Safety in Numbers for walkers and bicyclists: exploring the mechanisms

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INTRODUCTION
Safety in Numbers is the phenomenon by which the per-walker or per-bicyclist frequency of being struck by motorists declines as the amount of walking or bicycling on a street or in a region increases. That is, while the absolute number of walkers or bicyclists struck by motorists may increase with more people walking or bicycling, due to the increase in exposure, the number of such collisions is observed to increase more slowly than the increase in the number of walkers or bicyclists, or even decrease.

The emergence of Safety in Numbers in the 1990s as a widely observed phenomenon reinforces the understanding that the number of injuries suffered by walkers or bicyclists is an imperfect indicator of the danger of walking or bicycling. Rather, the number of walking or bicycling injuries must be adjusted for the numbers of individuals walking or bicycling.

An example from a different context may be helpful here. The fact that no one is attacked in shark-infested waters doesn’t demonstrate that the waters are safe for swimming. The low casualities could simply mean no one swims. Similarly, people tend to refrain from walking or bicycling where they believe they will place themselves in danger by doing so. Consequently, safety is best measured by the risk of injury, not by the number of injuries. Safety is indicated by the absence of danger, not by an absence of injuries.

The Safety in Numbers effect for motorist collisions with pedestrians and bicyclists was first described in the context of intersections in Sweden in 1993. Thereafter, the effect was also found to apply to entire towns, cities and countries, and even across time periods. Numerous additional studies using a variety of data sources confirmed the existence of the Safety in Numbers effect.

Mathematically, the most concise formulation of Safety in Numbers is that the number of people walking or bicycling who are struck by motorists increases only with about 0.4 power of the number of people walking or bicycling (the precise value of the exponent varies with the data set; one review found exponents ranging from 0.14 to 0.74). According to this relationship, doubling the number of people walking or bicycling would increase the number of people struck by only 32% (2 raised to the 0.4 power equals 1.32, less 1, to yield the increase). Any individual’s risk of being hit would then decrease to 66% of the previous risk (132% divided by 2).

In sharp contrast, motorist crashes vary nearly linearly with the number of motor vehicles. The fact that the incidence of motorist striking pedestrians or bicyclists increases much less than linearly with the latter’s numbers suggests that there are one or more special mechanisms influencing these collisions.

The impetus for writing Safety in Numbers was to reduce the conflict between encouraging walking and bicycling for the health benefits of physical activity and discouraging walking and bicycling to prevent injuries. Safety in Numbers also means that injury prevention efforts that inadvertently reduce walking or bicycling may actually make walking and bicycling more dangerous for those who continue to walk or bicycle. This can present a serious ethical dilemma for policy makers. Furthermore, given the health benefits that accrue from regular physical activity, the reduced level of walking or bicycling may impose health costs that exceed the benefit from any reduction in injuries. Since then, Safety in Numbers has also been used to show that encouraging a shift from driving to walking and bicycling to mitigate climate change will improve health.

The mechanisms underpinning the Safety in Numbers phenomenon remain poorly understood. This commentary explores possible mechanisms and policy implications.

Possible hypotheses to explain safety in numbers
Several hypotheses have been presented for explaining the Safety in Numbers effect. Ecological comparisons of the amount of walking or bicycling at micro level (intersections and along corridors) and at macro level (cities, regions, countries) show that as activity level varies several fold, corresponding injury risk varies by nearly a factor of 10. Hence, the likely causative hypotheses need to show a similar sized effect.

Safer street regulations, design and operation
Laws and regulations protective of people walking and bicycling, and adherence to those laws and regulations, are more likely to exist and be observed in societies with more walking and bicycling. Safer street designs and operations for people walking and bicycling attract more people to walk and bicycle, and consequently the correlation could merely be an artefact of these improvements. However, the population effect of these interventions is an order of magnitude less than observed in ecological comparisons between countries and within countries, and hence would only explain some of the Safety in Numbers effect. Furthermore, the Safety in Numbers effect has been shown with daily and seasonal fluctuations in bicycle use, indicating that it operates independently of infrastructure changes.

Changes in behaviour of people walking or bicycling
 Jacobsen has commented that “it seems unlikely that people walking or bicycling obey traffic laws more or defer to motorists more in societies or time periods with greater walking and bicycling. Indeed it seems less likely...” Greater rule-breaking was observed during seasons with higher numbers of bicyclists in Norway, a phenomenon that would tend to undermine rather than explain Safety in Numbers.

