BIOSECURITY

Assessing the Bioweapons Threat

Is there a foundation of agreement among experts about risk?

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The United States government (USG) has taken steps intended to diminish the likelihood of misuse of research; in one recent action, declaring a funding moratorium on "gain-of-function" influenza studies until a risk-benefit analysis can be conducted.(*1*) The analysis is expected to examine biosafety concerns, the potential for such research to produce a biological weapons agent, and the possibility that publication may lower barriers towards bioweapons development.(*1*) To analyze security risks of biological research, however, it is first necessary to determine the likelihood that bioweapons will threaten national security and to what degree legitimate research is at risk of misuse. This type of assessment is fraught with uncertainty.

Available empirical data to inform a threat assessment is sparse: thankfully, there have been only a handful of historical examples of bioterrorism or biowarfare (use by a nation state), although multiple nations and terrorist organizations have developed the capability to varying degrees. Intelligence about bioweapons programs and intent to use them has been historically difficult to acquire; miscalculations include type 1 errors (Iraq was thought to have a biological weapons program during the lead up to the Second Gulf War, when it did not) and type 2 errors (the former Soviet Union was not thought to have a biological weapons program, but in fact employed tens of thousands of weapons scientists). Given the paucity of other data, judgments about the bioweapons threat rest largely on expert opinions. Understanding how experts in national security, biosecurity, and biosafety perceive the bioweapons threat is therefore important for assessing the threat as well as the potential for misuse of legitimate research.

Assessing collective judgements

We used a Delphi Method study to elicit, combine, and analyze the collective judgments of multiple experts. Focused on obtaining collective expert opinion, but avoiding "groupthink", the Delphi Method's salient features are preserving the anonymity of participant inputs, iterated response and feedback, and statistical aggregation of expert judgments.(*2*) Individuals were invited to participate in this study if they held responsibility for shaping public policy at the nexus of life science and national security, based on their expertise and knowledge in the field, or based on recommendations of other participants (using a snowball sampling methodology). Participant affiliations included USG, former USG, academia, NGO, and private sector/industry organizations. The length of time participants had responsibility for shaping public policy ranged from ~3 to more than 45 years. Participant training and background included biological and non-biological science, medicine, public health, national security, political science, foreign policy and international affairs, economics, history, and law. Of the 63 experts originally approached to participate in the study, 62 completed the first round of the survey, and 59 completed the second round.

Participants were asked to anonymously respond to questions about biological threats, review each other's answers, and either amend or maintain their answers after reflecting on others' opinions. They were asked to supply rationales for their responses.(*3*) The process was terminated when, for successive rounds, the mean response did not change more than 1 standard deviation across all questions, which occurred after two rounds (*4*). The final results of the study were analyzed with STATA statistical package 11.2. Wilcoxon-Mann-Whitney nonparametric tests (significance level $p \leq 0.05$).

Likelihood of a bioweapons attack

We asked participants to estimate the percentage likelihood of a large-scale biological weapons attack occurring within the next 10 years in any country (Fig. 1). We defined a large-scale attack conservatively, as resulting in more than 100 ill people. There was a wide diversity of opinions. Participants' answers ranged from 1- 100% likelihood, with a mean of 57.5%, [95%CI 49.4-65.7]. In general, those trained as biological scientists perceived a lower likelihood of bioweapons use than other participants (z=2.9, p=0.0035), though that was certainly not true in every case. Also, participants classified as members of the Baby Boomers/Silent Generation (50 years of age or older) believed the likelihood of attack was greater than did Generation X/Millennials (21 to 49 years of age); with mean responses of 64.6% and 46.0%, respectively, z=-2.1, p=0.035.

The most likely actor and agent

Participants were also asked about the likelihood of different types of state and non-state actors to be the perpetrator of a biological weapons attack within the next 10 years. Although participants held a wide range of opinions, overt state bioweapons use was considered to be less likely than covert use by a state or use by a non-state group. An overt attack by a state actor was rated significantly less likely than even the next lowest rated actor – criminal groups (z=-3.9, p<0.001). Religious extremist were judged to be the most likely group to perpetrate an attack – significantly more likely than a covert attack by a state actor (z=-3.6, p<0.001) or any other attack by a state, but not significantly more likely than a right-wing violent non-state actor or a disgruntled or mentally ill individual.

Participants who were especially concerned about terrorist use cited rapid technological advances in the biosciences, ease of acquiring pathogens, democratization of bioscience knowledge, information about non-state actors' intent, and the demonstration of the chaos surrounding the Ebola epidemic in West Africa in 2014 as support for their views. Those who were more concerned about the nation state threat cited the technological complexities of developing a bioweapon, the difficulty in obtaining pathogens, and ethical/cultural barriers to using biological weapons. Pathogen access and technical complexity required to produce a biological weapon were cited as support for opposite conclusions about the potential actors.

