Epidemiology modelling has generally followed two major approaches: the continuous and the discrete. In the continuous (deterministic) approach, we use differential or partial differential equations, characterised by lumped or aggregated variables and presumed constants relating them. We try to predict the variables, such as the number of susceptible or infected people, given constants, such as the rate of transmission [5,6]. In the discrete (individual) approach [7], we divide the population into individuals, and try to model their interactions, sometimes describing them as occurring on a social network, which is a discrete structure in the sense of graph theory. This discrete structure can take the extreme of complete representation of urban geography and transportation [8]. An analogy may be made with the physics of fluids. We may try to solve the continuous equations of fluid flow, as in computational fluid dynamics [9], or we may try to simulate the behaviour of all the individual molecules in the fluid and their interactions with those they come in contact with, as in Monte Carlo molecular dynamics [10-14].

Stochastic process modelling [15] represents a compromise, in which we attempt to use aggregated parameters when approximating large populations, but add in "noise" to represent individual variations. Stochastic models generally agree with deterministic models when the disease is endemic, but may differ significantly when the disease is close to extinction or just starting. Stochastic effects tend to drive outcomes that are near zero to actual extinction, which would theoretically take an infinite amount of time in deterministic models.

Certain control points, i.e., parameters that we think we can manipulate to alter the course of an epidemic, are evident with HIV/AIDS. For example, it has long been known that HIV/AIDS could be significantly controlled with condoms, if only we could get enough people to use them [16-21]. Thailand took this approach, which met with great success [22,23], but continual attention is needed as behaviour changes [24]. For example, the growth of intravenous drug use provides a route of transmission for which condoms are ineffective, exasperated by the observation that condom use is difficult to promote amongst intravenous drug users for protecting their sexual partners [25]. For HIV/AIDS, we must therefore have multiple control points.

Two observations, however, make the multiple control point approach dubious [26]. First is the observation of, at best, a weak correlation between the aggregated parameters of the continuous approach, that cannot be dismissed as mere statistical inaccuracy in estimating parameters [27]. In other words, when we guess at what factors are important (such as aggregating people into certain categories) and how they should affect one another (such as presuming which aggregated groups mate with which other groups), the predictive value of our models proves to be quite poor, or downright wrong. More refined continuous models help to some extent in unravelling deeper causal relations and improving correlations, but the very concept that all people in one group randomly mate with people in another group is obviously a poor approximation to how, where, when and how often they actually pair up. Poisson statistics are implicitly assumed, which are themselves but a crude approximation to the time course of human behaviour.

The second doubt [26] about the multiple-control-point approach is the dynamic nature of networks of human sexual behaviour when controls are applied. For example, police action may close down one venue for sex work, but an alternative arises to replace it. Thus, shifting behaviour and "hidden groups" [28,29] not foreseen by field workers make control points a matter of guesswork. One hope is that a higher understanding of dynamic networks as complex systems may give us new points of control [26], but how to observe changing networks of behaviour with limited field work resources is problematic.

In a way, these efforts to refine different models make them approach one another. We discretise the continuous approach, by subdividing aggregated parameters, or smooth the discrete approach, by looking at the overall behaviour of networks, their so-called emergent features. But do they thereby better approximate the real world?

While we try to empower people through education, stigma reduction, harm reduction, free condoms, needle exchange programs, etc., the role of the individual in halting the HIV/AIDS epidemic is basically passive with these approaches. We somehow hope that when they choose a mate, engage a sex worker, etc., individuals will modify their behaviour in a way that reduces or eliminates their contribution to the dynamics of the epidemic. When they fail to do as we hope, we attribute this to inadequate education or empowerment, or the heat of the moment. We

Waivers that allow tracking of all transactions were signed by all 13 million Second Life participants [44] when they joined [45]. The social networks of havatars observed in a virtual world may prove a better representation of real-world disease transmission networks than any attempt at direct observation of the real world could ever produce.

