U.S. Army Armament Research, Development, and Engineering Center

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Effects of Control Force Number, Threat, And Weapon Type on Crowd Behavior

Kevin Tevis, MSME Target Behavioral Response Laboratory
Presented to the Military Operations Research Society Symposium (MORS), June 4-6 2014

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
23 JUL 2014	**Conference Presentation**	**00-00-2008 to 00-00-2014**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Effects of Control Force Number, Threat, And Weapon Type on Crowd Behavior Presented at the Virtual 82nd Military Operations Research Society Symposium July 23-24 2014	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Mezzacappa Elizabeth; DeMarco Robert; Tevis Kevin; Reid Gladstone	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
Army, ARDEC, Target Behavioral Response Laboratory,RDAR-EIQ-SD,Building 3518,Picatinny Arsenal,NJ,07806-5000	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This article reports the findings from an experimental investigation of effectiveness of control force measures using simulated non-lethal weapons in a crowd management situation. The Crowd Behavior Testbed is a 6,000 square foot facility housed in the TBRL. The laboratory is fully equipped with a comprehensive suite of experimental controls, computer hardware and software, cabling, devices that are sources for stimuli, and means for data capture. Two different types of weapons that were suitable for crowd situations were chosen after a test phase. The simulated hand-to-hand combat weapon chosen was a foam sword used in martial arts. It has a 10 inch handle and 25 inch long foam area. The simulated stand-off weapon shoots a foam dart; the magazine holds 10 darts. The ends of the baton and the ends of the foam dart were covered in chalk to mark impacts. Subjects were tasked with throwing ???rocks??? into targets on a M1008 Commercial Utility Cargo Vehicle (CUCV). Each successful throw was awarded points and dollars for the group. The armed control force stood between the crowd and the CUCV. Subjects also were tasked with avoiding being hit with the hand-to-hand combat weapons and the projectiles from the stand-off weapons. A 2x2x2 within subjects factorial design was employed with the two levels each of Weapon (Hand-to-hand or Stand-off), Number of Control Force (One or Many persons), and Threat (No Threat or Threat). Hypotheses Compared with the condition of One Control Force, the Many Control Force condition will have fewer successful target hits and more bean bags not thrown. Compared with the condition of No Threat, the Threat condition will have fewer successful target hits and more bean bags not thrown. Compared with the condition of Hand-to-Hand, the Stand-off weapon condition will have fewer successful target hits and more bean bags not thrown. Results The results support all but one of the hypotheses. The results have both methodological and conceptual implications. Methodologically, the results suggest that the research paradigm can be used to investigate crowd behavior, specifically throwing behavior. Conceptually, the results validate the theoretical framework for this program of research. That is, the model can be used to predict behavior and generate hypotheses that can be subsequently tested using the research paradigm.

15. SUBJECT TERMS

Non-lethal Weapons, Target Behavioral Response Laboratory, Crowds, Human Experimentation, NLW Effectiveness Testing, Control Force

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Public Release**	**31**	

Overview

- **Introduction**
  - ARDEC Introduction
  - Crowd Background
  - Crowd Behavior Research at TBRL
- **Experimental Framework**
  - Real World Test Scenarios
  - “Weapon” Types
  - Rules of Engagement
  - Size of Control Force
- **TBRL Crowd Experiment Design**
  - The Stop Approach Scenario
  - The Area Clearing Scenario
- **Test Bed Attributes**
- **Test Bed Layout**
- **Hypotheses**
- **Experimental Execution**
- **Analysis**
- **Results**
  - The Stop Approach Scenario
  - The Area Clearing Scenario
- **Conclusions**

US Army - ARDEC

Assigned/Direct Support
Coordination

Headquarters, Department of the Army

Assistant Secretary of the Army
Acquisition, Logistics and Technology
Ms. Heidi Shyu

Army Materiel Command, AMC
Gen. Dennis L. Via

Joint Munitions & Lethality LCMC
BG Kevin O'Connell

TACOM LCMC
MG Michael J. Terry

Research, Development and Engineering Command, RDECOM
Mr. Dale Ormond

PEO Ammunition
BG John J. McGuiness

- Program Executive Office Combat Support and Combat Service Support
- Program Executive Office Ground Combat Systems
- Program Executive Office Soldier

Armament Research, Development and Engineering Center, ARDEC
Dr. Gerardo J. Melendez

ARDEC's Role


RESEARCH


DEVELOPMENT


PRODUCTION


FIELD SUPPORT


DEMILITARIZATION

Advanced Weapons:
Line of sight/beyond line of sight fire; non line of sight fire; scalable effects; non-lethal; directed energy; autonomous weapons

Ammunition:
Small, medium, large caliber; propellants; explosives; pyrotechnics; warheads; insensitive munitions; logistics; packaging; fuzes; environmental technologies and explosive ordnance disposal

Fire Control:
Battlefield digitization; embedded system software; aero ballistics and telemetry

ARDEC provides the technology for over 90% of the Army's lethality and a significant amount of support for other services' lethality

Background

Military Need for Crowd Behavior Research

- The motivations underlying adversarial behavior
- Behavior of contested populations
- How do the behaviors of populations vary cross-culturally?
- What are the innate human behaviors that extend across cultural boundaries?