We also asked about types of biological agents likely to be used as weapons within the next 10 years. Participants felt that the likelihood of use was highest for biological toxins. This was followed by spore-forming bacteria, non-spore-forming bacteria, and viruses. Participants generally did not think that fungi and prions were likely to be weaponized, and felt that the likelihood of a synthetic pathogen being used as a weapon in the next 10 years was fairly low (*4*).

Since 2001, a point of emphasis for the U.S. Intelligence Community (IC) has been the prevention of the use of a weapon of mass destruction (WMD). Despite significant investments made by the IC, however, most participants believed that intelligence agencies are unlikely to provide actionable information or warnings prior to a biological attack (Fig. 2). Of 59 participants, 53 considered there to be a

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50% or lower probability that such a warning would be forthcoming in advance of an attack.

Although a few participants felt that there had been improvements in level of access and detection capabilities many cited the difficulties inherent in detecting and tracking biological weapons capabilities due to: the intrinsic dual use nature of biology; the ease of concealing preparations for a biological attack; limitations in expertise and investment in biological threats by the IC; and past experiences of the challenges associated with intelligence collection against biological threats. The realities of classification of information make a fully informed analysis of IC capabilities vis-à-vis the biological threat impossible – a fact that several participants acknowledged.

Red line for research

Our study also obtained participants' judgments about acceptable limits for US biodefense, particularly "threat characterization" laboratory studies - usually classified - that are performed to gain knowledge about potential bioweapons for purposes of defense (i.e. is there a "red line" that should not be crossed?). Most said yes (51), but there were a wide variety of opinions of what types of research would cross that line.

Three participants felt that the only "red line" for biodefense is human subjects research, and that all other defensive research that furthers national security should be allowed. A majority of participants said that research which violates the Biological and Toxin Weapons Convention (BWC) crosses a red line and should not be pursued. On the other hand, two participants felt that threat characterization research should not be conducted at all because of the inherent risks involved. Twenty seven participants mentioned gain of function type experiments as a situation where a red line could be drawn. Even under the secure conditions of biological threat characterization research, there was a lack of consensus among highly qualified experts about where the "red line" should be drawn and whether that line is gain of function research.

Risk of misuse of research

The potential for devastating consequences if biological weapons were used is enough to spur planning for such a contingency. Yet given the scantiness of the historical record, it is not too surprising that experts ascribe different weights to various actors' technical capability, access, and intent in their assessments of how likely a biological weapons attack could be. It is possible that highly classified intelligence, if available, could have reduced the degree of variation in survey responses; given the importance of experts and policymakers having a shared, informed perception of the threat in order to productively prepare, investments should be made to acquire intelligence on biosecurity threats and to share information with stakeholders.

The diversity of views, even in this experienced group of participants, means that it will be more challenging to assess the risks that research would be misused and to develop a regulatory system for legitimate, dual-use research. This does not mean that risks and benefits should not be examined and recommendations made about the conduct of this or other types of research. However, it does indicate that a red line for what is allowable and what is forbidden in the name of security may not be clearly defined, and that the way forward will be nuanced and complicated, possibly requiring a case-by-case evaluation with guidelines agreed upon by the scientific and policy communities.

REFERENCES AND NOTES:

1. White House Office of Science and Technology Policy, "Doing Diligence to Assess the Risks and Benefits of Life Sciences Gain-of-Function Research" (2014).
2. G. Rowe, G. Wright, *Int J Forecasting* 15, 353 (1999).
3. G. Rowe, G. Wright, in *Principles of Forecasting,* J. S. Armstrong, Ed. (Springer US, 2001), vol. 30, pp. 125-144.
4. Further details are described in SOM

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Fig. 1 What do you estimate to be the likelihood of a large-scale biological weapons attack occuring within the next 10 years?

Fig. 2 If a biological attack were being planned today, what is the probability that intelligence information will provide actionable indications and warning preceding the attack?

Figure 1: What do you estimate to be the likelihood of a large-scale biological weapons attack occurring within the next 10 years anywhere, using any biological agent, by any non-state or state actor?

