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BEYOND INSTANTANEOUS PARTNERSHIPS: CAPTURING PARTNERSHIP-LEVEL HERD EFFECTS IN COMPARTMENTAL MODELS OF SEXUALLY TRANSMITTED INFECTIONS

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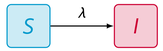
BACKGROUND: INSTANTANEOUS PARTNERSHIP MODELS

- Compartmental models of STI & HIV are **key tools** in epidemic response [1]
- Modelled rate of new infections depends on **average infection prevalence**
- So: **newly infected immediately contribute to more infections** (incidence)
- Assumption: partnerships are effectively instantaneous [2]
- Reality: partnerships include before & after transmission
- This assumption can **bias estimates of intervention impact** [3]



OBJECTIVES

(1) Develop a **new compartmental model** which avoids instantaneous partnerships

(2) Explore whether **modelled incidence is biased** with instantaneous partnerships
(a) **overall**, and (b) in **longer vs shorter** partnerships

LIMITATIONS OF INSTANTANEOUS PARTNERSHIP MODELS

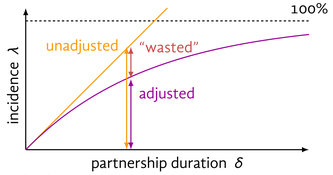
Modelled incidence rate:

$$\lambda = [1 - \underbrace{(1-\beta)^{F\delta}}_{\text{probability of escaping infection}}]\, C\, I$$

- I : prevalence of infectious
- C : number of concurrent partners
- δ : average partnership duration *
- F : sex frequency per-partnership
- β : transmission probability per contact

How duration δ is used:

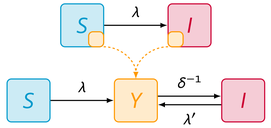
- Contacts after transmission are "wasted"
- So: adjust for wasted contacts via probability of escaping infection
- However: **forced to assume either**
  - **true duration** → underestimate early transmission
  - **max 1-year duration** → underestimate wasted contacts



Limitations:

- Partnerships are assumed instantaneous
- Forced to capture either early transmission or wasted contacts

METHODS: OBJECTIVE 1 — PROPOSED MODEL



Core idea:

- Individuals who recently acquired (S) or transmitted (I) might be **still with same partner**
- So: they **might not contribute to incidence**

The details:

- New compartment (Y) for recently acquired or transmitted
- Remove Y from incidence rate λ:
  - until: they change partners (duration^{-1})
  - if > 1 partnership types: only 1 type affected
  - if > 1 concurrent partners: only 1 partner removed

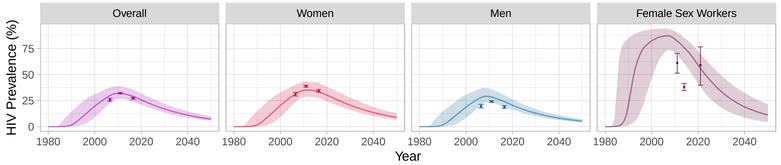
$$\lambda = \beta F [\underbrace{Y(C-1)}_{-1 \text{ partners after transmission}} + IC]$$

METHODS: OBJECTIVE 2 — SIMULATION STUDY

Context: Heterosexual HIV transmission in eSwatini

Full compartmental model:

- 8 risk groups, 5 HIV stages, 5 treatment cascade states
- 4 partnership types, including:
  main (12–25 years), casual & sex work (0–2 years)
- Calibrated to HIV prevalence, incidence, treatment cascade data under *instantaneous* model; repeat for *proposed* model:

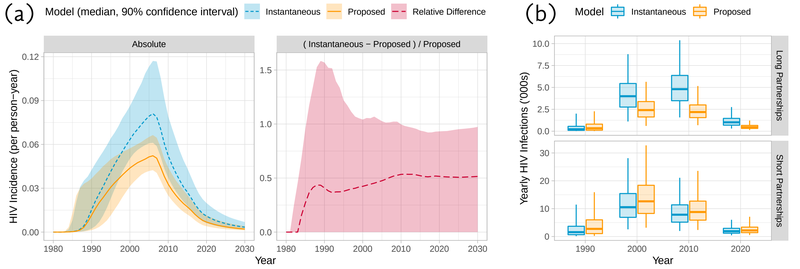


Experiment: Compare *instantaneous* vs *proposed* models:

(a) **overall incidence**, with equal parameters from *proposed* calibration
→ direct influence of instantaneous partnerships

(b) **incidence in longer vs shorter partnerships**, with model-specific parameters
→ indirect influence on model-inferred prevention priorities

RESULTS: OBJECTIVE 2 — SIMULATION STUDY



(a)
- With equal parameters, overall incidence higher in *instantaneous* vs *proposed*
- Differences grow over time due to **partnership-level herd effects** in *proposed*: infections become "trapped" within partnerships after transmission

(b)
- With model-specific parameters, incidence in *instantaneous* vs *proposed*: higher in longer partnerships, lower in shorter partnerships

IMPLICATIONS

- Proposed model overcomes decades-old partnership modelling challenge [2]
  - Captures **true partnership duration** → early transmission and wasted contacts
  - Captures accumulation of **partnership-level herd effects**
  - Avoids need for more complex modelling frameworks (e.g. network)
- **Existing models likely overestimate impacts of prevention in longer partnerships**, and underestimate impacts of prevention in shorter partnerships

REFERENCES + ACKNOWLEDGMENTS

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2. Rao, D.W. et al. (2021) "Partnership dynamics in mathematical models and …" *Annals of Epi.* DOI: 10.1016/J.ANNEPIDEM.2021.04.012
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No conflicts declared.