Introduction

Crowd Behavior Research at the Target Behavioral Response Laboratory (TBRL)

- Human behavior can be explained as attractions and repulsions toward and away from goals (Lewin, 1935)
- Building on this, the TBRL devised crowd experiments on the basis of monetary gain and loss being attractive and repulsive forces, respectively
- The framework of this model can be considered akin to an attractive force of a motivated mob throwing rocks at a target; and the repulsive force being (pain/adverse effect associated with) a non-lethal stimuli
- The TBRL Crowd Behavioral Test Bed has been used to gather locomotive, psychosocial, and effectiveness data

Experimental Framework

- **Develop and test two scenarios (from the perspective of the control force) that would reflect real world applications:**
  - The Halt/Stop Approach Scenario: To prevent/deter a crowd from approaching a protected target/area (for a specific time duration)
  - The Area Clearing Scenario: To clear a crowd from a sensitive/restricted area (within a specific time duration)
- **Test effectiveness of two different repulsive "weapon" types:**
  - long range "weapon"
  - short range "weapon"
- **Test effectiveness of two different rules of engagement:**
  - An active engaging control force, reacting to a high threat crowd
  - Passive/non-engaging control force, reacting to a low threat crowd
- **Test effectiveness of different Control force sizes:**
  - One control force member
  - Many control force members

Test Bed Layout

Testbed Attributes

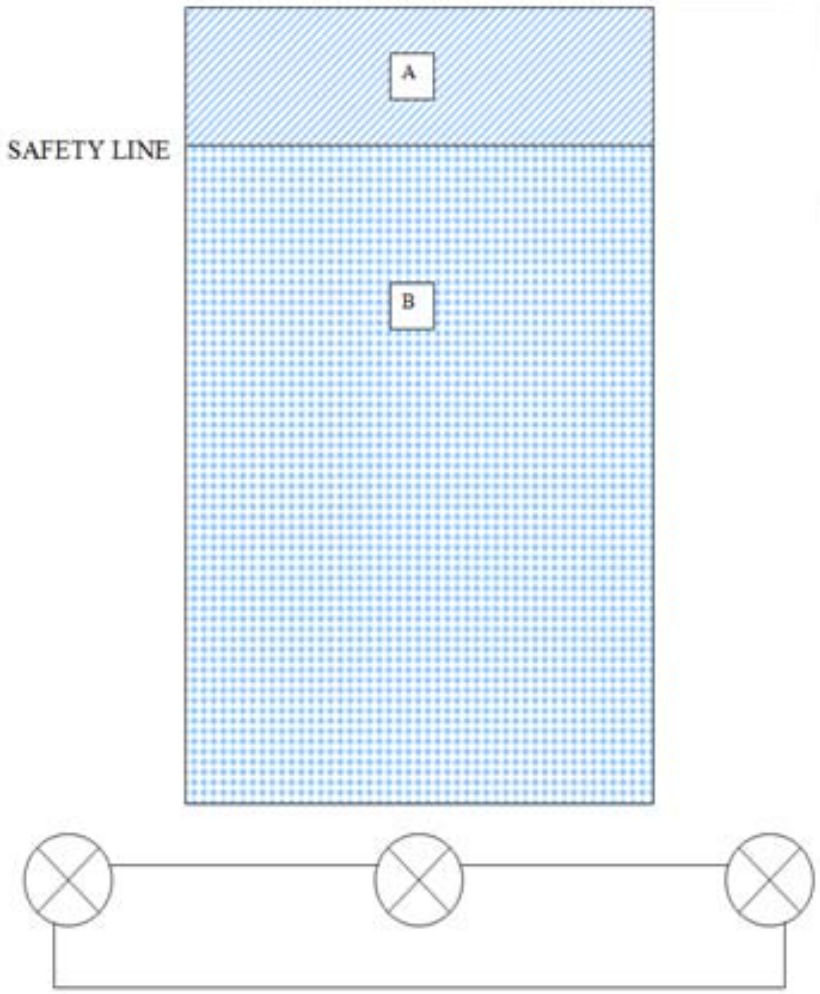
- Approximately 1500 sqft arena (35’ x 45’ area) to allow ample room for crowds of 20+ to maneuver as needed
- Equipped with (24) ViCON motion capture cameras to track/record individual movement
- Retro reflective balls were placed in unique configurations on each subject’s helmet to identify/track each person
- ViCON system operates at 120Hz and is accurate to 10mm
- Equipped with several video cameras to capture crowd movement from different perspectives
- Projection screen for subjects to monitor their score/money in real time