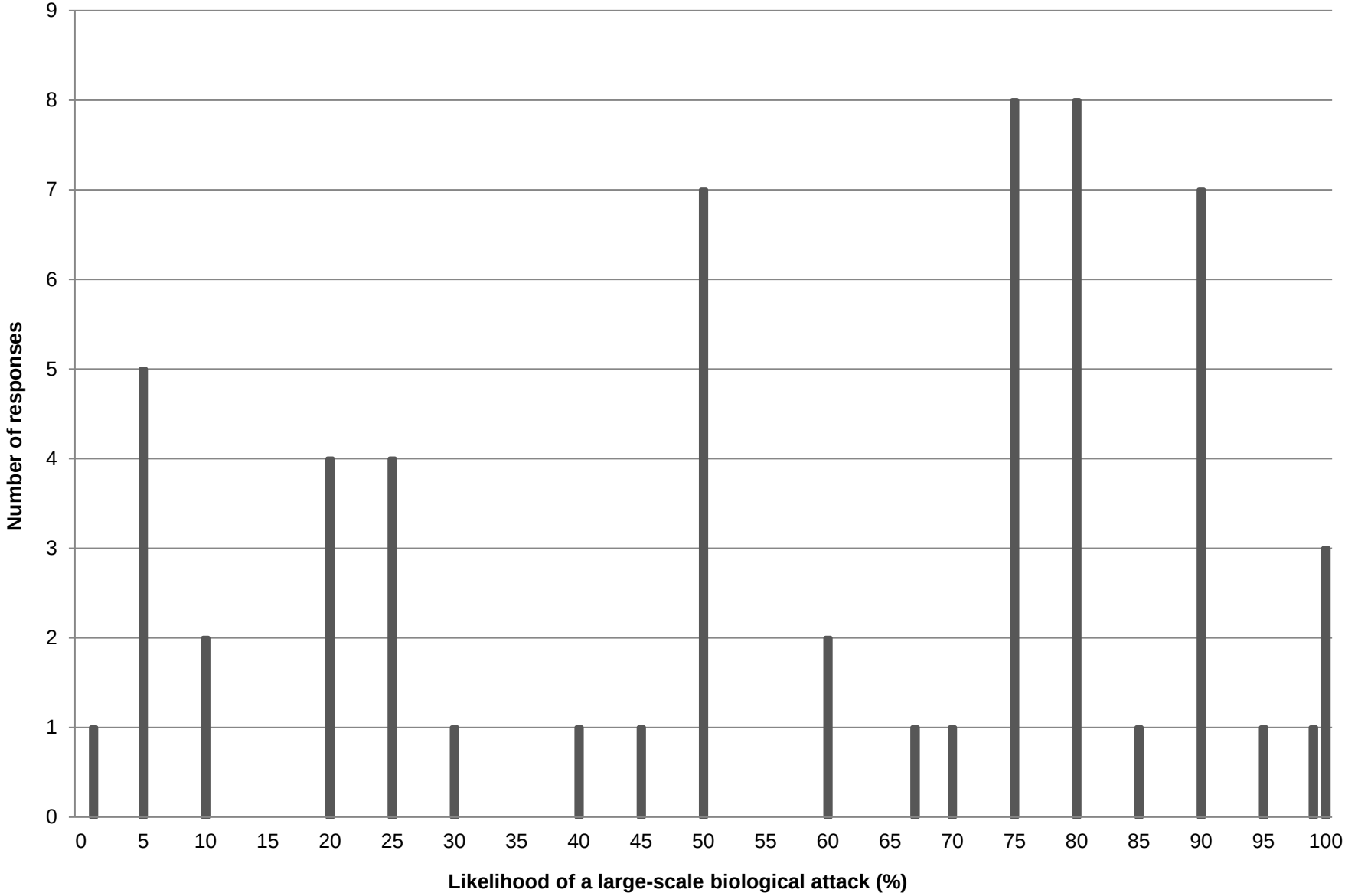
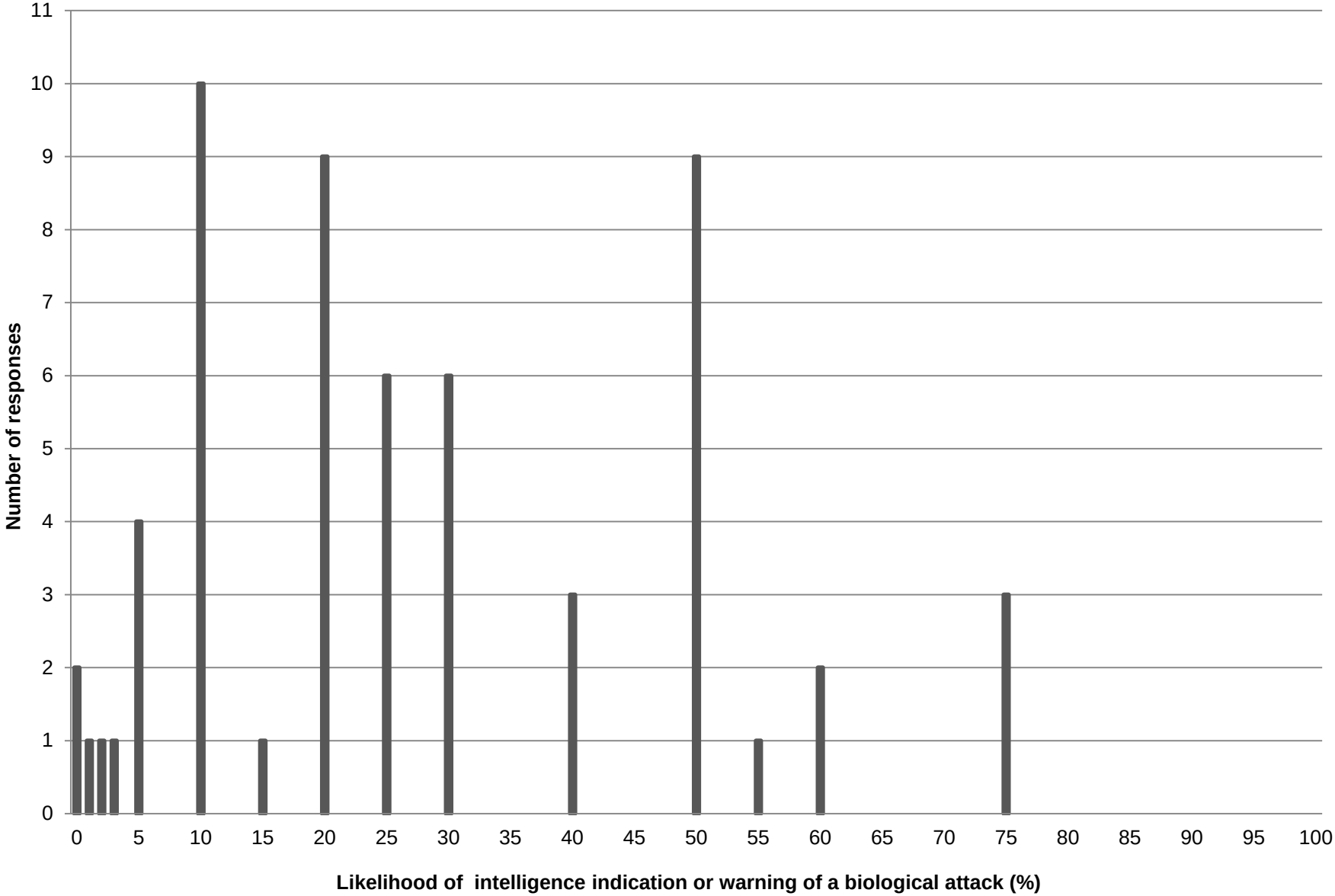


