Upper and lower bound on vaccines received

The RCT gives the mean number of vaccines received in the control group and both interventions, so the average increase in number of vaccines for each intervention is known. However the RCT did not record which vaccines were given, and depending on this the overall effectiveness could change significantly. This document finds a lower bound and an upper bound for effectiveness by changing which vaccines were given, while keeping consistent with the data given in the RCT.

Given the information available for the control group[1] and the information available for the intervention groups[2] a lower bound for effectiveness is:

Overall cost per death averted	
Camps only	15,479
Camps and incentives	13,441

and an upper bound for effectiveness is:

Overall cost per death averted	
Camps only	2,936
Camps and incentives	5,647

Calculations:

The ordering of the vaccines from most to least beneficial to receive is:
BCG, Measles, DPT1, DPT2, DPT3. This is calculated by multiplying the efficacy (or additional efficacy in the case of DPT2 and DPT3) of the vaccine by the chance of death if not immunized. Both of these inputs are on the summary page.

Worst and best case scenario for the control group:

For the control group we are given that 51% of people had no vaccines, 6% of people were fully vaccinated, 28% had BCG scars, and the mean number of vaccines received was 1.20.[3] We already know what vaccines were received for the group that received no vaccines, and the fully vaccinated group, so we then are aiming to find the most effective and least effective ways of distributing the remaining unknown vaccines.

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[1] Mean number of vaccines received, proportion of children who received no vaccines, proportion who are fully vaccinated, proportion who had BCG scars.
[2] Mean number of vaccines received, proportion of children who received no vaccines, at least one vaccine, at least two vaccines, at least three vaccines, at least four vaccines, proportion who were fully vaccinated, and proportion who have BCG scars
[3] Pg 6, Table 2, https://www.povertyactionlab.org/sites/default/files/publications/Improving%20immunisation%20coverage%20in%20rural%20India.pdf

Then the mean number of vaccines received for people who received at least one vaccine but fewer than 5 vaccines (the maximum number) was 2.093.[4] For this group, approximately 51.2% received BCG vaccinations[5], so the mean number of vaccinations for this group excluding BCG is 2.093 – 0.512 = 1.581.

To maximize the effectiveness of these vaccines, we would give 100% of this group a measles vaccine, and 58.1% of this group a DPT1 vaccine, since out of the available vaccines to choose from (Measles, DPT1, DPT2, DPT3), this maximizes effectiveness (see ordering of vaccines by effectiveness above). So the overall proportion of the control group that received each vaccine would be:

- DPT1: 6%+(100%-51%-6%)*58.1% = 31.0%
- DPT2: 6%
- DPT3: 6%
- Measles: 6% + (100%-51%-6%) = 49%
- BCG: 28%

To minimize the effectiveness of these vaccines, we would give 52.7% of the people in this group (including all of those who did not receive BCG) the three vaccines DPT1, DPT2, and DPT3, and the remaining percentage no additional vaccines. The reason for distributing based on whether people received BCG is to ensure that no person in this group receives no vaccines, which is contrary to the definition of the group as people who have received more than one but less than five vaccines. So the overall proportion of the control group that received each vaccine would be:

- DPT1: 6%+(100%-51%-6%)*52.7% = 28.7%
- DPT2: 6%+(100%-51%-6%)*52.7% = 28.7%
- DPT3: 6%+(100%-51%-6%)*52.7% = 28.7%
- Measles: 6%
- BCG: 28%

Worst and best case scenario for the camps-only intervention

We are given approximately (inferred from Figure 3 on page six) the percentage of people who received each possible number of vaccines: Roughly these seem like 22% for zero, 7% for one, 29% for two, 19% for three, 5% for four, and 18% fully vaccinated. To maximize the effectiveness of this intervention, we want to give the vaccines that have most positive effect (using the ordering BCG, measles, DPT1, DPT2, and DPT3, as described above). To minimize the effectiveness, we want to give the least effective vaccines possible. In each case, we want to maintain 52% of people are given the BCG vaccine.