WG22_MEZZACAPPA_Tevis_820_3 of 3.wmv

TBRL Crowd Experiment Design

- **Operational test scenarios:**
  - The Halt Approach Scenario
    - Prior to each trial, subjects gathered behind a line (the safe line) located a fixed distance from the protected area (military vehicle)
    - At the start of a trial, Subjects were instructed to “attack” a military vehicle by throwing “rocks” (bean bags) at vulnerable points/targets
    - Subjects were given 1 “rock” each trial and each trial lasted 30 seconds
    - Subjects were able to cross the safe line (once) and approach the military truck to increase their chance of “hitting” a target, however this action put them at risk of being targeted by control force.
    - For every successful target, the individual/group was awarded 2 points
    - Each time a subject was hit/marked the individual/group lost 10 points
    - If marked, subjects could no longer throw their “rock”
    - Subjects could cross back into the safe zone, but they were then considered “out of play” and forfeited any further action for that trial
    - During baseline trials, the military truck was unprotected
    - During experimental trials, the military truck was protected by a number of control force, armed with different “weapons” using different engagement tactics.

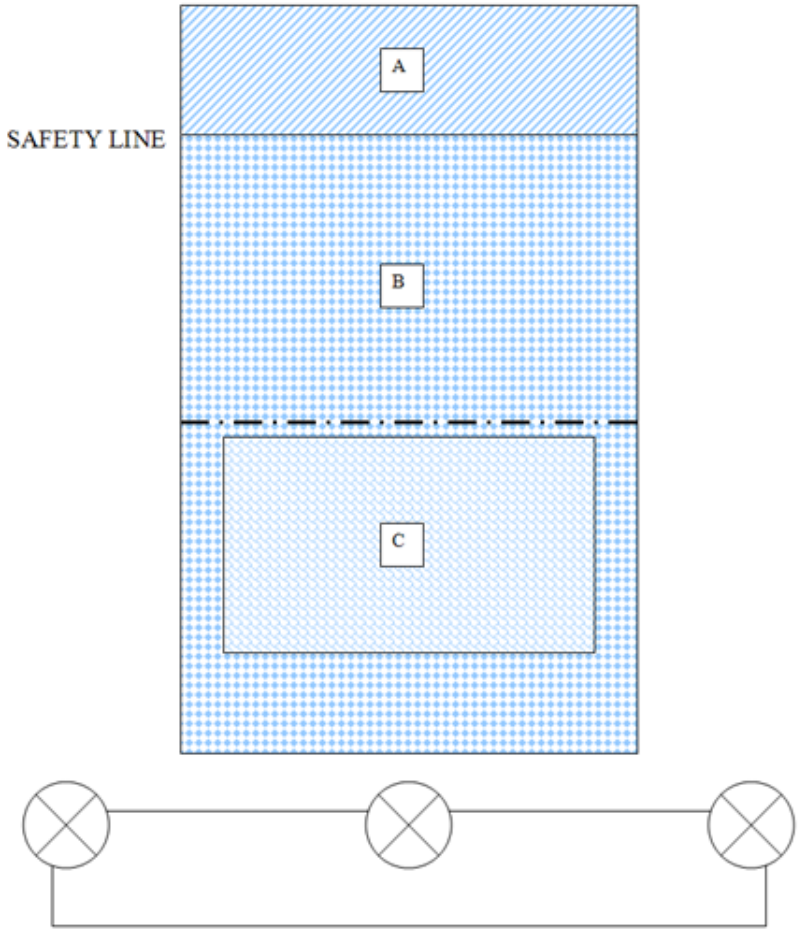
TBRL Crowd Experiment Design (Cont.)



TBRL Crowd Experiment Design (Cont.)

- **Operational test scenarios:**
  - The Clear Area Scenario
    - Prior to each trial, subjects gathered inside a “box” located a fixed distance from the protected area (military vehicle)
    - At the start of a trial, subjects were instructed to “wait”/maneuver inside the box as long as possible, avoiding being hit/marked by control force members
    - After 30 seconds, any subjects remaining in the “box” were able to throw their “rock” at the military truck for points
    - Subjects could cross back into the safe zone at anytime, but they were then considered “out of play” and forfeited any further action for that trial
    - Subjects were given 1 “rock” each trial
    - Each “wait” cycle lasted 30 sec
    - For every successful target, the individual/group was awarded 2 points
    - Each time a subject was hit/marked the individual/group lost 10 points
    - During baseline trials, there were no control force present to mark subjects
    - Due to the nature of the waiting game, only the foam baton was used by the control force

TBRL Crowd Experiment Design (Cont.)