Figure 2: If a biological attack were being planned today, what is the probability that intelligence information will provide actionable indications and warning preceding the attack?



Summary of methodology S1

We used a Delphi Method study to elicit, combine and analyze the collective judgments of multiple experts. Focused on obtaining collective expert opinion, but avoiding "groupthink", the Delphi Method's salient features are preserving the anonymity of participant inputs, iterated response and feedback, and statistical aggregation of expert judgments. Individuals were invited to participate in this study if they held responsibility for shaping public policy at the nexus of life science and national security, based on their expertise and knowledge in the field, or based on recommendations of other participants (using a snowball sampling methodology). Participant affiliations included USG, former USG, academia, NGO, and private sector/industry organizations. Participant training and background included biological and non-biological science, medicine, public health, national security, political science, foreign policy and international affairs, economics, history, and law. Of the 63 experts originally approached to participate in the study, 62 completed the first round of the survey, and 59 completed the second round.

Participants were asked to anonymously respond to questions about the biological threat, review each other's answers, and either amend or maintain their answers after reflecting on others' opinions. Participants were asked to supply rationales for their responses. The process was terminated when, for successive rounds, the mean response did not change more than 1 standard deviation across all questions, which occurred after two rounds. The final results of the study were analyzed with STATA statistical package 11.2. Wilcoxon-Mann-Whitney nonparametric tests were conducted to evaluate the difference in distributions of responses between groups of participants and between question sub-parts (significance level $p \leq 0.05$).

List of Delphi study participants S2

Individuals were invited to participate in the study if they held responsibility for shaping public policy at the nexus of life science and national security, based on their expertise and knowledge in the field, or based on recommendations of other participants (using a snowball sampling methodology). Participant affiliations included USG, former USG, academia, NGO, and private sector/industry organizations. Participant training and background included biological and non-biological science, medicine, public health, national security, political science, foreign policy and international affairs, economics, history, and law. Participants' affiliations are current as of the time of Delphi study administration. Listing an individual's employer does not imply institutional endorsement of our conclusions.