Where more people walk or bicycle, it seems likely that more vulnerable populations, such as older adults and children, would also walk or bicycle more, which would tend to increase the average injury risk. Yet that is the opposite of what we observe in Safety in Numbers. Conversely, where few people walk or bicycle, those who do may have little choice due to poverty or disability, and hence may be more vulnerable; or it could be that the few people who do walk or bicycle may be the most risk-tolerant, and therefore more vulnerable to motorist collisions. The role of self-selection in explaining Safety in Numbers is mixed and thus unlikely to qualify as a major factor.

That pedestrians and bicycle riders may cluster, like ships into convoys, could also explain Safety in Numbers. An agent-based...
model that assumed bicyclists would favour safer roads, and shy away from dangerous traffic, showed a Safety in Numbers effect. However, this hypothesis fails to explain why Safety in Numbers is so widely observed without clustering; nor is it based on any empirical evidence of actual clustering by people on bicycles. Indeed, pedestrian volume was predicted to be concentrated on the busiest traffic volume streets in Oakland, further undermining the clustering hypothesis.

Changes in behaviour of person driving
In places or during time periods with more walking and bicycling, motorists are themselves more likely to walk or bicycle at least occasionally, and accordingly might give greater consideration to people walking and bicycling. In one study, Australian drivers who also bicycled were 50% more likely than drivers who did not to self-report safer driving behaviours related to sharing roads with bicyclists. Similarly, of motorists who collided with motorcyclists in Italy, Spain, Germany, Holland and France, motorists who were also licensed for motorcycle operation were found to be less likely to be responsible for the collision. Therefore, with a factor of two, this hypothesis may explain a portion of the Safety in Numbers effect.

Signal detection theory provides a possible framework for understanding the Safety in Numbers effect. It theorises that probability of detection depends upon (1) how clearly the target can be detected, (2) the observer’s relative frequency of experiencing the target, and (3) the consequences of detection.

Unfortunately, motorists cannot always clearly detect people walking or bicycling. Over 90% of the information drivers receive is visual. Driving requires continual and rapid decision-making and makes significant cognitive demands of the motorist, who must detect, recognise, predict, and respond to a variety of stationary and moving objects, in a range of sizes, in a highly dynamic environment. Furthermore, drivers must not just select targets for their attention; they must continuously identify the most important target for their driving task. In short, driving demands a tremendous amount of visual and cognitive processing.

Most humans can process no more than three pieces of visual information per second. Driving presents many situations in which motorists operate beyond their visual or perceptual capabilities.

Consequently, motorists create mental models based on their expectations and experience. Thus, if the motorist mostly encounters motor vehicles, their model will be of motor vehicles. This understanding is evidenced by experienced motorists more commonly having ‘looked but failed to see’ in the event of a collision. Providing more time helps; reducing motorists’ speed at intersections enabled them to see bicyclists better. Furthermore, motorists focus their attention on the parts of the visual field with the most dangerous hazards (e.g., other motor vehicles), and hence away from the edges of the road where pedestrians and bicyclists are more likely to be found. That drivers look to the centre of the road compounds the limits of human vision acuity, which is greatest towards the vision’s centre and rapidly diminishes towards the periphery. Finally, pedestrians and bicyclists are smaller than motor vehicles, and hence motorists are less likely to see them. In studies using static images of traffic scenes, observers missed as many as 65% of the pedestrians. As the otherwise identical scenes were modified to add more motor vehicles, observers were less likely to see bicyclists, motorcyclists and particularly pedestrians.

Signal detection theory also shows the importance of the observer’s relative frequency of experiencing the target. Rare targets are often missed and very rare targets are highly likely to be missed. A study using static images showed a strong non-linear relationship between prevalence and detection, with a sharp drop in accuracy at around 1% of the trials. This effect was even more pronounced with hard to detect targets. In addition, the observers would stop searching more quickly when searching for rare targets. In most motorists’ experience, the prevalence of pedestrians and bicyclists in their field of vision is low. Stated more simply, the rarity of people walking and bicycling makes them harder to detect and to require more response time than more common objects. This difficulty in detecting rare targets is consistent with the empirical results observed in Safety in Numbers.

Much of the understanding of prevalence effects results from static environments, where the observer decides whether the target is present. A dynamic environment complicates detecting pedestrians and bicyclists, as the motorist is under time pressure and the situation is interactive.

In one driving simulator study, motorists were able to detect motorcyclists and buses more quickly when they were more prevalent. For example, when motorcyclists were made more prevalent, they were detected 51 m further away, which equated to motorists having an extra 3 s to respond. This additional time exceeds the accepted motorists’ perception and response time of 2 s, which provides a plausible explanation of why crashes are less likely with increasing prevalence. Indeed, the Safety in Numbers effect has also been found with child passengers on motorcycles. Simulator studies with bicyclists and pedestrians would help confirm this evidence.