TBRL Crowd Experiment Design (Cont.)

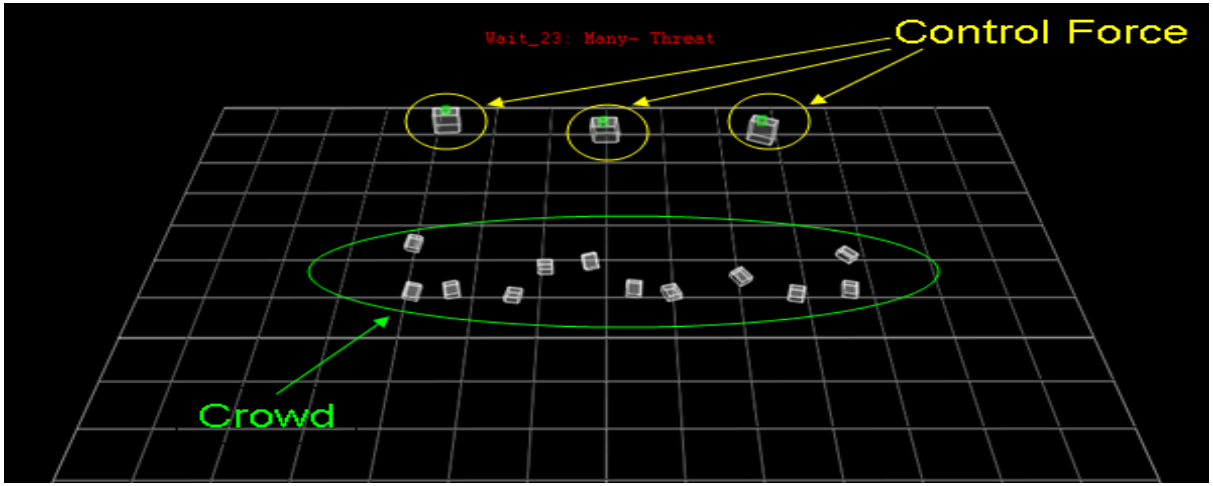
- **"Weapon" types**
  - Long range weapon - Nerf gun with chalk tipped darts, 1-10m
  - Short range weapon - Foam baton with chalk tipped end, 1-2m

- **Rules of engagement**
  - Active engaging control force – "attack" anyone OUTSIDE the safe line
  - Passive/non-engaging control force – gesture, but do NOT attack anyone regardless of their location in the Test Bed

- **Different Control force sizes:**
  - One control force member
  - Many (2-3) control force members

- **Emphasis on tactically relevant situations:**
  - Control force were dressed in military fatigues and employed realistic stances and gestures
  - Volunteers were instructed to throw "rocks" (bean bags) at military vehicles, specifically a M1008 Commercial Utility Cargo Vehicle (CUCV)

Sample Data



Hypotheses

- H1: Compared with the condition of One Control Force, the Many Control Force condition will have fewer successful target hits
- H2: Compared with the condition of One Control Force, the Many Control Force condition will have more bean bags NOT thrown
- H3: Compared with the condition of No Threat, the Threat condition will have fewer successful target hits
- H4: Compared with the condition of No Threat, the Threat condition will have more bean bags NOT thrown
- H5: Compared with the condition of Hand-to-Hand, the Stand-off weapon condition will have fewer successful target hits
- H6: Compared with the condition of Hand-to-Hand, the Stand-off weapon condition will have more bean bags NOT thrown

Experimental Execution

- Each crowd experienced 2 trials of each condition combination
- The first set of trails followed an escalation of force (i.e. one control force Baton >> Nerf gun)
- The second set of trials followed randomized conditions
- 28 trials were run for each crowd:
  - Stop Approach Scenario: (2) baseline, (8) EOF, (8) RAN
  - Area Clearing Scenario: (2) baseline, (4) EOF, (4) RAN
- Subjects were unaware of the conditions of each trial, but could quickly deduce how many control force, their rules of engagement, and their weapon type
- 101 Volunteers – 8 groups/crowds (consisting of 7-19 subjects), recruited from the local area, represented local demographic

Analysis

- Because of the nature of piloting, these analyses are considered exploratory preliminary investigations
- Analysis was conducted on the group level, not the individual
- Stop Approach Scenario:
  - 8 groups were analyzed using a with-in subjects repeated measures design with Control Force (One vs. Many), Threat (Non-threat vs. Threat), Weapon (Hand-to-hand vs. Stand-off) and Trial (EOF vs. RAN)
- Area Clearing Scenario:
  - 7 groups were analyzed using a with-in subjects repeated measures design with Control Force (One vs. Many), Threat (Non-threat vs. Threat), and Trial (EOF vs. RAN)

Analysis Cont.