Bruce Altevogt, Institute of Medicine
Scott Becker and Chris Mangal (completed together), Association of Public Health Laboratories
Kenneth Bernard, Former White House National Security & Biodefense Advisor
David Blazes, US Department of Defense
Patrick Boyle, Ginkgo BioWorks
Roger Breeze, Centaur Science Group
Rob Carlson, Biodesic, LLC
Hillary Carter, US Department of State
Seth Carus, National Defense University
Rocco Casagrande, Gryphon Scientific
Susan Coller-Monarez, National Security Council, Executive Office of the President
Andrew Ellington, The University of Texas at Austin
Julie Fischer, The George Washington University
Pat Fitch, Battelle National Biodefense Institute, LLC
Robert Friedman, J. Craig Venter Institute
Daniel Gerstein, RAND
John Glass, J. Craig Venter Institute
John Grabenstein, Merck & Co.
Lauren Grosso, University of Maryland
Richard Hatchett, US Department of Health and Human Services
Donald A. Henderson, UPMC Center for Health Security
India Hook-Barnard, The National Academies of Science
Kendall Hoyt, Dartmouth College
Emily A. Iarocci, University of Maryland
Michael Imperiale, University of Michigan Medical School
Tom Inglesby, UPMC Center for Health Security
Barbara Johnson, Biosafety and Biosecurity International
Robert Kadlec, East West Protection, LLC
Laura Kelley, Harvard Business School
Gregory Koblentz, George Mason University
George Korch, US Department of Health and Human Services
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Todd Kuiken, The Woodrow Wilson International Center for Scholars
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Amy Patterson, National Institutes of Health
Alan Pearson, US Department of Agriculture
Erik Prentice, Proactive Worldwide
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Kathleen Vogel, North Carolina State University
Jaime Yassif, US Department of Defense
Raymond A. Zilinskas, Middlebury Institute of International Studies at Monterey
1 Anonymous member of a scientific non-profit organization
1 Anonymous DHS official
3 Anonymous representatives of the intelligence community

Table S3: Delphi Data

Respondent ID	Gender	Age	Training	Affiliation	Government Expertise	Terrorism Expertise	Scientific Expertise	Biological Science Expertise	Question 2: What do you estimate to be the likelihood of a large-scale biological weapons attack occuring within the next 10 years?
1	0	1	0	1	0	1	0	0	20
2	0	1	9	3	1	0	0	0	25
3	1	0	5	3	1	0	1	1	90
4	0	1	4	3	1	0	1	0	10
5	1	1	5	0	0	0	1	1	40
6	0	1	5	0	0	0	1	1	25
7	0	1	4	3	1	0	1	0	90
8	1	1	9	1	0	0	0	0	100
9	1	1	5	3	1	0	1	1	75
10	0	2	4	4	1	0	1	0	70
11	0	2	6	3	1	0	1	0	95
12	0	2	5	2	0	0	1	1	50
13	0	2	3	0	0	0	1	0	50
14	0	2	1	3	1	1	0	0	50
15	1	0	5	0	0	0	1	1	75
16	1	2	6	3	1	0	1	0	90
17	0	1	5	3	1	0	1	0	80
18	1	1	5	1	0	0	1	1	60
19	1	1	5	3	1	0	1	1	75
20	0	2	5	0	0	0	1	1	60
21	0	1	4	0	0	0	1	0	75
22	1	1	5	3	1	0	1	1	5
23	0	1	5	0	0	0	1	1	20
24	0	3	3	0	0	0	1	0	100
25	0	1	2	3	1	1	0	0	25
26	1	2	0	0	0	1	0	0	45
27	0	2	4	2	0	0	1	0	90

Table S3: Delphi Data

Respondent ID	Gender	Age	Training	Affiliation	Government Expertise	Terrorism Expertise	Scientific Expertise	Biological Science Expertise	Question 2: What do you estimate to be the likelihood of a large-scale biological weapons attack occuring within the next 10 years?
28	0	1	7	2	0	0	1	0	50
29	0	0	5	1	0	0	1	1	75
30	1	2	8	1	0	0	1	0	80
31	1	1	5	0	0	0	1	1	20
32	0	2	7	3	1	0	1	0	50
33	0	2	8	2	0	0	1	0	80
34	0	2	5	3	1	0	1	1	5
35	0	2	4	3	1	0	1	0	75
36	0	2	5	2	0	0	1	1	75
37	0	0	5	2	0	0	1	1	10
38	0	1	5	0	0	0	1	1	75
39	0	2	9	0	0	0	0	0	80
40	0	2	5	2	0	0	1	1	50
41	0	2	5	2	0	0	1	1	90
42	1	2	9	4	1	0	0	0	100
43	0	1	9	3	1	0	0	0	90
44	1	1	5	2	0	0	1	1	85
45	0	2	5	3	1	0	1	1	5
47	0	1	5	2	0	0	1	1	67
48	0	2	2	0	0	1	0	0	99
49	1	2	5	3	1	0	1	1	1
51	0	3	5	4	1	0	1	1	90
52	1	1	5	3	1	0	1	1	5
53	0	1	5	2	0	0	1	1	30
54	1	0	3	0	0	0	1	0	80
55	0	1	5	2	0	0	1	1	20
56	0	2	2	3	1	1	0	0	80

Table S3: Delphi Data

Respondent ID	Gender	Age	Training	Affiliation	Government Expertise	Terrorism Expertise	Scientific Expertise	Biological Science Expertise	Question 2: What do you estimate to be the likelihood of a large-scale biological weapons attack occuring within the next 10 years?
57	0	1	5	3	1	0	1	1	5
58	0	2	5	1	0	0	1	1	80
60	0	2	5	3	1	0	1	1	80
61	0	2	5	3	1	0	1	1	50
62	1	1	5	1	0	0	1	1	25

Table S3: Delphi Data

Question 3: In our opinion, what is the likelihood of different types of actors to be the perpetrator of a biological weapons attack resulting in at least 100 illnesses if it occurs within the next 10 years?