Ignoring BCG, we first distribute the most effective vaccines:

- 7% of people receiving one, receive: Measles
- 29% of people receiving two, receive: Measles, DPT1
- 19% of people receiving three, receive: Measles, DPT1, DPT2

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[4] By solving the equation: 6%*5 + 51%*0 + (1-6%-51%)*x = 1.2

[5] By solving the equation: 6%*1 + 51%*0 + (1-6%-51%)*y = 28%

- 5% of people receiving four, receive: Measles, DPT1, DPT2, DPT3
- 18% of people receiving five receive: BCG, Measles, DPT1, DPT2, DPT3

Then to maximize effectiveness, we want to use our remaining BCG percentage (52%-18% = 34%) to replace the weakest vaccines possible. So we replace DPT3 for 5%, DPT2 for 19%, and DPT1 for the remaining 10% left of the BCG distribution. Thus we have:

- 7% of people receiving one, receive: Measles
- 29% of people receiving two, receive: 10% receive Measles, BCG, 19% receive Measles, DPT1
- 19% of people receiving three, receive: Measles, DPT1, BCG
- 5% of people receiving four, receive: Measles, DPT1, DPT2, BCG
- 18% of people receiving five receive: BCG, Measles, DPT1, DPT2, DPT3

Similarly in the other direction, we can first fill in the distribution with the weakest possible vaccines, excluding BCG:

- 7% of people receiving one, receive: DPT1
- 29% of people receiving two, receive: DPT1, DPT2
- 19% of people receiving three, receive: DPT1, DPT2, DPT3
- 5% of people receiving four, receive: Measles, DPT1, DPT2, DPT3
- 18% of people receiving five receive: BCG, Measles, DPT1, DPT2, DPT3

and here replace the strongest vaccines possible with BCG. So we replace measles with BCG for 5% of people, DPT1 with BCG for 7% of people, and DPT2 for the remaining 52%-18%-5%-7% = 22% of people, giving us:

- 7% of people receiving one, receive: BCG
- 29% of people receiving two, receive: 22% receive BCG, DPT1, and 7% receive DPT1, DPT2.
- 19% of people receiving three, receive: DPT1, DPT2, DPT3
- 5% of people receiving four, receive: BCG, DPT1, DPT2, DPT3
- 18% of people receiving five receive: BCG, Measles, DPT1, DPT2, DPT3

Camps and incentives intervention

Using the same process as above, to maximize the effectiveness of the camps and incentives intervention we end up with the distribution:

- 4% of people receiving one, receive: Measles
- 16% of people receiving two, receive: Measles, DPT1
- 9% of people receiving three, receive: 7% BCG, Measles, DPT1, and 2% Measles, DPT1, DPT2.
- 6% of people receiving four, receive: BCG, Measles, DPT1, DPT2
- 39% of people receiving five receive: BCG, Measles, DPT1, DPT2, DPT3

And to minimize the effectiveness of the distributions we get:

- 4% of people receiving one, receive: BCG

- 16% of people receiving two, receive: 3% DPT1, BCG, and 13% DPT1, DPT2
- 9% of people receiving three, receive: DPT1, DPT2, DPT3
- 6% of people receiving four, receive: BCG, DPT1, DPT2, DPT3
- 39% of people receiving five receive: BCG, Measles, DPT1, DPT2, DPT3

Finding the best and worst outcomes of the intervention

To find the lower bound for how effective the intervention could be, we can replace the 'proportion in the control group that received this vaccine' with the best case scenario, and the 'Proportion in the camps-only intervention that received this vaccine' and 'Proportion in the camps and incentives intervention that received this vaccine' with the worst case scenario.

This changes B7 to D11 in sheet 'Number of vaccines received' from

Vaccine name	Proportion in the **control group** that received this vaccine	Proportion in the **camps-only intervention** that received this vaccine	Proportion in the **camps and incentives intervention** that received this vaccine
DPT1	0.36	0.65	0.7
DPT2	0.18	0.44	0.58
DPT3	0.08	0.24	0.46
BCG	0.29	0.525	0.53
Measles	0.3	0.485	0.6

to

Vaccine name	Proportion in the **control group** that received this vaccine	Proportion in the **camps-only intervention** that received this vaccine	Proportion in the **camps and incentives intervention** that received this vaccine
DPT1	0.31	0.71	0.7
DPT2	0.06	0.49	0.67
DPT3	0.06	0.42	0.54
BCG	0.28	0.52	0.52
Measles	0.49	0.18	0.39

this changes the overall cost per death averted to:

Overall cost per death averted						
Camps only	15,479					
Camps and incentives	13,441					

To find the upper bound for effectiveness, we replace the 'proportion in the control group that received this vaccine' with the worst-case scenario, and the 'Proportion in the camps-only intervention that received this vaccine' and 'Proportion in the camps and incentives intervention that received this vaccine' with the best-case scenarios:

Vaccine name	Proportion in the **control group** that received this vaccine	Proportion in the **camps-only intervention** that received this vaccine	Proportion in the **camps and incentives intervention** that received this vaccine
DPT1	0.287	0.61	0.7
DPT2	0.287	0.23	0.47
DPT3	0.287	0.18	0.39
BCG	0.28	0.52	0.52
Measles	0.06	0.78	0.74

Changing the overall cost per death averted to:

Overall cost per death averted						
Camps only	2,936					
Camps and incentives	5,647					