



NATIONAL SECURITY RESEARCH DIVISION

***Behavioral Indicators of Potential
Violent Action:
Review of the Science Base***

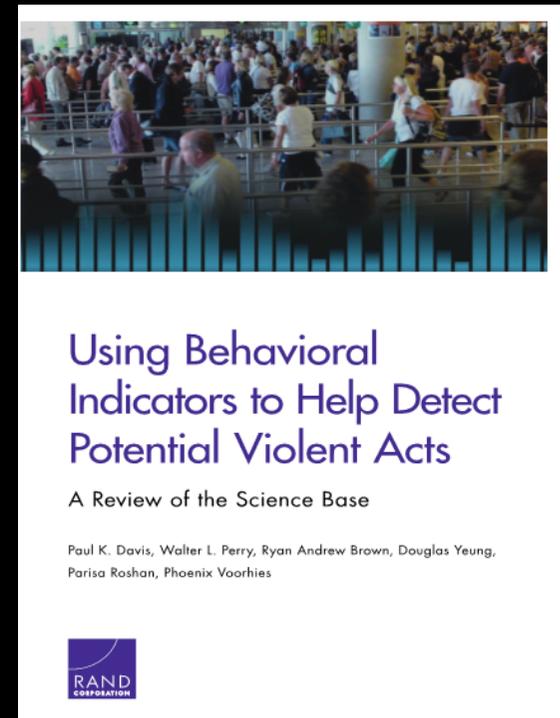
Walter Perry, Paul Davis, and Ryan Brown, RAND Corporation

