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DNA: Differentially private Neural Augmentation for contact tracing

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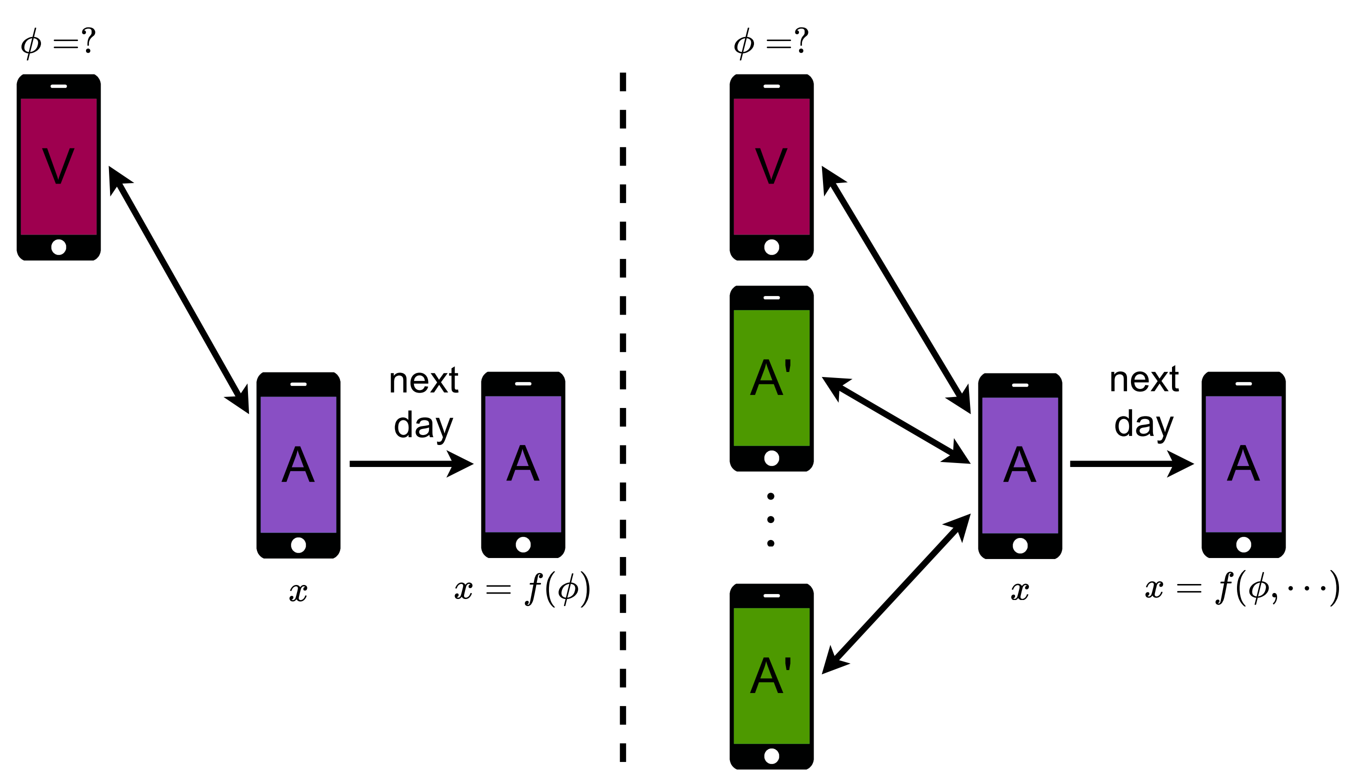
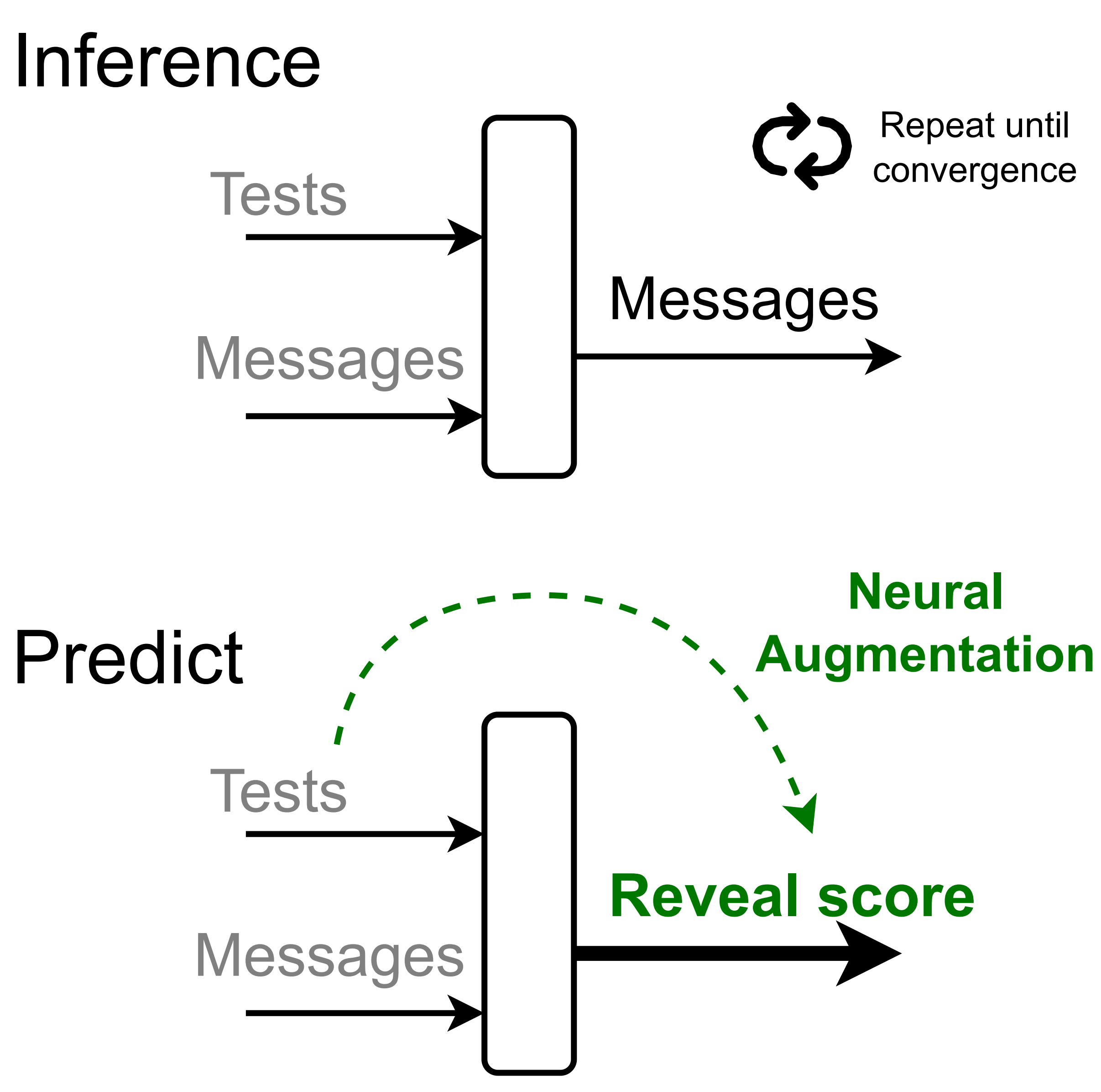
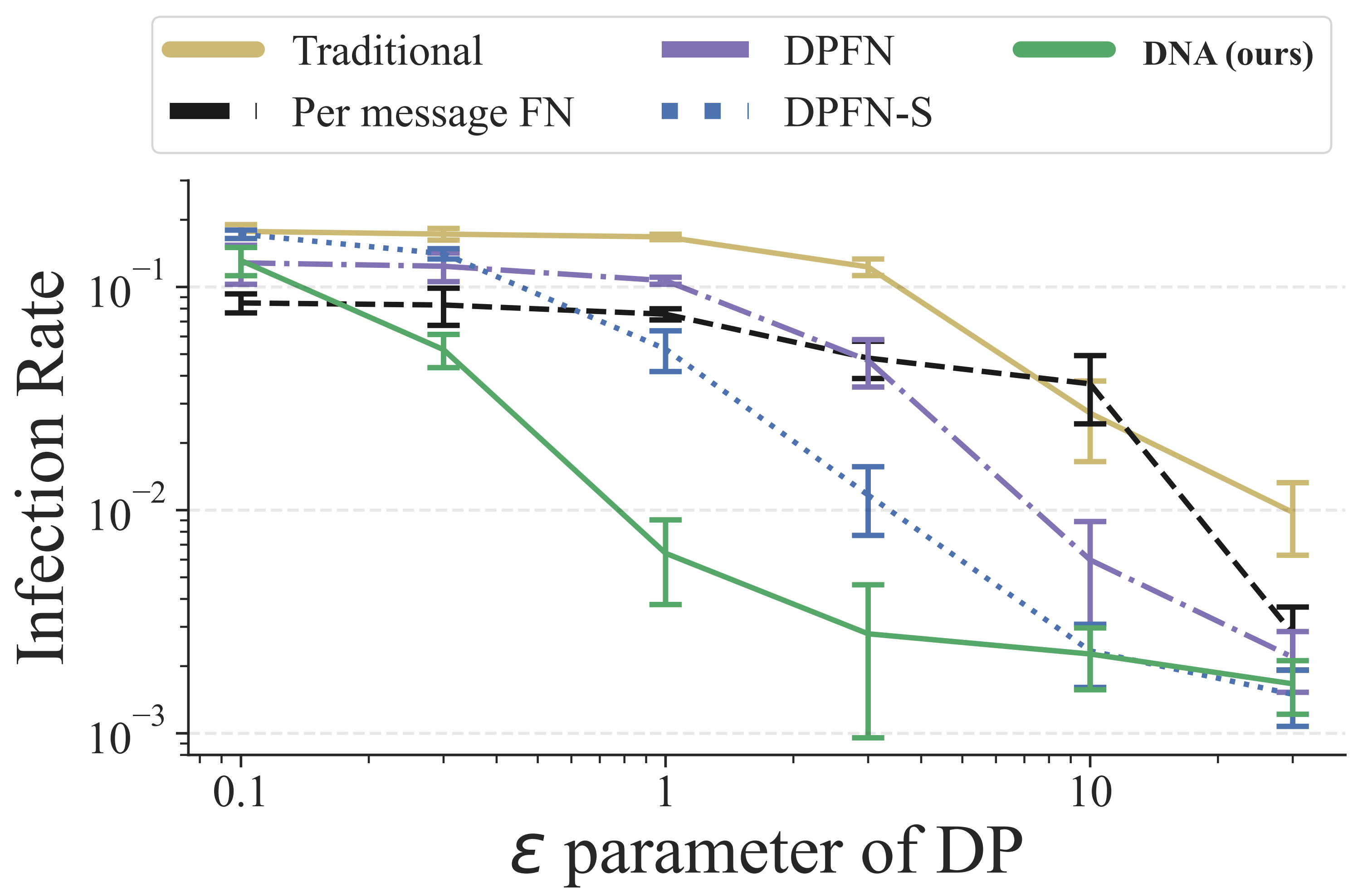
Concerns about privacy are the main reason for low adoption of contact-tracing algorithms, even though they are shown to be effective [1,2,3]. We present a **Differentially Private (DP)** version of Neural Augmentation to improve predictions in decentralized contact tracing.



