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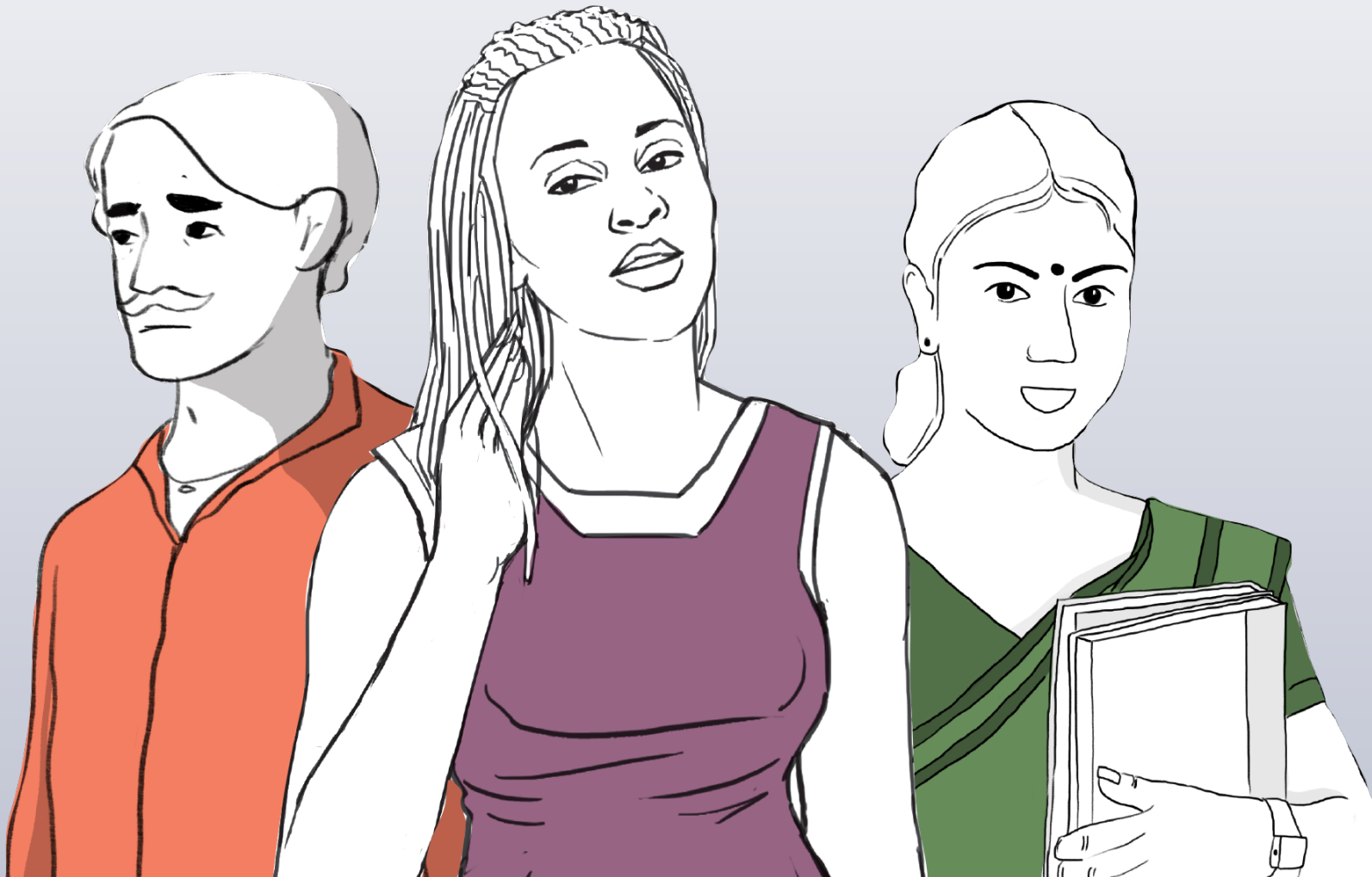
Understanding Complex Behavioral Interactions

A Game Theory Perspective

AUTHORS: NISHAN GANTAYAT, ISHA JAIN & ALOK GANGARAMANY **EDITOR:** JAMES BAER



Global development issues such as the COVID-19 pandemic, HIV prevention, and sanitation are complex. Behavioral science sees the problems as rooted in long-embedded social and institutional norms. But understanding behavior is often complicated by the number of stakeholders involved. Interactions and reactions influence individuals' decisions and behaviors. This dynamic can be convoluted even when only two people are interacting, and is much more so when interactions happen in groups. Another key factor is how people's behaviors are shaped by their beliefs about other stakeholders – especially in the absence of full information about them.