Presented to the 30th ISMOR

July 2013

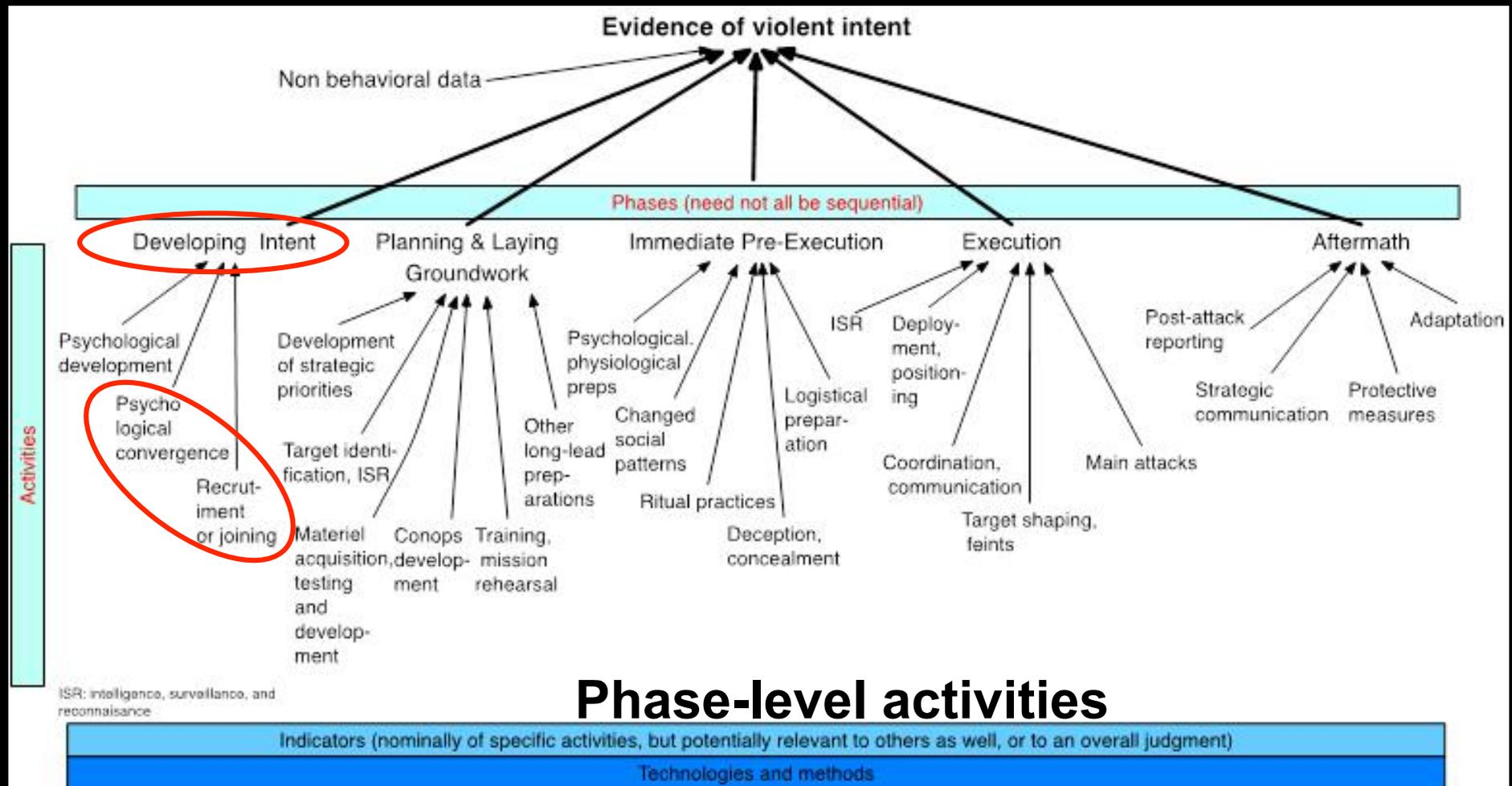
Project Background

- **Objectives**
 - Review science for relevant individual-level behaviors
 - Review relevant technologies and methods
 - Suggest broad priorities for attention and investment
- **Scope**
 - Actions by individuals or small groups such as suicide terrorism or IED-laying
 - Nontraditional observations and analysis
 - Technical feasibility, not tradeoffs with civil liberties—but with red flags posted
- **Sources: scientific literature, interviews, past work, new thinking**



http://www.rand.org/pubs/research_reports/RR215.html

Conceptual “Factor Tree” Model of Opportunities for Observation



Combining Information is Critical, but How?

- **Heuristic and Simple-Model Methods**

- **Checklists**
- **Risk indices**

- **Information Fusion**

- **Classic Bayes**
- **Dempster-Shafer**
- **Dezert-Smerandache**
- **Possibility Theory**
- **Information Theory**
- **Filtering**
- **Multi-attribute assessment**
- **Other?**

**An example using
traditional Bayes and
Shafer-Dempster**

*Watching Ahmed **

- **Authorities alerted about Ahmed al-Hiry, who reports suggest may:**
 - **Be developing intent to commit hostile act—alone or with group**
 - **Be becoming involved with al-Hasqua Jihad movement, whose goal is to destroy symbols of capitalism in U.S.**
- **Evidence in the form of indicator reports from various sources and sensors**
 - **Reports must be converted to a likelihood**
 - **Likelihood assessment based on source, false alarm rate and plain common sense**
 - **Most critical and difficult part of the fusion process**

* Disclaimer: This story is purely fictional. Any resemblance to persons living or dead is purely coincidental

Fusion Using Bayesian Updating

- Two hypotheses or propositions:
 - h_1 = “Ahmed is committed to ideals of al-Hasqua”
 - h_2 = “Ahmed has joined al-Hasqua”
- To this we add an additional two propositions—
 - h_3 = “Ahmed is both committed and he has joined al-Hasqua”
 - h_4 = “Ahmed is neither committed nor has he joined”

Initial Assessment

Proposition (h_j)	$P(h_j)$	Assessment
h_1 = “Ahmed is committed to al-Hasqua ideals”	0.20	Blogs suggest commitment—but without more evidence our level of belief is low—he could just be venting.
h_2 = “Ahmed has joined”	0.10	He has been seen at one or two meetings, but not much more.
h_3 = “Ahmed is both committed to and has joined”	0.05	We find it possible, but highly unlikely given the information we have on hand.
h_4 = “Ahmed is not committed and has not joined”	0.65	This is most likely case given current evidence.