Respondent ID	State (covert)	State (overt)	State (within its borders)	Criminal Group	Right-Wing Violent Non-State Actor	Left-Wing Violent Non-State Actor	Disgruntled/ Mentally ill individual	Single-Issue Actor	Religious Extremist
1	2	1	4	1	6	1	1	1	6
2	1	1	1	1	1	1	1	1	3
3	2	1	4	3	7	7	8	8	9
4	6	1	5	1	5	1	8	1	7
5	3	1	3	1	6	4	5	4	8
6	1	1	1	1	2	1	4	1	2
7	4	1	2	2	5	5	5	2	5
8	5	2	1	6	7	7	10	7	9
9	5	3	4	1	8	8	1	1	8
10	4	2	6	6	7	4	8	7	9
11	9	6	5	2	4	4	3	2	2
12	1	1	3	1	5	5	5	5	5
13	2	1	1	1	5	5	7	3	3
14	3	1	4	2	6	6	5	4	7
15	8	3	8	2	4	3	5	3	8
16	3	3	2	2	4	4	2	9	1
17	5	1	2	2	7	5	7	7	9
18	3	1	1	1	9	9	10	9	7
19	9	4	7	4	3	4	8	7	9
20	5	3	3	6	7	6	8	5	8
21	4	2	2	4	2	2	1	3	5
22	6	2	6	1	2	2	1	1	2
23	4	1	3	8	9	9	5	3	4
24	6	1	1	8	3	5	2	8	2
25	3	1	3	2	5	5	9	5	8
26	2	2	4	2	4	4	4	3	5
27	2	7	3	3	4	4	6	4	9

Table S3: Delphi Data

Question 3: In our opinion, what is the likelihood of different types of actors to be the perpetrator of a biological weapons attack resulting in at least 100 illnesses if it occurs within the next 10 years?

Respondent ID	State (covert)	State (overt)	State (within its borders)	Criminal Group	Right-Wing Violent Non-State Actor	Left-Wing Violent Non-State Actor	Disgruntled/ Mentally ill individual	Single-Issue Actor	Religious Extremist	
28	8	1	8	3	2	2	5	2	2	
29	9	1	8	7	7	7	9	8	5	
30	6	6	6	1	5	5	5	2	9	
31	3	3	2	4	6	4	5	3	6	
32	4	1	3	2	7	3	8	3	9	
33	7	1	6	3	8	2	5	1	9	
34	3	1	2	2	2	2	4	2	5	
35	3	1	1	2	8	6	3	1	7	
36	1	2	2	3	4	3	8	3	8	
37	2	1	1	2	2	1	3	1	3	
38	8	6	6	8	3	3	8	3	3	
39	2	1	3	2	4	4	2	2	4	
40	3	1	1	3	6	4	5	2	7	
41	8	2	8	8	8	8	8	8	8	
42	10	2	10	3	4	2	4	4	4	
43	6	2	7	7	9	3	9	9	9	
44	3	1	9	1	6	1	6	6	9	
45	1	1	1	2	1	1	2	1	4	
47	8	1	4	3	3	3	4	3	8	
48	4	5	2	6	2	4	3	2	8	
49	3	1	4	3	5	5	5	3	4	
51	3	1	3	2	2	2	4	2	9	
52	3	1	5	3	4	4	4	4	5	
53	2	2	3	2	2	1	2	1	2	
54	6	4	4	4	8	7	9	8	7	
55	7	1	3	3	3	3	3	3	5	
56	4	1	2	1	8	8	8	2	8	

Table S3: Delphi Data

Question 3: In our opinion, what is the likelihood of different types of actors to be the perpretator of a biological weapons attack resulting in at least 100 illnesses if it occurs within the next 10 years?

Respondent ID	State (covert)	State (overt)	State (within its borders)	Criminal Group	Right-Wing Violent Non-State Actor	Left-Wing Violent Non-State Actor	Disgruntled/ Mentally ill individual	Single-Issue Actor	Religious Extremist	
57	2	1	2	1	2	1	3	1	1	
58	2	1	1	7	8	7	9	8	5	
60	7	2	6	6	7	7	8	8	9	
61	3	1	2	1	8	8	5	6	8	
62	3	1	5	4	9	8	7	10	7	

Table S3: Delphi Data

Question 4: In your opinion, which biological agents are most likely to be used as weapons within the next 10 years