Game theory is a tool that can be used to model and analyze these multiple interactions and beliefs and incorporate the dependencies surrounding an individual's actions. It enables a theoretical understanding of the interactions between people which can guide strategic thinking, allowing an exploration of the possibilities of alternate behaviors.

Since its early application in classical economics, game theory has evolved to describe complex social phenomena where players may not think of themselves as playing a game. Some of the most popular applications have been Cold War deterrence strategy (satirized in the black comedy Dr Strangelove), auction theories, and modeling reciprocal altruism.

But how do we apply the intricacy and nuance of this tool to challenges in the public health sector? One starting point is to use game theory to reframe problems. For example, instead of seeing public health issues as affected by dominant individual preferences and judgements, they can be thought of as decisions that are continuously being taken in an environment characterized by social norms, information asymmetry, the preferences of actors involved, and repeated interactions. This view emphasizes the conditional nature of optimal decisions – in other words, good decisions generally depend on predicting other people's decisions.

What are the characteristics of game theory that make it conducive to understanding interactions in the public health sector?

- Interactions involve a set of intelligent decision-makers or **players** – independent individuals with the capacity to assess their environments and make decisions.
- Interactions are influenced by each player's **goal**, which alters how they behave. The goal may be to compete or to cooperate for resources, to manage one's reputation, or to achieve a particular **payoff** (outcome).
- Interactions proceed when a player chooses one action from a set of possible actions. These depend in part on the actions of other players, which gives rise to **behavioral strategies**. For example, wearing a mask to protect against disease may be an action taken in response to others doing so.
- Strategies lead to **payoffs** – the benefits / losses players expect – not just absolute terms, but also in comparison to different outcomes, and maybe also in comparison to other players. This introduces the dimension of relativeness.
- The assessment of potential payoffs is based on **beliefs**, because when people interact, they may have to make decisions without complete information about others. Examples of such information asymmetry include not knowing another person's HIV status, or whether (in the context of COVID-19) they have touched an unhygienic surface.
- **Length and frequency of interaction** can also make a difference when assessing payoffs. In a one-off interaction, players are likely to consider from the start how to reach their goal and the payoff they want; but where an ongoing relationship is being established, or regular encounters are anticipated, a different strategy may be chosen.

We show how insights from game theory could be applied to different types of social interaction whether between two people meeting in a bar and making decisions about **protecting themselves from HIV**; or among **community members thinking about sanitation issues**; or between a public-health agency and members of the public in the **context of testing for COVID-19**.

We hope these examples will illustrate how game theory opens up new ways of thinking about complex behavioral problems.

STORY 1

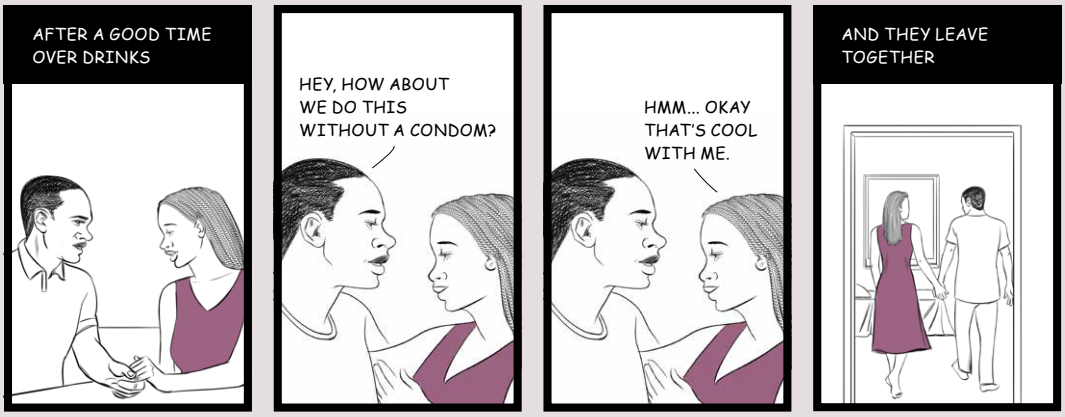
Analyzing high risk relationships to reduce risk of HIV

HIV is a shared risk, but programming and user understanding is siloed.