Agent R Reports on Ahmed

- **Trusted agent code-named “R”**
 - Reports, based on observations, 70% certainty that Ahmed is committed
 - Says he has no idea whether Ahmed has joined
- **Although trusted “R” sometimes misses things**
 - He’s drunk 20% of time, so misses meetings he monitors
 - But he’s 95% reliable when reporting positively on commitment and joining
 - Our first task, then, is to “consider the source”

Bayesian Formulation of R's Report

And...Considering Source

Proposition	Agent R's report $P(R_j | h_j)$	Our revision	Rationale
"Ahmed is committed"	0.7	0.90	Based on past experience with R, we consider his estimate to be low
"Ahmed has joined"	0.1	0.20	Being drunk, he may have missed a few meetings
"Ahmed is committed and joined"	0	0.30	Our assessment of R's report leads us to put some probability on this proposition
"Ahmed is neither committed nor joined"	0.1	0.01	It seems likely that he has done one or the other if not both

The conditional $P(R_j | h_j)$ is probability that R would report this support level given that the proposition h_j is true—another check on the source

Fusion Using Bayesian Updating

Basic Propositions: Ahmed...	Prior Assessment	After R's Report
...is committed	0.20	0.81
...has joined	0.10	0.09
...is both committed and has joined	0.05	0.07
...is not committed and has not joined	0.65	0.03

Bayesian update formula used to fuse R's report with the prior assessment $\longrightarrow P(h_j | R_j) = \frac{P(h_j)P(R_j | h_j)}{\sum_{j=1}^4 P(h_j)P(R_j | h_j)}$

- R's estimate increased probability of Ahmed's commitment from .2 to .81
- Probability that Ahmed is neither committed nor joined is minimal

Another Report

Dealing with Disconfirming or Conflicting Evidence

- **Abu, Ahmed's close friend tells authorities:**
 - **He has heard that his friend of 30 years is under surveillance**
 - **Is upset by this:**
 - **Ahmed has served in U.S. military,**
 - **Has only recently become active in local Muslim community so may have been seen, but**
 - **In no way could be affiliated with al-Hasqua**
- **Abu himself was born in U.S., served in military, holds a security clearance, and is employed by DIA**
- **Our assessment, after background check on Abu:**
 - **He is considered reliable**
 - **However, he is Ahmed's friend, so may not be totally unbiased**

Fusing Abu's Report

- The hard part: our interpretation of Abu's report...

$P(A_1 | h_1) = 0.1$ We are not quite ready to abandon previous assessment

$P(A_2 | h_2) = 0.1$ Same reasoning

$P(A_3 | h_3) = .01$ Less likely

$P(A_4 | h_4) = .85$ Based on Abu' vehement support

Basic Propositions: Ahmed...	Prior Assessment	After R's Report	After Abu's Report
...is committed	0.20	0.81	0.70
...has joined	0.10	0.09	0.07
...committed and joined	0.05	0.07	0.01
...not committed nor joined	0.65	0.03	0.22

Combined Assessment

- **Abu's support of Ahmed made a difference**
- **Our assessment of non-involvement probability increased from 0.03 to 0.22**
- **We still think he is committed, but have less confidence (0.81 to 0.7)**
- **Drawbacks to method**
 - **We must allocate probabilities to all propositions so they sum to 1, even if evidence doesn't quite translate that way**
 - **We had to create separate propositions for committed and joined (conjunction) and for not committed or joined (complement)**

Another Fusion Method: Dempster-Shafer

- We start with the same four basic propositions:

$h_1 =$ “Ahmed is committed to ideals of al-Hasqua”

$h_2 =$ “Ahmed has joined al-Hasqua”

$h_3 =$ “Ahmed is committed and has joined al-Hasqua”

$h_4 =$ “Ahmed is neither committed nor has joined”

- With DST, we can represent “fuzziness” inherent in our assessments

- Instead of assigning probabilities to just the basic propositions, we can express support for their *disjunctions*

- A logical disjunction is union of two or more propositions

$$\{h_1, h_2\} = \{h_1 \cup h_2\}$$

- Hence we get $2^4 = 16$ possibilities!

