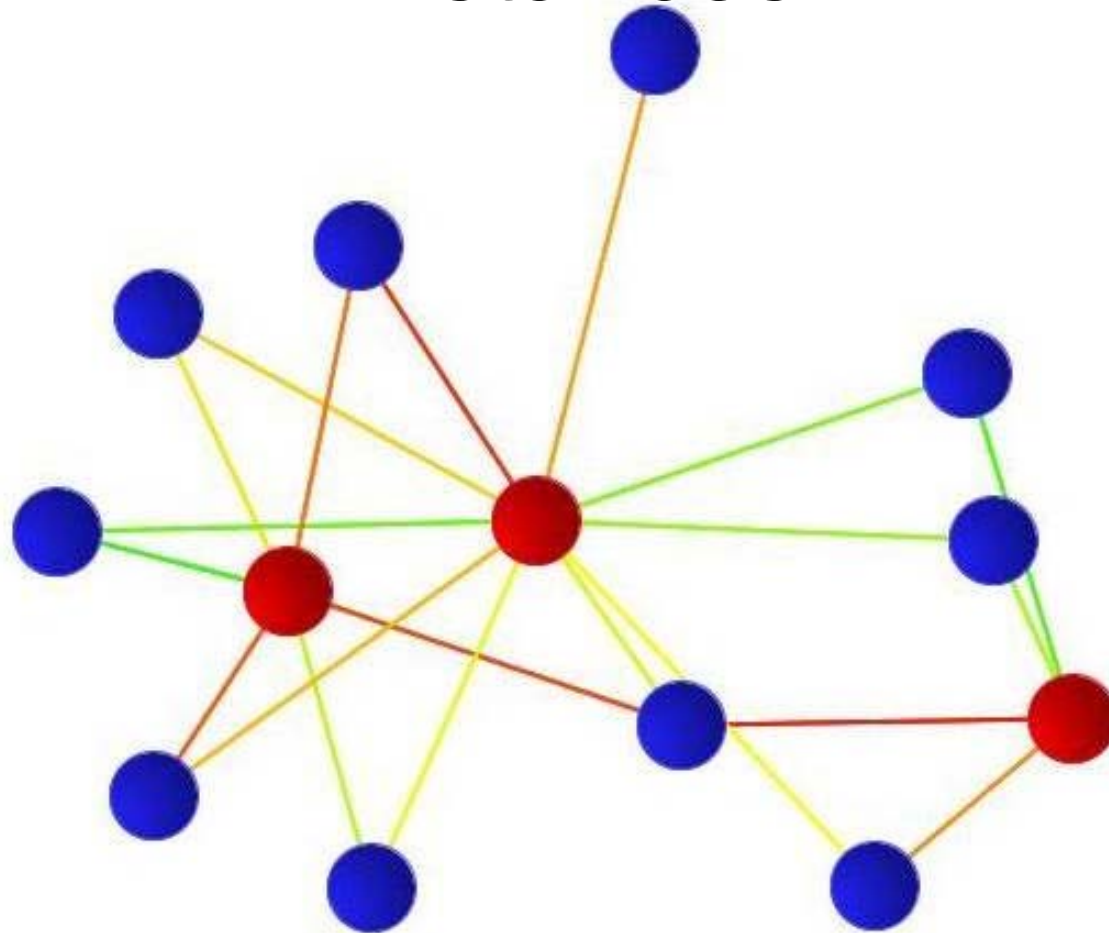
Crowd Level Sociometrics

<i>Variable</i>	CROWD A		CROWD B	
	Beginning	End	Beginning	End
Node Count	12	12	12	12
Link Count	22	21	8	20
Number of Subgroups	4	4	2	1
Number of Quads	1	4	0	0
Number of Triads	1	0	1	0
Number of Dyads	2	0	1	0
Number of Isolates	1	0	7	1
Density	0.1667	0.1591	0.0600	0.1515



Network Analysis

Control Force – Crowd Member Distances





Conclusion

Crowd Behavior Metrics

- Empirical data collected and analyzed under controlled laboratory conditions
- Motion capture analyses yield quantitative methods for analyses of crowd responses
- Network analyses yield quantitative methods for crowd psychosocial characterization
- Both individual and crowd level analyses



The Way Forward



- With the development of crowd measures and metrics and wide variety of applied, practical, and tactically relevant questions can be explored
- Target selection
- Threat assessment
- Input into modeling and simulation investigations
- Comparisons of effectiveness of a variety of non-lethal weapons and systems and tactics, techniques, and procedures



Backup Slides



Theoretical Model



Mechanisms of Non-Lethal System Effects on Crowd Members