- Because of the small N only the main effects of Control Force, Threat, Weapon (for the Stop Approach Scenario) and Trial were run; that is, no interactions or covariates were included in the model for these preliminary analyses on this small N data set, because of the lack of statistical power
- Two dependent variables were chosen for these preliminary analyses:
  - the number of successful throws into the target per group
  - the number of bean bags not thrown per group

Stop Approach Scenario - Results

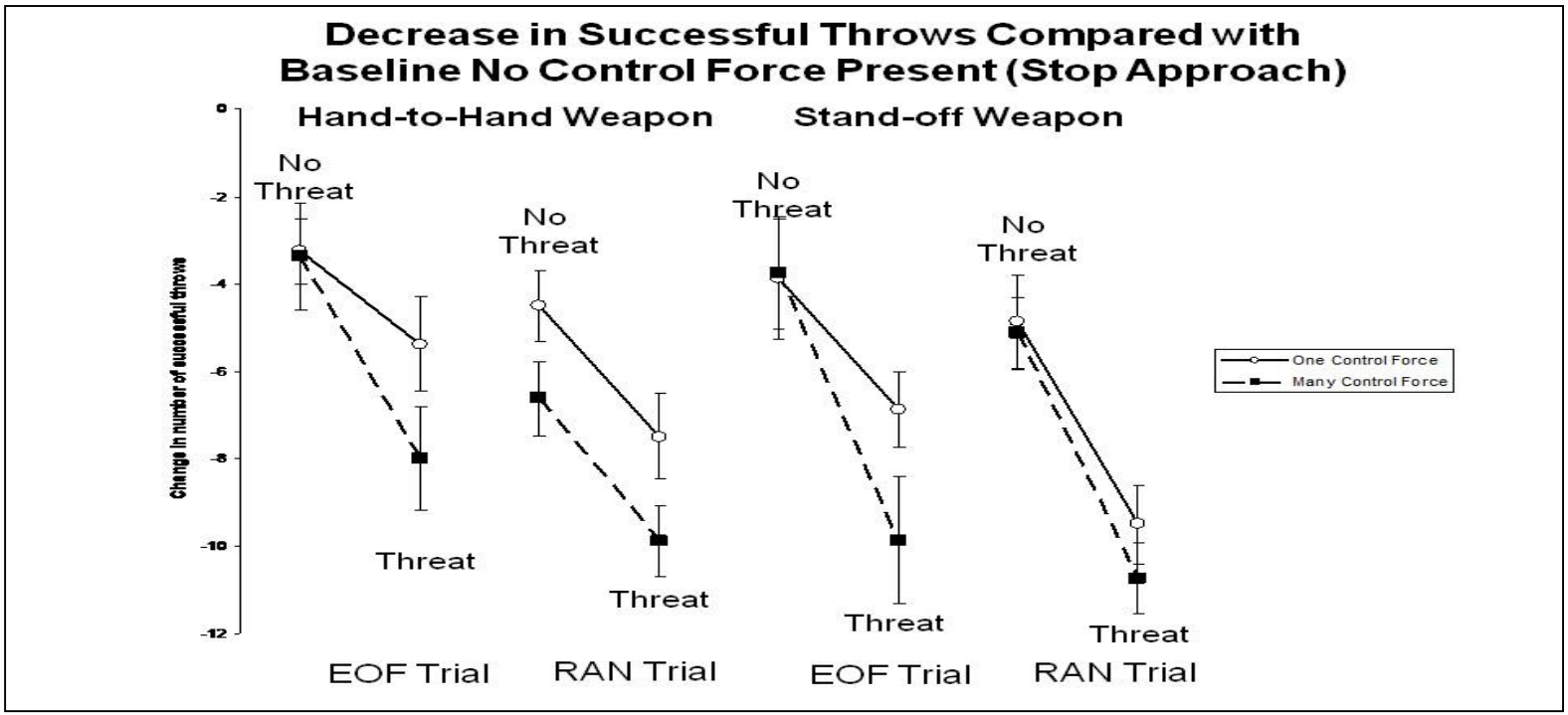


Figure 1: Change in Successful Throws: Threat vs. Non-threat

There were significantly fewer successful throws into the target when there was more than one control force compared with only one control force; during a threat condition compared with a non-threat condition, when the control force was using a stand-off weapon compared with a hand-to-hand weapon, and during the RAN trial compared with the EOF trial.

Stop Approach Scenario - Results (cont.)