Our Initial Assessment Now

We can account for Fuzziness

Proposition $\{A\}$	$m(\{A\})$	Initial Assessment
$\{h_1, h_2\}$ = Committed <u>or</u> has joined	0.15	Recent blogs are confusing, but we feel that he is either committed or has joined.
$\{h_1\}$ = Committed	0.10	At same time, we are not sure if he has joined, but feel a little more confident that he is committed.
$\{h_4\}$ = Neither committed nor joined	0.30	Because evidence so far is flimsy, we consider possibility of neither committed nor joined.
$\{H\}$ = The 13 other possibilities (e.g., joined but not committed)	0.45	Sum of support levels for all 16 possibilities must be 1.0

$m(\{A\})$: **basic probability assignment and**
H : set of basic propositions referred to as the “frame of discernment”

Agent R's Report Is Less Certain

R's Proposition $\{A\}$	$m(\{A\})$	R's Assessment
$\{h_1, h_3\}$ = Ahmed is committed <u>or</u> he is both committed and joined	0.10	Blogs suggest that he is committed. but we are less certain that he has joined so we get the dichotomy: he is committed or committed and joined.
$\{h_1\}$ = Ahmed is committed	0.40	This accounts for 50% of R's support.
$\{h_2\}$ = Ahmed has joined	0.05	R hedges in case Ahmed is just trying to ingratiate himself with Youssef, a friend and member of the group;
$\{h_2, h_4\}$ = Ahmed is either joined, <u>or</u> neither joined nor committed	0.15	Ahmed may have joined or he may still have nothing to do with them.
$\{H\}$ = Every other possibility	0.30	

Fusion Using Dempster's Rule of Combination

$Bel_{prior} \backslash Bel_R$	0.15 $m_p(\{h_1\})$	0.10 $m_p(\{h_1, h_2\})$	0.30 $m_p(\{h_4\})$	0.45 $m_p(\mathbf{H})$
0.10 $m_R(\{h_1\})$	.0514	.0772	0	.2315
0.40 $m_R(\{h_1, h_3\})$	.0129	0	0	.0579
0.05 $m_R(\{h_2\})$	0	.0096	0	.0289
0.15 $m_R(\{h_2, h_4\})$	0	0	.0579	.0868
0.30 $m_R(\mathbf{H})$	.0386	.0579	.1158	.1736

- Column headings are support levels prior to R's report
- Row headings are R's support levels
- Cells are calculated as follows:
 1. Calculate the row-column products for all cells
 2. Sum the entries in all cells where one proposition is not a subset of the other
 3. Divide each cell entry by the complement of that sum and enter "0" in all cells summed
 4. The sum of the remaining cell entries is 1.0

After R's Report, Situation Still Not Clear

Basic Probabilities	Bel_{prior}	Bel_R	$Bel_{prior,R}$
$m(\{h_1\})$	.10	.40	.4116
$m(\{h_2\})$	0	.05	.0385
$m(\{h_4\})$	.30	0	.1737
$m(\{h_1, h_2\})$	.15	0	.0579
$m(\{h_1, h_3\})$	0	.10	.0579
$m(\{h_2, h_4\})$	0	.15	.0868
$m(H)$	.45	.30	.1736

- Initially (prior)

- Little support for commitment,
- None for belonging
- Little for either
- Uncertainty absorbed almost 50% support

- After R's Report

- Strong support for commitment
- But also strong for neither
- Uncertainty reduced
- But results are ambiguous-- contradictory