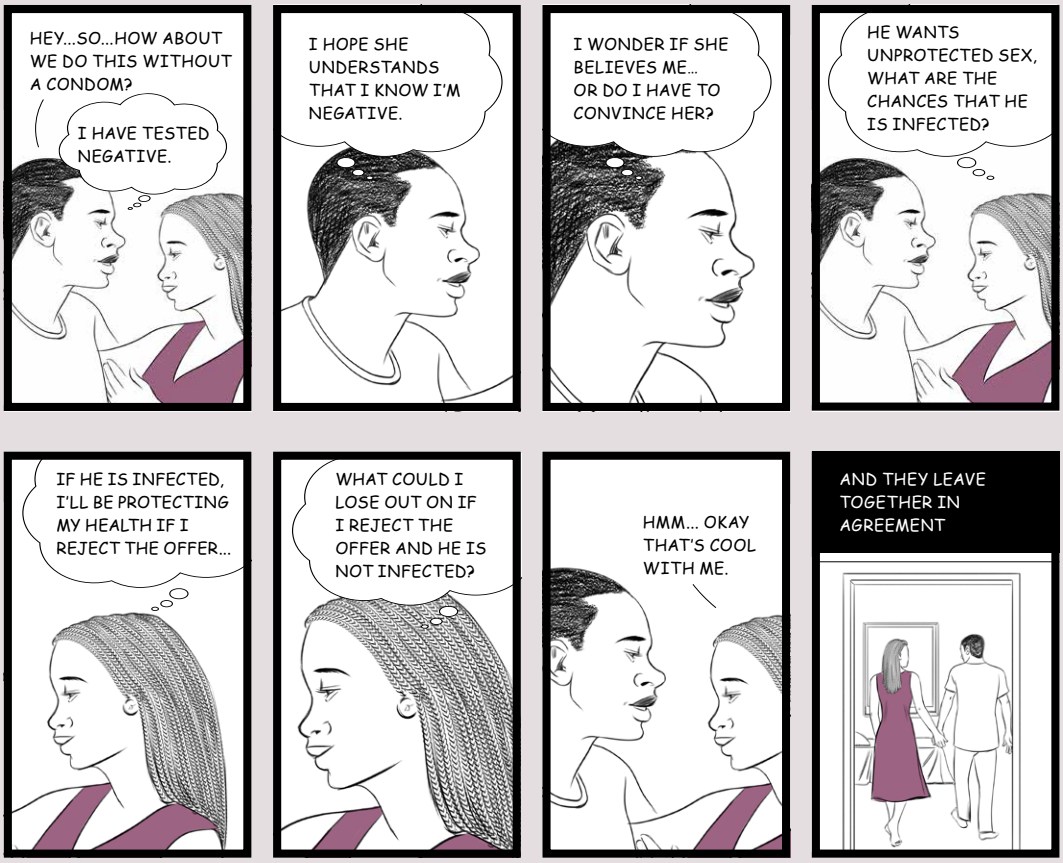
Many HIV prevention research projects and interventions focus on either men or women, rather than taking an integrated approach. For example, how can one encourage safer sex behaviors between men and women in high-risk settings like bars and nightclubs? Here the risk of HIV transmission is known to be high, particularly for adolescent girls and young women who engage in casual sexual relationships in exchange for gifts or financial support. Decisions in such settings are characterized by factors such as instant gratification (physical and material), significant information asymmetries, the short-term nature of the relationships, and a narrow timeframe to negotiate the use of prevention options.

To understand these interactions and how they affect decision-making, it can be valuable to see men and women as strategic players in a game based on limited information and rapid decision-making on trade-offs of risk and reward.

Let's imagine a scenario where two individuals meet at bar and the man suggests leaving the bar together, making it clear that they will be having unprotected sex. When assessing the problem from an individual decision-making perspective, we might think of the interaction as transactional and one-sided.



But the interaction is more strategic than the woman simply responding to the man's question. Each of them may be playing out numerous scenarios in their mind, before making their decision.



From a game theory perspective, the woman is not necessarily motivated purely – or even primarily – by sexual attraction. She's thinking about the likelihood of receiving material benefits from the man, and weighing it up against the possibility that he might be HIV-positive. But other considerations may also be going through her mind – and the man may be trying to read these from her words or behavior, and he may adjust his offer as well.

For example: The woman accepts the offer of unprotected sex because she trusts the man and assumes that he doesn't do this often, and she wants to be able to impress her friends by buying new clothes. The man believes the woman benefits more from accepting the offer than rejecting it, even if she thinks he may be HIV-positive.

The woman considers rejecting the offer of unprotected sex, even though she assumes the man to be HIV-negative, because other potential losses, such as becoming pregnant or acquiring some other sexually transmitted infection, outweigh the benefits. Meanwhile, the man wonders whether his offer will be rejected even though he signaled that he is HIV-negative, because the woman's benefits of protected sex are greater, so perhaps he should revise his offer and agree to using protection.

To sort through these complexities and build a holistic understanding of the interaction, it can help us to think in terms of three components: beliefs, payoffs, and decisions.

