# Volunteers in NESTA experiment Technical Report

Rafal Urbaniak

The winning model, given our model selection method, is specified as follows:

$$
\begin{aligned}
\mathsf{interventions} &\sim \mathsf{NegativeBinomial}(\lambda, \phi) \\
log(\lambda) = l_{\mathsf{volunteerID[i]}} + enth_{\mathsf{volunteerID[i]}} &\times \mathsf{daysOfProject} + comp_{\mathsf{volunteerID[i]}} \times \mathsf{competition} \\
l_{\mathsf{volunteerID[i]}} &\sim \mathsf{Norm}(lbar, lsigmabar) \\
lbar &\sim \mathsf{Norm}(2, .9) \\
lsigmabar, enthsigmabar, compsigmabar &\sim \mathsf{Exp}(.5) \\
enth_{\mathsf{volunteerID[i]}} &\sim \mathsf{Norm}(enthbar, enthsigmabar) \\
comp_{\mathsf{volunteerID[i]}} &\sim \mathsf{Norm}(compbar, compsigmabar) \\
enthbar, compbar &\sim \mathsf{Norm}(0, .3) \\
\phi &= puser_{\mathsf{volunteerID[i]}} \\
puser_{\mathsf{volunteerID[i]}} &\sim \mathsf{Exp}(1)
\end{aligned}
$$

Intuitively, volunteer interventions are assumed to have negative binomial distribution around their own expected value $\lambda$ and individualized dispersion parameters $\phi$. On each day each a user has their own daily expected value, which is determined by the following factors:

- First, there's user's individual baseline activity for the whole treatment period, $l_{\mathsf{volunteerID[i]}}$.
- next, each user has their own dispersion parameter, $puser_{\mathsf{volunteerID[i]}}$.
- then, there is (usually dwindling) enthusiasm: the impact of time on that user, $enth_{\mathsf{volunteerID[i]}}$ to be (after exponentiation) multiplied by the number of days that have passed since the experiment started,
- finally, we have the impact that the presence of competitions made on a user, $comp_{\mathsf{volunteerID[i]}}$, which (after exponentiation) becomes the activity multiplier to be applied during competitions only.

Moreover, the model is hierarchical: the individual level parameters are drawn from distributions whose parameters are in turn to be estimated as well. Thus, *lbar* is the overall baseline for the whole group, *enthbar* is the overall estimated group enthusiasm coefficient, and *compbar* is the overall estimated competition impact coefficient (all of them come with their own nuisance sigma parameters).

All of these parameters are given priors in a manner analogous to the introduction of priors for the other time series models, as explained in the appendix.[1]

Raw data and daily means are illustrated in Figure 1, and the individualized totals with the key coefficients based on the trained model are illustrated in Figure 2.

[1] Interestingly, if we are interested in the causal effect of competitions, we should not use an auto-regressive predictor. If we auto-regress on a lag in the $[1, 7]$ range, for some days we will be conditioning on interventions conducted during the same competition, which will already contain some information about the impact of that competition. In other words, auto-regression with short lags would lead to post-treatment bias. On the other hand, auto-regression with longer lags would either lead to dropping a lot of data in the beginning (where lagged information is not available), or degenerate the analysis by using 0s for missing lagged values in a long initial period. All this without much gain, as we have already inspected null models with auto-regression with large lags and they do not lead to performance improvement.

