'Clustering of exemptions' as a collective action threat to herd immunity

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Abstract

In this paper, we examine the phenomenon of 'clustering of exemptions' to childhood vaccination, and the dangers this poses both to those exempted as well as the general population. We examine how clusters of exemptions might form through collective action as described by Thomas Schelling, and how religious groups who live in close proximity to one another can "self-select" in a way that exacerbates this phenomenon. Given the growing number of exemptions and the increasing visibility of the anti-vaccine movement, policy makers must be vigilant for dangerous clustering in order to avoid loss of herd immunity.

1. Introduction

Herd immunity is a concept that is at the foundation of any public health vaccination program. No vaccine is 100% effective, so the eradication, elimination or radical reduction of epidemics relies on the protection provided when a large enough percentage of a given population is immune, so as to prevent potential outbreaks of vaccine-preventable disease from getting started. In this way, even those for whom vaccination is not effective are protected through the unlikelihood that they will be exposed to the disease (since an outbreak cannot get a "foothold" where herd immunity is achieved). Along with those who are vaccinated but do not achieve immunity to vaccine-preventable diseases, children exempted from mandatory vaccination are protected through herd immunity. The greater the number of people not immune, however, the greater the chances become that the protection provided through herd immunity will be lost.

In this context, the medical literature has recently begun to focus on the potential harmful effects of the anti-vaccination movement and expanding exemptions to mandatory childhood vaccination [1]. For example, one study found that drops in vaccination rates due to this movement in the UK, Japan, Sweden, Russia, Ireland, Italy, the former West Germany and Australia have resulted in Pertussis incidence 10–100 times greater than in countries where high vaccine coverage was maintained [2]. The level of vaccination required in order to achieve herd immunity varies by disease, but generally ranges from 83 to 94% [3]. Although historically, the level of exemptions to vaccination in the US has not been high enough to pose a threat (not exceeding 3% for any state prior to 2000), the exemption rate is rising. In Michigan, the percentage of children entering the school system who were exempt from vaccination

requirements exceeded 3% for the first time in 2000 [4]. In Colorado, the percentage of those seeking exemptions rose by 59% between 1987 and 1998.

In order to avoid loss of protection through herd immunity, the literature calls for greater public and parental education about the risks associated with being vaccinated versus not being vaccinated, in order to counter the influence of the anti-vaccination movement [5]. Education concerning the relative risks of opting out of vaccination is mitigated, however, when the basis of exemption is not related to risk assessment, but to religious beliefs. In particular, one important area related to this concern has not received proper attention: the phenomenon of "clustering" and how this might exacerbate the effects of the anti-vaccination movement. Clustering, as this relates to vaccination, is a phenomenon in which the proportion of people who seek exemption to mandatory vaccination is higher in a particular locality than it is for the broader population. It is this phenomenon that we examine in this paper.

2. The phenomenon of clustering and critical mass

The phenomenon of clustering is attributable to a number of things. For example, a child may have an adverse reaction to vaccination; when this happens in a small community, it may become a focus of that community's attention, leading to a higher than normal exemption rate. Most importantly for our purposes, people who share religious beliefs that object to vaccination will, in many cases, live in close proximity to each other. For example, in Ohio, the Amish population is concentrated in nine of the state's 88 counties, with 7 of those 9 counties being contiguous [6]. Whatever the reasons that motivate some individuals to seek exemption to mandatory childhood vaccination, there is a danger of clustering once exemption begins to take hold in a particular community. As we will see below, this can create conditions in which exemption to vaccination multiplies.

In a classic book titled Micromotives and Macrobehavior [7], Thomas Schelling examines the ways in which the behavior of some individuals effect the behavior of others. The foundational concept Schelling works from is the concept of "critical mass." This concept involves an understanding of behavior as becoming widespread and self-sustaining once enough people have begun to engage in this behavior. The examples Schelling gives are as follows:

   I walk across the lawn if that seems to be what others are doing; I sometimes double-park if it looks as though everybody is double-parked…. If a few people get away with smoking in a non-smoking section… so many others will light up… [8].

Schelling goes on to observe:

   What is common to all these examples is the way people's behavior depends on how many are behaving a particular way… [9].

The influence of the behavior of some people on the behavior of others may well lead to a multiplying effect once a critical mass is reached. An example Schelling uses to illustrate this phenomenon involves students deciding whether to take a course for a letter grade or pass–fail [10]: if this option is available to all students, there will be some who take the course for a grade and some who take it pass–fail regardless of what others do. Many students, however, will choose according to how many others are choosing in that particular way—this is called the "intermediate group." The actual number of other students required to influence the "intermediate group" will differ, however, among the members of

the intermediate group. Nonetheless, if a critical mass of students who choose one option independent of the actions of others is reached, the intermediate group can soon begin to choose in a common way.

Schelling explains that if the number of students who choose to take the course pass–fail is great enough to induce those who require only a minimum number of others in order to choose pass–fail, then these students will be influenced to choose this option. When these "intermediate group" students requiring only a minimal level of others are added to those who choose pass–fail independent of the behavior of others, however, it forms a group of enough students choosing pass–fail to induce more "intermediate group" students to choose the pass–fail option. The addition of these students to those choosing pass–fail, in turn, induce even more intermediate group students to choose this option, and so on until all but the students who will choose to take the course for a letter grade regardless of the behavior of others are taking the course pass–fail. This phenomenon is known as "tipping" [11].

How do the above phenomena relate to threats to herd immunity? Because those whose religious or personal views create a willingness to seek exemption to mandatory childhood vaccination often live, as we discussed earlier, in proximity to others who share these outlooks, the possibility of reaching a "critical mass" of exemptors large enough to undermine herd immunity is made more likely. Herd immunity, though not requiring 100% compliance with mandatory vaccination, nonetheless requires a very high percentage of the population to be vaccinated (since not all of those who are vaccinated will achieve immunity).