Beliefs: When two people meet at a bar, they lack complete information about one another, and will therefore act in a way that is consistent with their beliefs about each other. For example, the woman may hold a prior belief about the type of man she has met, which she updates as the evening progresses. A young woman meeting an older man may believe initially that he's likely to be more affluent than her, and she may confirm or revise these beliefs based on what he discloses, or what she discerns by picking up on more subtle signals – where he says he lives, what he does for a living, his accent, references to previous girlfriends, a hint that he may have spent time in prison. All these factors could affect both her belief about the man's goals in the interaction, and her belief about the level of risk she will incur if she agrees to his request for sex without a condom.

Payoffs and decisions: For the young woman, there are various potential payoffs if she agrees to go home with the man and have unprotected sex. These may include physical gratification, emotional connection, material benefits (gifts or money), maybe even the potential for a longer-term relationship. But payoffs can also be negative – the risk of contracting HIV or another sexually transmitted infection, the possibility of violence, the likelihood that she won't receive the promised gift. In weighing these up, the woman is also subject to the influence of external factors like peer pressure and her physical environment. And in deciding on her actions – whether to go home with the man, whether to accede to sex without a condom – she will be aware that the man is also considering a range of payoffs for himself – such as pleasure, or demonstrating his financial power – and that there are environmental factors at play for him, too, such as pressure to conform to local norms of masculine behavior. Each person ranks the payoffs in relation to their goal for the interaction, while being aware that these payoffs will be affected by the decisions the other makes.

Developing a game-theoretic model of this interaction can make it possible to elucidate and quantify this complex set of calculations. The model can then be used to change the game dynamics and improve the payoffs and take the interaction towards a desired end. If the model predicts that a certain variable has a significant impact on the payoffs, we can develop interventions for this variable to alter the payoffs and their distribution. For example, if peer pressure to engage in transactional sex is determined to be a significant influence on young women, peer counseling sessions might change their calculation of the payoffs (by reducing their positive assessment of social status due to transactional sex). An intervention that affects the point of interaction itself could be to change the portion sizes (or even names) of drinks served in bars. This could lower the risk of inebriation and thus extend the length of their interaction, and this in turn would support the individual's capacity to strategize beyond short-term payoffs.

By using game theory to model behavior, we change the questions we ask and in turn, the problem we're trying to solve.

What we ask now:

How does the girl/woman make decisions regarding sexual health? What kind of surrounding factors influence these decisions?

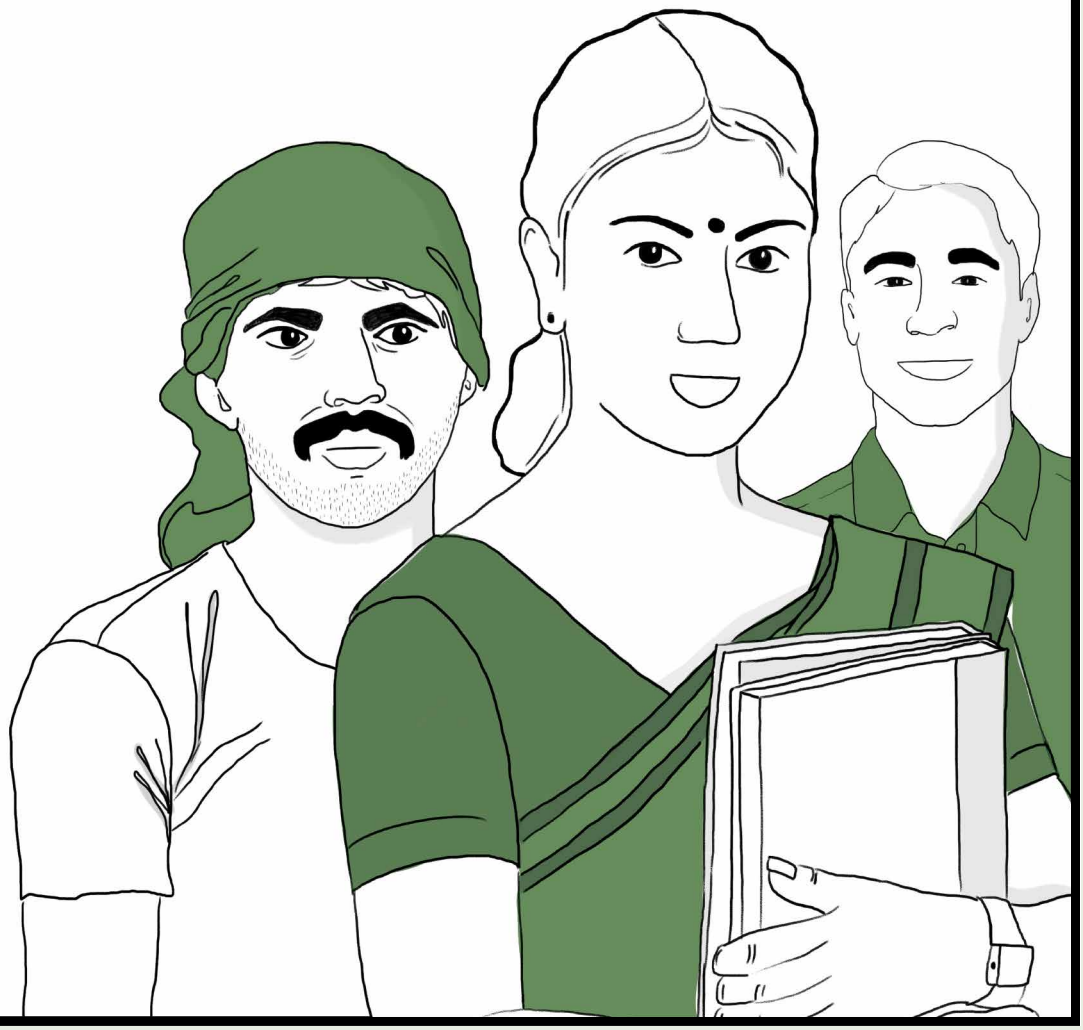
What should we ask:

How do both partners analyze their trade-offs? How do we understand and influence interactions in a high-risk setting? Can increasing the interaction time between the couples reduce the negative impact created in a high-risk setting?

STORY 2

Influencing sanitation norms in a community

Sanitation programs start strong but are often not sustained, understanding group dynamics can help improve uptake of pro-sanitation behavior



Sanitation is key to good health and is a critical issue in India. More than a quarter of the country's population do not use an indoor toilet, leading to the spread of fecal-borne diseases. The millennia-old practice of open defecation persists despite government campaigns to discourage it and to build toilets. It's clear that simply providing a service is not sufficient to change people's behavior. To achieve better health outcomes, all community members must cooperate in campaigns to use toilets.

Where campaigns have had some success, it has been by bringing communities together in meetings to discuss the issue of open defecation frankly and foster cooperation. The range of activities in these meetings vary but they are united by a common theme of community involvement and sparking feelings of disgust and shame to change norms. Nevertheless, the sustenance of such campaigns tends to be short, and it is hard to keep people using toilets even when these are available.

When it comes to adopting sanitation, the costs and benefits of this public good vary for different types of people. Facing different payoffs, they are not all equally likely to cooperate in a sanitation campaign.

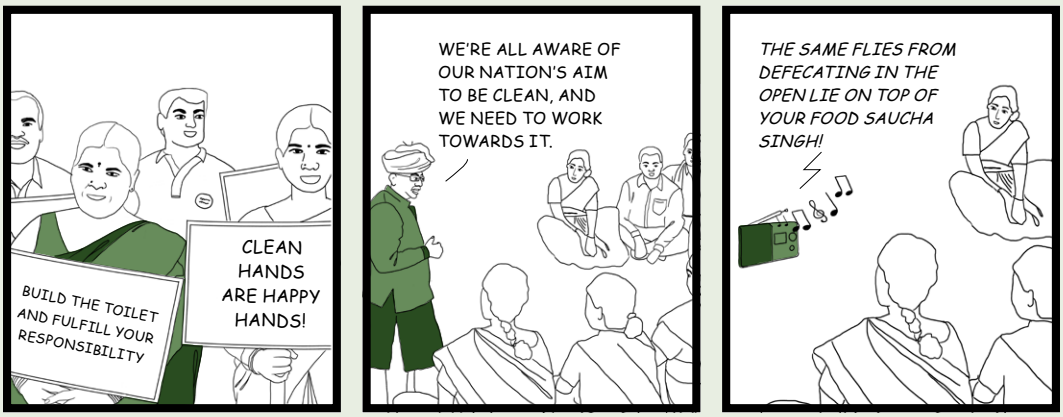
Game theory can be one of the useful tools to understand why this might be so. Sanitation is not simply a problem of individual behavior, but one of a public good – a resource provided for the benefit of all.

This means that it will take different levels of effort to get their participation – and the influence that certain people have in their community will affect the payoffs gained from their participation in the campaign.

A game-theory perspective of these dynamics can help campaigners decide how to form groups in the campaign – and in what order.

Sanitation programs typically work by asking community members to adopt toilets in their houses and stop practicing open defecation. The pro-sanitation norm is created using community influencers, and it relies on each community member's decision to join the pro-sanitation team.

Current State



But the program could be more effective by maximizing how much each individual contributes toward a clean and hygienic community, in order to maximize the benefits to the community as a whole. In this sense, the value of each individual to a campaign depends on the strength of their influence in the community – in other words, how much they can contribute to the creation and retention of the social norm surrounding sanitation.