Another Report

More Disconfirming Evidence from Abu, Ahmed's Friend

Abu's Propositions $\{A\}$	$m(\{A\})$	Abu's Assessment
$\{h_4\}$ = Ahmed is neither committed nor has he joined the group	0.850	Abu is adamant that his friend is having nothing to do with al-Hasqua. This is considerably higher than our current estimate of 0.1656.
$\{h_1, h_2\}$ = Ahmed is either committed <u>or</u> he has joined	0.040	This is our assessment. It is based on the previous estimate of 0.3927
$\{h_1, h_4\}$ = Ahmed is either committed <u>or</u> neither committed nor joined	0.050	Based on Abu's strong support for Ahmed and our previous assessment of Ahmed's commitment.
$\{h_1\}$ = Ahmed is committed	0.030	We retain some support given previous reports.
$\{h_2\}$ = Ahmed has joined	0.001	Almost no support for this.
$\{H\}$ = Every other possibility	0.029	Little uncertainty because of Abu's strong support.

With Abu's Report, the Situation Is Clearer

Focal Element	Bel_{prior}	Bel_R	$Bel_{prior,R}$	Bel_A	$Bel_{prior,R,A}$
$m(\{h_1\})$	.10	.40	.4116	.030	.1444
$m(\{h_2\})$	0	.05	.0385	.001	.0062
$m(\{h_4\})$	.30	0	.1737	.850	.7898
$m(\{h_1, h_2\})$	.15	0	.0579	.040	.0226
$m(\{h_1, h_3\})$	0	.10	.0579	0	.0035
$m(\{h_1, h_4\})$	0	0	0	.05	.0179
$m(\{h_2, h_4\})$	0	.15	.0868	0	.0052
$m(H)$	.45	.30	.1736	.029	.0104

- **Prior to Abu's report**

- Strong support for commitment
- But also strong for neither
- Uncertainty reduced
- But results ambiguous—contradictory

- **After Abu's report**

- Only weak support for commitment
- Strong support for non-involvement
- Uncertainty greatly reduced

Bayes or DST?

Bayes

- Only allowed support for basic propositions
- In absence of prior information, all propositions are supported equally
- No support for combinations of basic propositions
- Combining rule simple
Bayesian updating rule

Dempster-Shafer

- Support can be assessed for a richer set of propositions
- In absence of prior information, propositions may have no support
- Support for combinations of basic propositions allowed
- Dempster's rule of combination is prohibitively complex for more than a few basic propositions

Dezert-Smarandache Theory (DSmT)

A Better Approach?

- DSmT extends DST by creating larger and richer set of allowable propositions
 - Allows us to better use reports that are imprecise, fuzzy, paradoxical and conflicting
- Two versions of DSmT:
 - Hyper-Power Set: extends DST power set to include conjunctions
 - Super-Power Set: extends DST to include conjunctions and negation
- Combining rule in both cases is complex—both mathematically and computationally
 - Bayes: $\{A, B\}$
 - DST: $\{\emptyset, A, B, (A \text{ or } B)\}$
 - Hyper-Power DSmT: $\{\emptyset, A, B, (A \text{ or } B), (A \text{ and } B)\}$
 - Super-Power DSmT: $\{\emptyset, A, \sim A, B, \sim B, (A \text{ or } B), (A \text{ and } B), \sim(A \text{ and } B)\}$
- DSmT is better by admitting expression of more nuanced information, and more imprecision

Issues Regardless of the Method Selected

- **Indicator reports are likely to be fuzzy and, at times inconsistent with the fusion method chosen**
 - **Dealing with negation: “I know Ahmed is not a member of al-Hasqua”**
 - **Dealing with conjunctives: “Not only is he committed to al-Hasqua, he has joined the group”**
- **Considering the source**
 - **In our example, we demurred a bit about our trusted agent’s report**
 - **We vetted Abu before accepting his report—and even then we discounted it a bit**
- **Selecting a fusion method**
 - **Can we develop a hybrid that combines the best of several methods?**
 - **Should we associate fusion method with application (check lists for TSA, more sophisticated mathematical methods for fusion centers)?**



NATIONAL SECURITY RESEARCH DIVISION