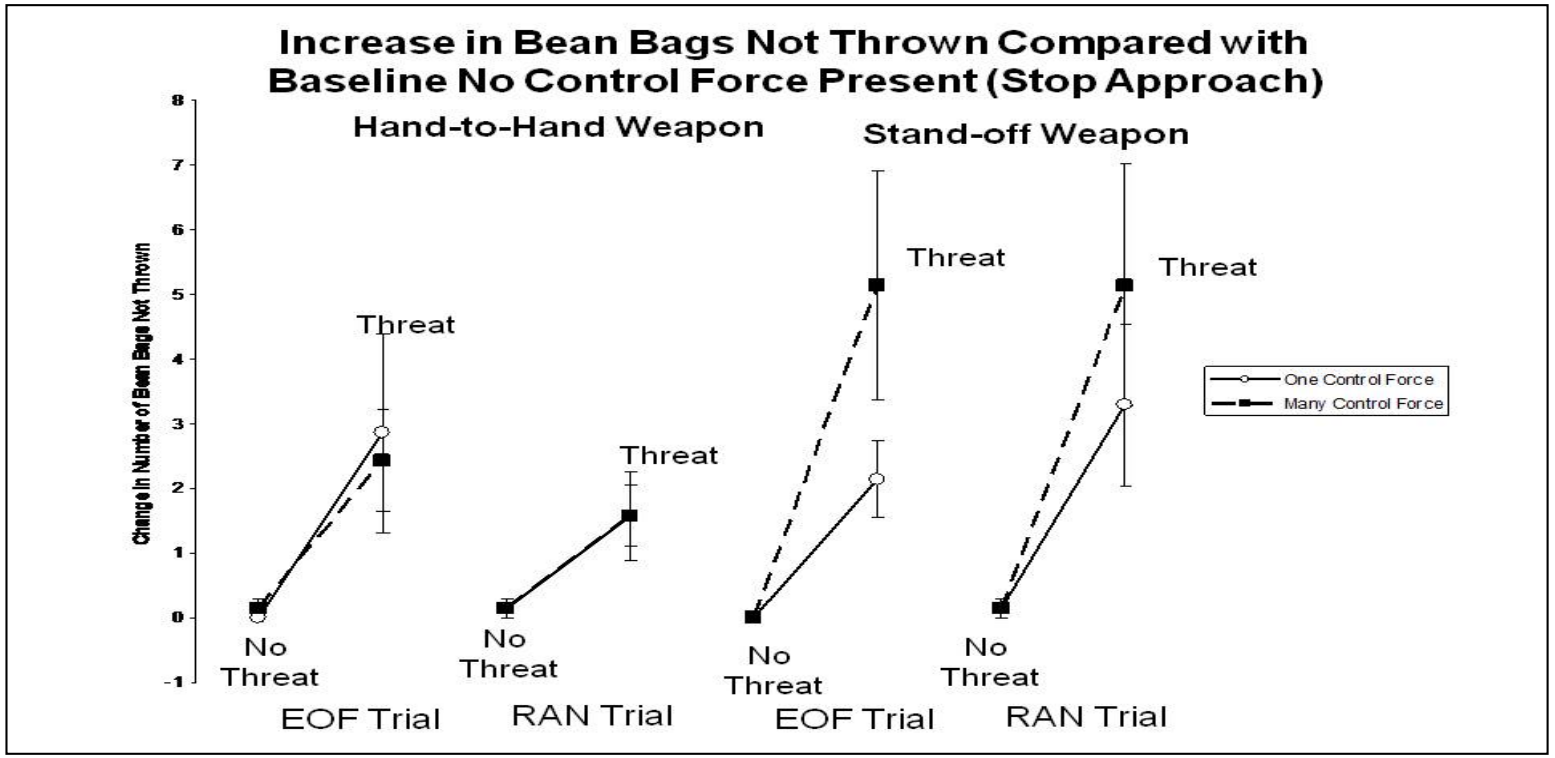


Figure 2: Change in the Number of Bean Bags Not Thrown

There were significantly more bean bags not thrown during a threat condition compared with a non-threat condition and when the control force was using a stand-off weapon compared with a hand-to-hand weapon.