Based on national and state averages, the number of people who seek exemption from mandatory childhood vaccination is, on average, very low [12]. There are "clusters" of exemptions in local communities, however, that are much higher than the national or state averages. For example, while the percentage of people exempted from mandatory childhood vaccination is only 0.64% nationally, Utah has a rate of exemption twice that percentage (1.2%). Furthermore, one county in Utah (Washington county), has an exemption rate nearly six times the national average (3.7%). This high exemption rate undermined herd immunity for this county, resulting in an outbreak of measles lasting 6 viral generations and 107 cases, half of which were contracted by people who had been vaccinated [13].

Returning to Schelling's analysis, even if we assume that most people will not fall into an "intermediate group" for seeking exemption to vaccination (unlike the students in Schelling's example), but instead will fall into the group that will choose vaccination for their child regardless of the behavior of others, the tendency of those who might be induced to seek exemption, to live in proximity to others who might also be induced to seek exemption, creates conditions in which a critical mass of exemptors could result in "tipping" that undermines herd immunity. That is, even if we assume that the "intermediate group" for seeking exemption to childhood vaccination is small, the tendency of those who do fall into this intermediate group to live in proximity to others in this intermediate group poses a potential "tipping" phenomenon that could undermine herd immunity.

Evidence for the results of clustering can be seen in recent outbreaks of pertussis and rubella among Amish populations, and in the period 1985–1994, when 13 outbreaks of measles among persons with religious exemptions were documented, resulting in more than 1200 cases and at least 9 deaths. This phenomenon is not unique to the US: a 1999 measles outbreak in the Netherlands also exemplifies this phenomenon. What began with a cluster of children enrolled in a religious school whose members routinely decline vaccination, grew into a 10-month-long outbreak, with 2961 reported cases. These cases were largely concentrated in the communities in which members of this religious organization reside, and the vast majority of those who contracted the disease—2317 of the 2961 cases—were found

to have been eligible for vaccination but had declined for religious reasons. In addition, five percent of those who contracted the disease whose vaccination status was known had received at least one dose of the measles mumps and rubella (MMR) vaccine [14]. While vaccination of children in the Netherlands is recommended rather than compulsory for entrance into schools, most children are vaccinated. However, in some communities with significant numbers of members of this religious group coverage rates were as low as 53%.

3. Local communities and critical mass

Central to the understanding of what dangers the phenomena Schelling describes pose to herd immunity, is a recognition that the number of "others" needed to induce "tipping" may be related to the make-up of the community one lives in. While some behaviors will be influenced by the absolute number of other people who engage in that behavior, Schelling observes that other behaviors are "undoubtedly" influenced by the proportion of other people who engage in that behavior, rather than absolute numbers [15]. For these behaviors, the make-up of a particular community becomes of great importance. If a community is composed of people that disproportionately tend to display a particular characteristic, the tipping phenomenon is increased when related to proportionate numbers. For example, consider attendance at an "optional" class field trip: if the attendance of some is influenced by the proportion of other class members who attend, it might matter if the course is one that is a "general required course" or one attracting only students who have an inherent interest in the subject. If the latter, the students may have "self-selected" according to characteristics that will bias the proportion who attend the field trip. Regarding this type of attendance phenomenon, Schelling states:

   By separating away half the population, and specifically the half least likely to attend, we have doubled the influence of everybody who attends—doubled the percentage that he or she represents [16].

In brief, when a group of people is composed in a way that tends to select for a certain characteristic or characteristics, the influence of those characteristics becomes greater. This phenomenon is known as "separating populations." States Schelling:

   If it is proportions that matter—smoking cigarettes or wearing turtlenecks… depending on the fraction of the relevant population that does so—there is the possibility of dividing or separating populations. If people are influenced by local populations—the people they live with or work with or play or eat with or go to school with or ride the bus with… any local concentration of the people most likely to display the behavior will enhance the likelihood that, at least in that locality, the activity will reach critical mass [16].

Exemption to mandatory childhood vaccination is often based on religious beliefs that are not "mainstream" in the society as a whole. Often, this type of shared religious belief will result in communities whose make-up is "self-selected" for this characteristic. The Amish, Christian Scientists, and Jehovah's witnesses are but a few examples of religious groups whose members are likely (relative to the population as a whole) to seek exemption to childhood vaccination. The fact that members of groups whose shared beliefs tend to make them open to seeking exemption also tend, as we have seen at the outset of this paper and in outbreaks described in the previous section, to live in proximity to other members of these groups, create conditions in which a clustering of exemptions sufficient to undermine herd immunity might occur.

The dangers that the 'clustering' phenomenon poses goes beyond the groups that opt out of vaccination. For example, in Colorado public health records confirmed that, for 11% of vaccinated children who contracted measles between 1987 and 1998, the exposure source was unvaccinated children; however, because two-thirds of the measles exposure sources during this time period were unknown, it is reasonable to deduce that the actual percentage of vaccinated children who contracted measles from unvaccinated neighbors was significantly higher. Awareness of this danger is essential for physicians advising parents in communities susceptible to clustering, and for local authorities who determine whether to grant exemption to mandatory childhood vaccination in a particular community.

Given the growing numbers of exemptions, it is imperative that physicians and policy makers be vigilant for dangerous "clustering" that might undermine herd immunity. In communities susceptible to the clustering phenomenon, difficult decisions may need to be made to deny exemptions, even where current rates of exemption fall below a level that threatens herd immunity, in order to avoid a snowballing of exemptions that would threaten not only those who seek exemption, but some percentage of those who undergo vaccination.

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