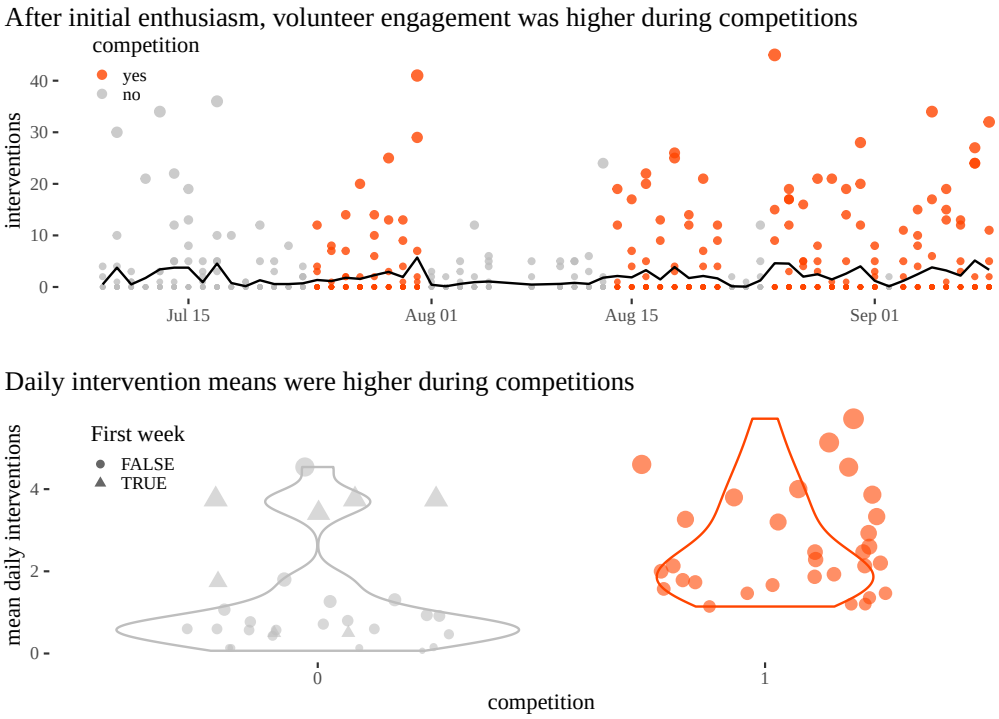


Figure 1: Daily individual voilunteer intervention counts accross time with competition periods marked (top) and daily group intervention means grouped by whether a competition was ongoing (bottom). Note most of high means in the non-competition period are in the first week.

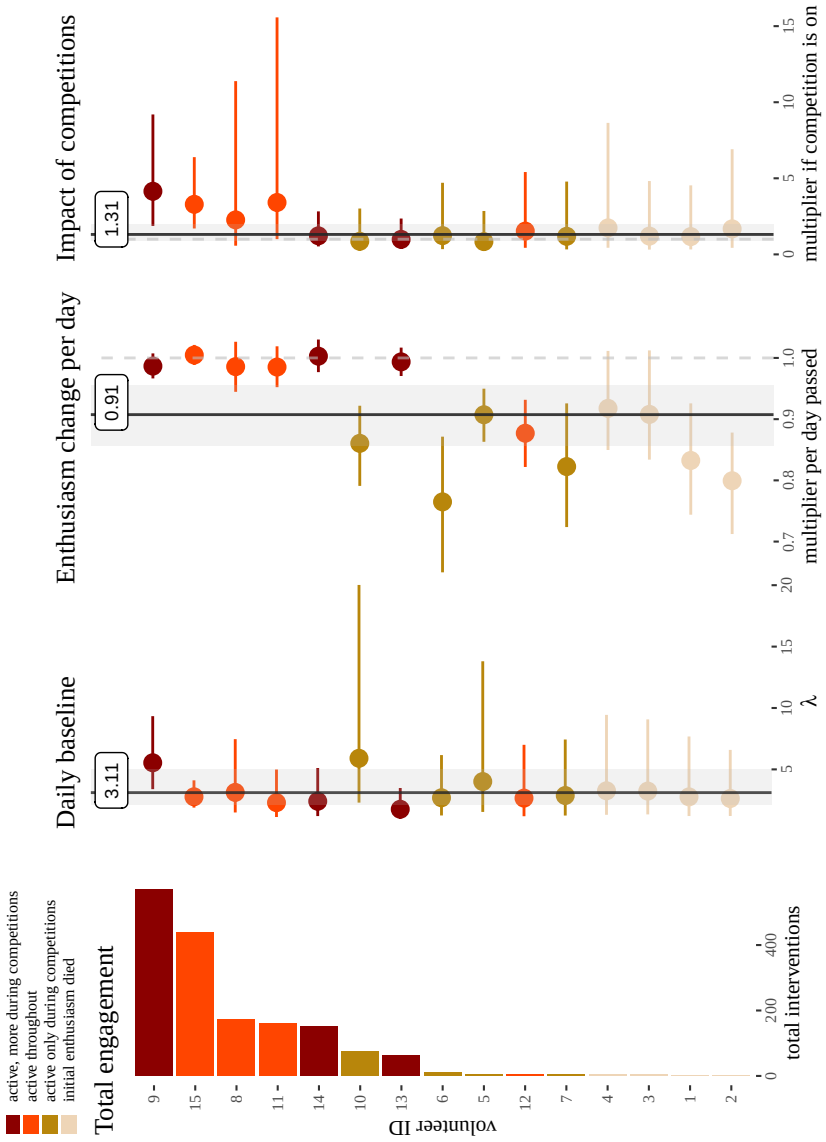


Figure 2: Volunteer total engagement with their daily baseline and multipliers for enthusiasm and impact of competition. Pointranges represent individual level coefficients, group coefficients are represented by black lines with shaded 89% HPDI areas.