Area Clearing Scenario – Results

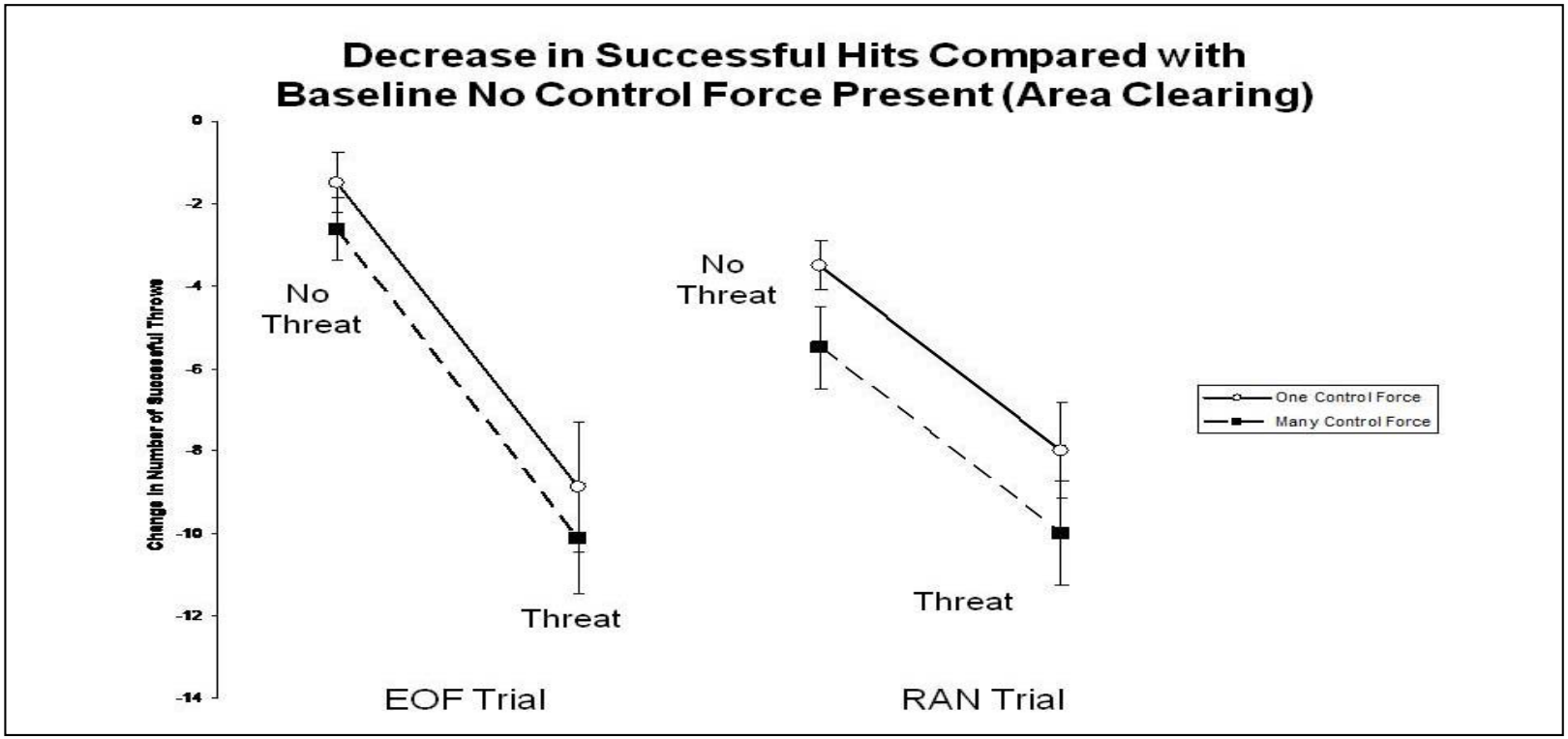


Figure 3: Change in Successful Throws: One vs. Many Control Force

There were significantly less successful throws into the target when there was more than one control force compared with only one control force and during a threat condition compared with a non-threat condition.

Area Clearing Scenario – Results (cont.)