The research on havatars that we propose raises questions of privacy, ethics and informed consent that are unresolved as of now, but it has been suggested that the general difficulty of a person knowing which other real life person corresponds to a given havatar may keep these problems at bay [46].

The next level of havatar epidemiology research would be to create consequences of disease transmission. In virtual worlds, people react to parameters at many levels, and have the opportunity to grasp a situation as a whole [47]. This is what makes multilevel control by havatars a potentially powerful means of epidemic control, because the person involved has the opportunity to grasp the epidemic in many ways. We can see this operating in the simulated "Whypox" epidemics [37]. Two simple consequences occurred for avatars: they acquired spots on their skins that the person could not remove, and they "sneezed", interjecting the word "achoo" at random in typed conversations between havatars, sometimes requiring retyping of a command that would have initiated an animated sequence. The people behind the avatars reacted strongly to this imposed situation, and changed their behaviour to alleviate or avoid it.

For an HIV/AIDS simulation, we could envision more drastic consequences for havatars, with permission of their human components. For example, most people design their avatars to look good. Simulated HIV/AIDS might make them look ghastly, with weight loss, etc., cause them to interrupt their behaviour to take antiretroviral drugs, or even get too sick to do much and die. This might lead to stigma, formation of ALWA groups (Avatars Living With AIDS), etc. Analogous avatar effects have been simulated for neurological conditions [48]. Economic losses [49,50], such as (simulated) drug costs, could also be of consequence not only to the avatar and its accoutrements, but also to the real-life person who has to pay for some of them with real money [51]. Thus, with such an epidemiological experiment, we would start crossing the virtual/real-world boundary. This boundary crossing can clearly be seen in the behaviour of real life married couples who enter a virtual world [52].

The third level of epidemiological research would fully cross the virtual world/real-world boundary. This is already being done with computer-controlled sex toys that can be controlled by other havatars [53], and could be regarded as an extension of the search for self-knowledge, which often involves sexual behaviour [54]. Of course, so long as these toys aren't shared between real people, real HIV won't be transmitted. But if the avatars can be computer infected, their people might react accordingly. This raises the general question of whether internet sex, like phone sex, will become sufficiently widespread, perhaps because of these remotely controllable haptic devices, to impact and cut into real-world sex work (Joel Kettner, personal communication). The argument that condom availability promotes promiscuous behaviour rapidly lost out to the perception that condoms prevent disease transmission, and, at least in the case of Thailand, promotion of condom use and HIV/AIDS awareness led to a decline in sex work [24]. Similarly, the current notion that the Internet facilitates sexual contacts may lose out to idea that the Internet prevents real disease transmission.

Whether havatar sex will have an impact on HIV transmission between real humans is of course not yet known. When one havatar encounters another, they can examine each other's "profiles", which include, for example, listings of the groups they belong to. The record could show simulated HIV status as one of the consequences in the virtual world. Attempts to do anything similar in the real world are limited so far. Sex clubs and pornography actors have tried to restrict membership to HIV-free people, and a few cases of failure to divulge one's HIV status have hit the courts, but how this plays out in daily life is uncertain, and obviously of insufficient impact to halt the HIV/AIDS epidemic. Transferring codes of ethics developed in virtual worlds to real life is problematic, though even in the free-wheeling atmosphere of Second Life, the reverse has already occurred in terms of gambling and banking [55]. However, havatars give us an interesting tool with which to explore these options for epidemic control.

It will be argued against this approach that the cost of Internet access is beyond the poor populations of the world where HIV/AIDS flourishes most, and that the havatar population is thus a biased sampling of the human population. However, if we consider the rate of adoption of cell phones [56] or programs to introduce rugged, hand- and solar-powered, internet-connectable computers at low cost worldwide [57], the democratising influence of virtual worlds [58], and the widespread use of the internet to make sexual contacts [59], this leapfrogging might occur quite rapidly.

Conclusion

This paper is part of an effort to develop a worldwide model of -5.6999998(c)hoLfC 9.72000026 313S of an ehever, i(t)-5.90

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