Let's think about how this might look in a typical Indian village. We'll consider four groups of people: working men, housewives, young men, and the village teacher. In rural India, the male breadwinner (the working man) has the greatest influence on social norms, but for that reason is often most tied to existing norms. Teachers are less influential among adults but can shape norms gradually through their influence on children, and may also be more willing to subscribe to new norms.

When it comes to sanitation, each group perceives certain costs and benefits to joining the pro-sanitation campaign.

Community Stakeholders

WORKING MAN

BENEFITS:
GOOD HEALTH, SAVES TIME, BEING A TREND-SETTER, LESS CASTE-BASED DISCRIMINATION SINCE THE PRACTICE IS PRIVATE

COSTS:
EFFORT TO BREAK HABIT, RELIGIOUS NORMS ON PURITY, PERCEIVED DISGUST IN USING TOILETS, LOW CONFIDENCE IN TOILET'S EFFICACY, LOW BELIEF IN COMMUNITY'S SUPPORT

HOUSEWIFE

BENEFITS:
PHYSICAL SAFETY, HYGIENE

COSTS:
EFFORT TO BREAK HABIT, RELIGIOUS NORMS ON PURITY, PERCEIVED DISGUST, LOW CONFIDENCE IN TOILET'S SUSTAINABILITY, MAINTENANCE EFFORTS

YOUNG MAN

BENEFITS:
SAFETY, GOOD HEALTH, SAVES TIME, QUALITY OF LIFE

COSTS:
EFFORT TO BREAK HABIT, BELIEF THAT INDOOR TOILETS WOULD MAKE INDOOR PLACES OF WORSHIP IMPURE, PERCEIVED DISGUST

TEACHER

BENEFITS:
SAFETY, GOOD HEALTH, SAVES TIME, QUALITY OF LIFE, BELIEVES THEY WILL BE A TREND-SETTER IN CREATING CHANGE

COSTS:
EFFORT TO BREAK HABIT, PERCEIVED DISGUST

For the working man, the costs of being associated with the pro-sanitation campaign outweigh the benefits, so the probability of his joining the campaign is low. At the other end of the scale, the personal payoff for the teacher is positive, and therefore she is more likely to join. Yet even though it will require more effort to get working men on board, it's their cooperation that is most needed, because of the greater influence they exert in the community. Without their participation, the campaign is likely to fail, for two reasons.

With less than 100% compliance by the community, the risk of spreading disease through open defection still exists.

Second, because of the influence working men exert, if they don't participate there's a greater chance that other members of the community will "defect" and revert to the old norm.

Desired State

Reducing the probability of defection requires maximizing the gain in benefits to the individual, and minimizing their expected costs. With working men, for example, this might mean assuring them that they will be respected as people who are helping their community progress to good health (maximizing benefit) and explaining that it is easy and inexpensive to maintain the toilet (minimizing cost).

The composition and sequence in which groups are brought into the campaign is also important.

Marginal contributions from community influencers brought in earlier are higher than if they are brought in late. This is because those inducted later may think they are considered less important, and thus put less effort into adopting the new norms. Thus, working men may make a larger contribution toward sanitation if they are inducted first, by having a heightened sense of their importance in bringing about positive change. Teachers, on the other hand, will be easier to induct and could be brought on board immediately afterward, followed by housewives and finally young men.

By using game theory to decide the composition and sequence of group formation for sanitation behavior, we reframe the problem we're trying to solve.

What we ask now:

How can we increase the number of people reached with pro-sanitation campaigns? How can we improve adoption using popular community figures?

What should we ask:

Who should we target first, and in what sequence? How should we structure community-wide communication to maximize the value that people perceive from adopting a new norm?

STORY 3

Exploring Interactions between groups during a health crisis

Uptake of contact tracing app is a strategic interaction between Public Health Officials and Citizens because of the social costs associated with COVID-19

As the COVID-19 pandemic continues, identifying those with the virus is an essential strategy for controlling its spread. In India, with the world's second largest population and a relatively weak public health system, the public health authorities need to target their limited testing resources at those most likely to be at high risk of contracting or spreading COVID-19. Travelers, in particular, run the risk of spreading the virus to fellow passengers, or to other people at their destination, and for that reason the government requires people to download its contact-tracing app as a condition of buying a plane or train ticket.

But how can authorities make best use of testing in the medium term, when we are "learning to live with COVID-19"? Let's hypothesize a scenario where the coronavirus has not been eradicated and full vaccination is not yet available, but the country is trying to return to as normal a life as possible. Having the contact-tracing app on one's phone is optional, and no longer a requirement for travel.

Travelers know that health officials at transport hubs are authorized to ask passengers to take a voluntary coronavirus test before boarding, even if they appear asymptomatic. But health officials don't want to pick travelers at random, because that is an inefficient use of limited testing resources and raises the risk of false-positive results. So how can they identify the people most likely to be at high risk for the virus?