In the **attack scenario,** the Attacker can reconstruct the score of the Victim -- even in the presence of multiple contacts. Our method reveals the score under DP.



The reveal of the risk score is a DP function (DPFN), but the predictions can be improved with Neural Augmentation.



In the **trade-off** between privacy and the peak infection rate [4], our method achieves a significantly lower infection rate at the crucial setting of ε = 1 DP.

DP definition

For $\varepsilon > 0,\ \delta \in [0,1]$, a function $f(\cdot)$, for any outcome Φ, and any two adjacent data sets D, D', satisfies [6]:

$$p(f(D) \in \Phi) \leq e^{\varepsilon} p(f(D') \in \Phi) + \delta$$

Sensitivity

Maximal change with respect to one message, score μ:

$$\Delta = \max_{\mu_1,\mu_1'} |f\left(\ \{(\mu_1,t_1)\} \cup D\ \right) - f\left(\ \{(\mu_1',t_1)\} \cup D\ \right)| \leq p_1\gamma_u \ \forall\ D.$$

Neural Augmentation

The Lipschitz-constrained model has a bounded sensitivity [5]:

$$\phi = G_\theta(\{(\mu_i,t_i)\}_{i=1}^{C_T}) = g_\theta^{(2)}\left(\ \frac{1}{C}\sum_i g_\theta^{(1)}([\mu_i,t_i]^T)\ \right).$$

Algorithm 1 DNA: Differentially private Neural Augmentation

Require: Dataset $D = \{(\mu_i,t_i)\}_{i=1}^{C_T}$, constants $p_1, \gamma_u \in (0,1)$;

$\mu_i \leftarrow \min(\mu_i, \gamma_u)$

$\bar{\phi} \leftarrow F(\{(\mu_i,t_i)\}_{i=1}^{C_T}) + p_1 \times G_\theta(\{(\mu_i,t_i)\}_{i=1}^{C_T})$

$\phi \leftarrow \bar{\phi} + \mathcal{N}(0, \frac{2}{\varepsilon^2}(\gamma_u p_1(1+\frac{1}{C_T}))^2 \log(\frac{5}{4\delta}))$

The neural augmentation (operations in green) increases the sensitivity, but the required additional noise compares favorably in predictions.

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[4] "OpenABM-Covid19—An agent-based model for non-pharmaceutical interventions against COVID-19... ," Hinch et al. PLOS 2021
[5] "Deep sets," Zaheer et al. NeurIPS 2017.
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