Relative frequency is also a factor in inattentional blindness, the failure to detect unexpected objects. This phenomenon gained attention through an experiment in which observers counted passes of basketballs among a handful of people while a human in a gorilla suit walked through the game. Strikingly, half of the observers failed to notice the gorilla. Inattentional blindness is more likely when the unexpected target differs from the focus of attention in size, colour, shape and location, all issues associated with a person walking or bicycling in a field of motor vehicles. This pattern is analogous to motorists focusing on motor vehicles and not seeing people walking and bicycling; the ‘looked but failed to see’ collision. Safety in Numbers could be an antidote, in real time, as multiple people walking or bicycling are harder to miss, and also over time, as motorists ‘learn’ to see what was previously anomalous and thus less apparent.

**DISCUSSION**

**Implications for policy makers**

An overall lesson of the Safety in Numbers effect is that interventions to reduce motor vehicle collisions with pedestrians and bicyclists are especially needed in areas with high numbers of injuries, and indeed individual risk is immaterial in this instance since the goal is to reduce the number of injuries. For example, in San Francisco, planners determined that 6% of the streets were responsible for 60% of pedestrian collisions, and they have made addressing those streets their highest priority. Similarly, safety infrastructure should be targeted to support interventions with the greatest potential to increase the number of people walking or bicycling—to maximise the health benefits from increased physical activity and to reduce risks.

If indeed failures in perception are an important contributory factor for motorist collisions with pedestrians and bicyclists, it has profound implications for injury prevention efforts. If ‘quite a large
proportion’ of motorists and the people they strike walking or bicycling are attempting to adhere to the rules.33 then a narrow emphasis on educating people to follow the rules may be an ineffectual way to reduce these collisions. The psychology of signal detection offers a way to evaluate interventions to improve the safety of people walking and bicycling. Improving the detectability of people walking and bicycling is one strategy. Perception and attention can be lowered so that motorists have more tolerance for the possible presence of people walking and bicycling. These reminders could be as simple as making crosswalks more visible and marking bicycle lanes on major streets; even though these interventions help, they may not be fully effective.25 Given humans’ narrow field of attention and visual acuity,26 curbs at intersections could be extended beyond parked cars so that a pedestrian is nearer the motorists’ zone of attention. Because driving taxes and sometimes exceeds motorists’ visual processing ability, either motorised traffic needs to be separated from vulnerable road users, or the speeds of the motorised traffic need to be lowered so that motorists have more time to detect and perceive people walking and bicycling. Note that these concepts are integral to Vision Zero’s approach to eliminating fatalities, which is based on the human body’s tolerance for trauma. Vision Zero calls for limiting motor vehicle speeds to 30 km/h (20 mph) on streets with people walking and bicycling and separating them on higher-speed roads.34

Increasing the frequency of motorist encounters with people walking and bicycling is the second approach to improve signal detection. Concentrating people walking and bicycling to fewer streets would make motorists more aware of them on those streets.5 Berkeley, California has successfully implemented such a system for bicycling.35 One concern with this approach is that it would likely increase the risk of walking or bicycling on non-preferred streets. Addressing the consequences for failure to detect people walking and bicycling is the third approach to improve signal detection. Changes to traffic laws in the USA shifted the responsibility for collision avoidance to the pedestrian.36 One explanation for the much lower risk of walking and bicycling in Germany and the Netherlands is their laws protecting people walking and bicycling, and more severe punishment of motorists for traffic violations.37 The effect of these and other changes on injuries needs research. Related to the consequences for failure to detect is the social acceptance of walking and bicycling. Promoting bicycling appears to reduce risks to bicyclists and even in some cases to reduce the total number of bicyclist injuries. Indeed, six European cities implementing comprehensive efforts to promote bicycling simultaneously increased bicycling and reduced injuries.38 Five cities in the USA and Canada that implemented bike-share programs reduced the annual number of injured bicyclists by an average of 28%, whereas five control cities that did not undertake bike-sharing experienced an average 2% increase in bicyclist injuries.39

The absolute decreases in injuries in these cities, as the amount of bicycling increased, indicates a negative exponent for the Safety in Numbers effect. Could promotion and bike share programmes legitimise bicycling,40 and increase motorists’ awareness of people on bicycles and help motorists expect them? Further research is required. Increasing regular physical activity through more walking and bicycling is a key policy tool to address premature mortality41 and mitigate climate change.42 Understanding the Safety in Numbers effect and applying it in public policy determinations will help ensure that injury risks are not overstated and that physical activity is promoted to the full extent warranted by its potential benefits.

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