One factor they can consider in choosing who to ask for a test is whether the traveler says they have downloaded the contact-tracing app. The app may be a social signal – something that conveys a nonverbal cue about their status. But what exactly does having the app tell the health officer at the airport or bus depot? Diligent, rule-abiding citizen, or risk-taking individual who doesn't care about exposure to the coronavirus? That's what the health officer needs to figure out.

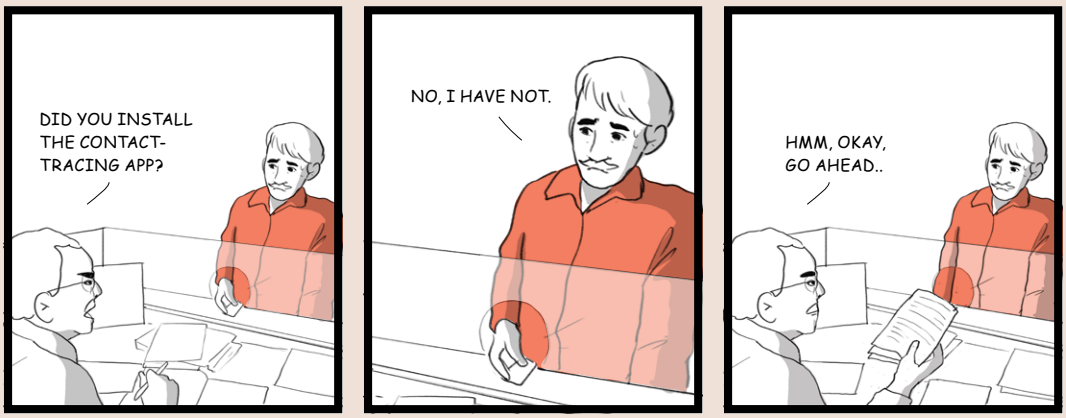
Game theory can lay out the differing preference sets of travelers and health authorities, and the incentives that may motivate adoption of the app.

We can look at the problem as a game in which the players on one side are local health administrators, with travelers on the other. Each set of players has different preferences, which may or may not be mutually aligned to achieve or promote social welfare. They also have different levels of information about risk status: the traveler knows whether they have engaged in risky behavior, but the health officer doesn't. This makes the officer's beliefs an integral part of how players analyze their payoffs.

Let's consider the traveler first. High-risk individuals have symptoms of the disease or have traveled abroad, met someone symptomatic, or not practiced social distancing. Low-risk individuals have taken adequate care to prevent infection. Downloading the app might seem to be both a self-interested and an altruistic act on the part of the individual: I want to be traced if I've come into contact with someone who's tested positive; and I want my own contacts to be protected if I test positive. Perhaps I also want to be a "good citizen", too.

But it may well be more complicated than that, because downloading the app has costs, too. For example, if the traveler is notified that they've been in contact with someone who has tested positive, they will face significant logistical, financial, and emotional costs of having to quarantine, not to mention the physical discomfort of getting tested. Some people will also be concerned about how the government will handle the privacy of contact-tracing data – and whether the app itself could be a surveillance tool.