Respondent ID	Non-spore forming bacterial agents	Spore-forming bacterial agents	Viral agents	Biological toxins	Prions	Fungi	Synthetic pathogen that does not exist in nature
1	6	6	2	9	1	1	1
2	4	2	2	2	2	2	2
3	8	8	6	8	4	4	5
4	8	3	6	10	1	1	1
5	3	3	5	4	2	3	2
6	2	2	2	2	1	1	1
7	5	6	5	5	1	2	2
8	3	10	6	6	3	3	3
9	6	6	9	8	2	2	8
10	6	9	9	9	2	4	7
11	8	10	9	9	3	2	7
12	4	5	5	6	2	3	2
13	7	8	7	2	2	1	5
14	8	7	5	10	1	1	3
15	7	8	8	8	1	1	6
16	8	9	7	5	1	1	2
17	7	7	8	8	1	2	7
18	10	5	10	8	4	4	1
19	7	8	7	8	5	4	6
20	8	7	3	9	1	2	1
21	5	10	5	10	3	3	6
22	4	4	3	4	1	2	2
23	7	7	5	8	2	5	5
24	9	6	7	3	1	2	1
25	4	7	3	10	1	1	2
26	3	4	3	6	2	2	2
27	8	8	9	8	3	7	2

Table S3: Delphi Data

Question 4: In your opinion, which biological agents are most likely to be used as weapons within the next 10 years

Respondent ID	Non-spore forming bacterial agents	Spore-forming bacterial agents	Viral agents	Biological toxins	Prions	Fungi	Synthetic pathogen that does not exist in nature
28	3	5	7	7	2	3	2
29	9	8	8	7	1	1	2
30	8	10	10	9	1	1	10
31	5	5	5	7	1	3	4
32	6	8	5	7	2	3	3
33	8	8	8	6	2	3	4
34	4	3	3	5	1	2	1
35	5	5	5	8	1	1	2
36	5	5	10	4	1	2	3
37	1	4	2	1	1	2	2
38	9	5	9	9	1	2	6
39	3	4	3	7	1	3	5
40	4	8	4	8	1	2	4
41	5	9	5	9	1	4	2
42	10	4	5	8	8	1	7
43	7	10	7	9	2	5	9
44	9	2	5	6	1	4	1
45	2	1	1	2	1	1	2
47	3	3	6	5	2	3	5
48	4	8	4	6	3	3	4
49	7	8	3	9	1	1	1
51	9	9	4	9	1	1	3
52	4	4	4	6	1	1	1
53	8	9	8	10	1	3	1
54	8	8	6	9	1	1	6
55	3	3	2	5	1	1	1
56	8	8	8	6	1	1	3

Table S3: Delphi Data

Question 4: In your opinion, which biological agents are most likely to be used as weapons within the next 10 years

Respondent ID	Non-spore forming bacterial agents	Spore-forming bacterial agents	Viral agents	Biological toxins	Prions	Fungi	Synthetic pathogen that does not exist in nature
57	4	2	2	8	1	2	1
58	8	6	9	5	2	4	1
60	6	7	6	9	1	2	1
61	3	8	3	8	1	1	3
62	5	5	4	7	6	5	2

Table S3: Delphi Data

Respondent ID	Question 6: If a biological attack were being planned today, what is the probability that intelligence information will provide actionable indications and warning preceding the attack?	Question 11: In your opinion, are there laboratory experiments that should not be performed as part of biological threat characterization in the US (eg, is there a "red line" that should not be crossed)?
1	10	1
2	20	1
3	50	1
4	10	1
5	30	1
6	25	1
7	30	1
8	20	1
9	20	1
10	30	1
11	5	1
12	50	1
13	10	0
14	10	1
15	50	1
16	50	0
17	50	1
18	40	1
19	30	1
20	30	1
21	20	1
22	50	0
23	20	1
24	3	1
25	5	1
26	20	1
27	1	0

Table S3: Delphi Data

Respondent ID	Question 6: If a biological attack were being planned today, what is the probability that intelligence information will provide actionable indications and warning preceding the attack?	Question 11: In your opinion, are there laboratory experiments that should not be performed as part of biological threat characterization in the US (eg, is there a "red line" that should not be crossed)?
28	60	1
29	15	1
30	50	1
31	25	1
32	30	1
33	10	0
34	2	1
35	10	1
36	25	1
37	10	1
38	40	1
39	50	1
40	40	1
41	20	1
42	0	0
43	60	1
44	75	1
45	20	1
47	55	0
48	10	1
49	0	1
51	5	1
52	5	1
53	75	1
54	10	1
55	50	1
56	10	1

Table S3: Delphi Data

Respondent ID	Question 6: If a biological attack were being planned today, what is the probability that intelligence information will provide actionable indications and warning preceding the attack?	Question 11: In your opinion, are there laboratory experiments that should not be performed as part of biological threat characterization in the US (eg, is there a "red line" that should not be crossed)?
57	25	1
58	20	0
60	75	1
61	25	1
62	25	1

Data Key

Gender
0=Male
1=Female

Age
0=21-33
1=34-49
2=50-68
3=69-86

Affiliation
0= NGO
1= Academia
2= Private Sector/Industry
3= Government
4= Former Government (retired)