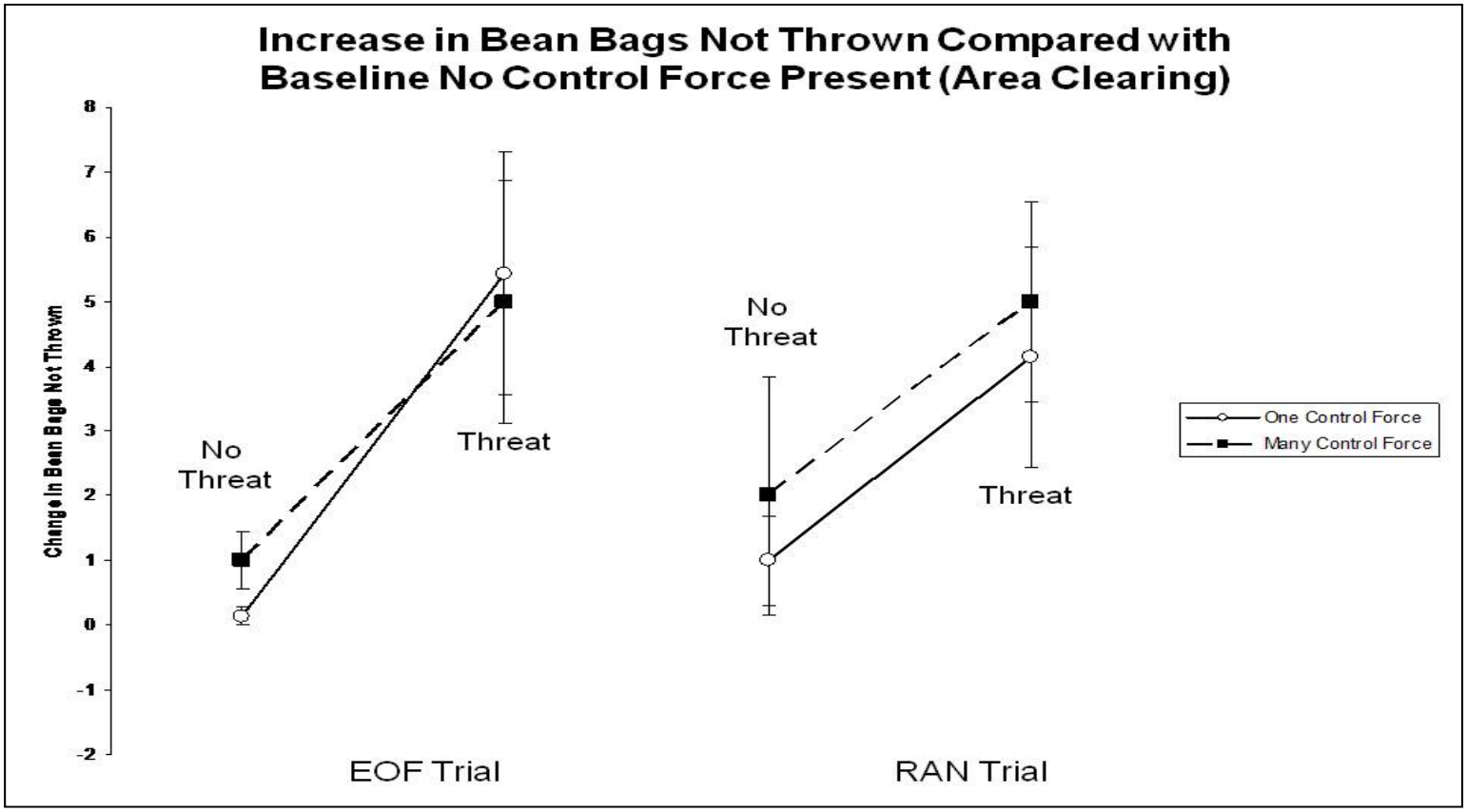


Figure 4: Change in Number of Bean Bags Not Thrown: One vs. Many Control Force

There were significantly more bean bags not thrown during a threat condition compared with a non-threat condition.

Hypotheses

- **The results support all but one of the hypotheses:**
  - H1: Compared with the condition of One Control Force, the Many Control Force condition will have fewer successful target hits
  - H2: Compared with the condition of One Control Force, the Many Control Force condition will have more bean bags NOT thrown
  - H3: Compared with the condition of No Threat, the Threat condition will have fewer successful target hits
  - H4: Compared with the condition of No Threat, the Threat condition will have more bean bags NOT thrown
  - H5: Compared with the condition of Hand-to-Hand, the Stand-off weapon condition will have fewer successful target hits
  - H6: Compared with the condition of Hand-to-Hand, the Stand-off weapon condition will have more bean bags NOT thrown

Conclusion

- It can be seen that manipulations generated by the number of control force used and rewards and punishment systems are powerful enough to evoke significantly different responses
- As such, this method can be used to evaluate effectiveness of non-lethal weapons and predict/measure crowd behavior

Questions?

US Army - Target Behavioral Response Lab

Kevin Tevis
Picatinny Arsenal, NJ
kevin.e.tevis.civ@mail.mil

Target Behavioral Response Laboratory
MORSS Presentations

- Virtual Employment Test Bed: Operational Research and Systems Analysis to Test Armaments Designs Early in the Life Cycle
- Method and Process for the Creation of Modeling and Simulation Tools for Human Crowd Behavior
- Squad Modeling and Simulation for Analysis of Materiel and Personnel Solutions
- The Squad Performance Test Bed
- Crowd Characteristics and Management with Non-Lethal Weapons: A Soldier Survey
- Effectiveness Testing and Evaluation of Non-lethal Weapons for Crowd Management
- Effects of Control Force Number, Threat, And Weapon Type on Crowd Behavior

BACKUP SLIDES

The Next Step – Modeling and Simulation

Attempts were made to enter variables into existing simulation software (MAICE) to replicate/validate test results.

WG22_MEZZACAPPA_Tevis_820_2 of 3.wmv

The Next Step – Modeling and Simulation

- However, due to complex nature crowd experimentation and software limitations, the resulting simulations were not representative nor realistic
- As a result, the TBRL began developing customized models to represent and predict crowd behavior based on existing and new crowd experimentation
- This will be discussed further in MORSS briefings:
  - Effectiveness Testing and Evaluation of Non-lethal Weapons for Crowd Management
  - Method and Process for the Creation of Modeling and Simulation Tools for Human Crowd Behavior