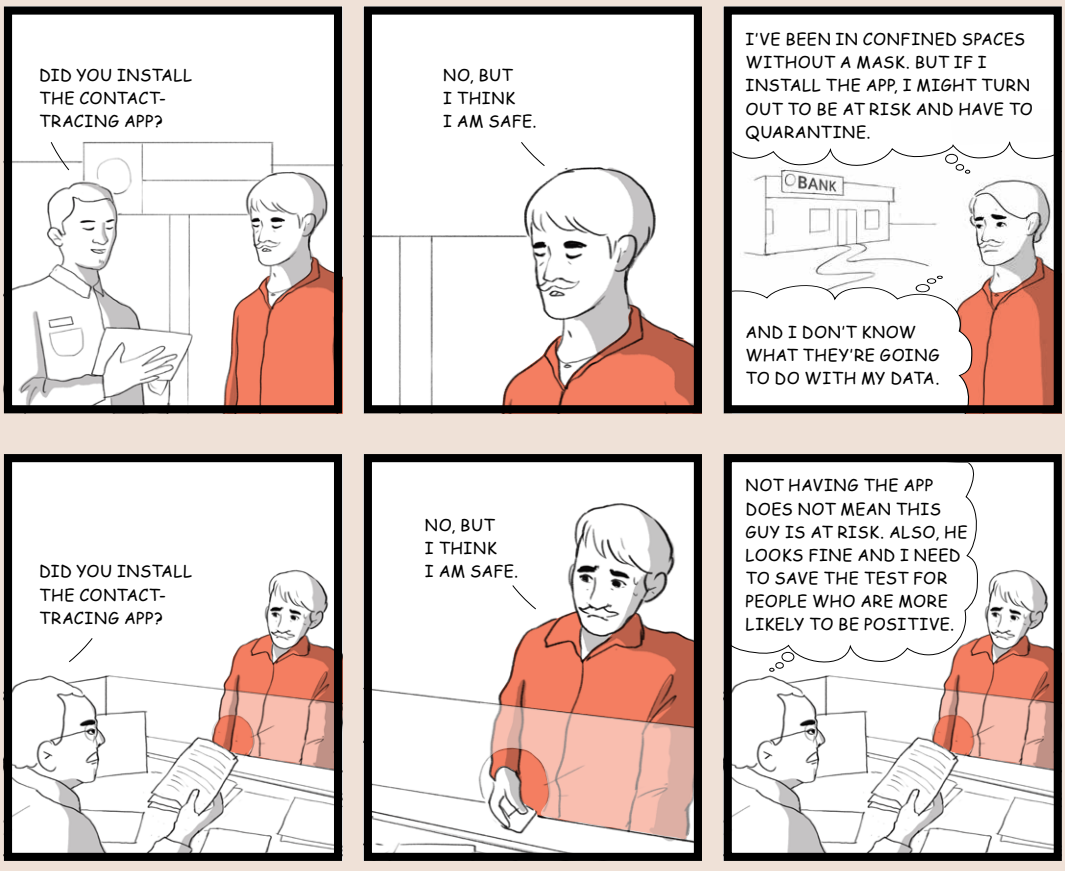
How we might think of interactions



Now let's turn to the health official at the transport hub. The payoff of testing someone at high risk of having the virus is that the limited number of test kits are used most effectively, which saves money; fewer high-risk individuals slip through the testing net to increase the risk of infection spread; and there's a reduced chance of false-positive results (from testing low-risk people). The overall payoff will be to control the spread of COVID-19.

The costs are the financial costs of testing – and the difficulty of deciphering the social signal that is being given by the person who has downloaded the app (or not). If a traveler has the app, the health officer could interpret it as a signal that the traveler is responsible and therefore probably low-risk. In that case, there is a limited payoff from testing for both players. Or are they a high-risk individual who is simply trying to send a (misleading) signal about their risk status?

How we should think of interactions



What is the optimal response?

The traveler will decide whether to install the app based on their prior beliefs, preferences about installation, and desire to minimize the cost for themselves. Similarly, the health officer will try to anticipate the calculations the traveler has made. Both players will respond after weighing what the other's optimal response will be. From the traveler's point of view, it may be to avoid installing the contact-tracing app, since it allows them to avoid the costs and may even signal to others that they are low-risk. We might see this behavior across both low- and high-risk individuals. The health officer's best response may be to decide not to test individuals who haven't downloaded the app, in order to reduce overall costs and the chance of false positives.

Implications: change the payoffs

From a public health perspective, the obvious problem with this outcome is that it discourages the use of the contact-tracing app. In an environment where some install the app and others do not, the cost to health officers of deciphering who is at risk and hence should be tested increases, and may be prone to their beliefs and biases. On the other hand, if installation of the app becomes a strong signal of a safe status, and everyone installs it, it may no longer be useful for determining who should be tested at travel points, but it does increase the efficiency and effectiveness of tracking and tracing the population as a whole. Since travelers can be a significant vector for spreading COVID-19, it's in everyone's interest to make sure they have the app.

This means the game needs to alter their preferences and reduce the costs associated with downloading it. Messaging, rewards, and norms can play an important role in this.

Increase shared interest and coordination:

Messaging to strengthen norms about social interdependence and an awareness of collective agency can create an additional payoff: this has helped increase contact-tracing uptake in countries like Taiwan.

Build trust and reduce fear:

In India there have been serious concerns about data privacy and the abuse of contact-tracing to conduct surveillance, particularly in ethnic-minority populations. Creating visible cues such as asking for only a mobile phone number rather than name, age and gender could reduce the privacy costs associated with downloading the app.

Keeping in mind a resurgence of COVID-19, future pandemics, or even commonplace communicable diseases, it is important to model contact tracing behavior and understand better how interactions take place. As the world builds preparedness for future outbreaks, it is worth considering the costs each stakeholder has to incur and the strategic interactions that take place between citizens (not just travelers) and the healthcare sector.

By using game theory to understand preferences for various groups in a health crisis, we alter the questions we ask and find different ways to navigate this complex space.

What we ask now:

How can we improve the use of contact tracing applications?

What should we ask:

For pandemics stretching over years, would uptake of a contact-tracing app serve as a strong signal about people's risk status and help public health officials to filter better samples for tests?