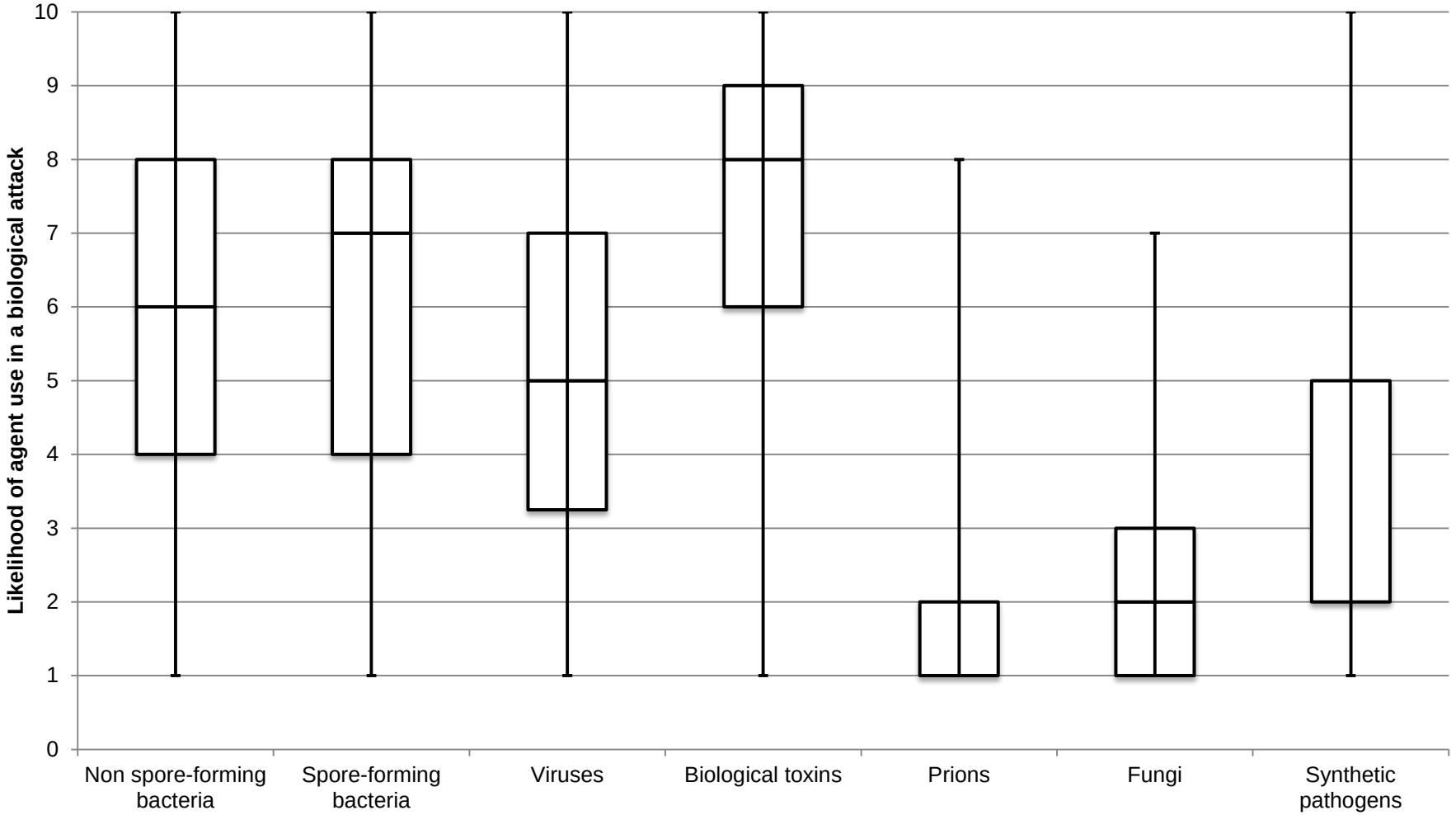
Expertise (all types)
0=No
1=Yes

Question 7
0=No
1=Yes
2=Don't Know

Question 11
0=No
1=Yes

Primary Training
0= Political Science
1= Foreign Policy/International Affairs
2= National Security
3= Public Health
4= Medicine
5= Biological Science
6= Chemistry
7= Physical Science
8= Veterinary medicine
9= Other (Econ, History, Law)

Figure S4: Interquartile ranges for likelihood that a biological agent will be used as a weapon in the next 10 years



The rated likelihood of toxin use was higher than any agent except for spore forming bacteria, and when compared to non spore-forming bacteria, the next highest rated agent after spore-forming bacteria, this difference was statistically significang $z=-2.4$, $p=0.015$. When likelihood of synthetic pathogen use was compared to that of viruses (the next lowest rated agent after synthetic pathogens), the difference was statistically significant $z=4.86$, $p<0.001$. Prions were rated significantly lower than all other agents except for fungi.