Safety in Numbers
- combining a panel design and cross-cultural survey to examine the suggested mechanisms

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ABSTRACT

In many European countries, it is a political goal that future growth in local travel should be absorbed by sustainable transport modes. Concerns that increased walking and cycling produce more accidents have been countered by the "safety in numbers" (SiN) argument. According to SiN, the more walkers/cyclists there are in a population, the lower their risk. SiN has mainly been demonstrated in cross-sectional studies, but the mechanisms behind the effect have yet to be proven.

Previous studies have mostly relied on register data. The current study carried out in 2013 and 2014 tests the existence of this effect in a more controlled manner. This is achieved by two data sets: (1) a panel study with interviews of cyclists, pedestrians and car drivers, where participants are recruited from a time series study in Oslo (preliminary results presented at ICSC in 2013) and (2) similar roadside survey data from Oslo and Aalborg. By exploiting the natural seasonal variation in cycling frequency, and by using a repeated measures design we can further control for other factors suggested to lie behind the SiN mechanism. Results from the study indicate that bicyclists experience decreased levels of inattention from car drivers with increased numbers, and that car drivers report to be more attentive with increased numbers of bicyclists.

Keywords: safety in numbers, cycling culture, interplay

1. INTRODUCTION

Bicycle advocates and other stakeholders with an interest in arguing for a shift from motorized to non-motorized travel often site the concept of "Safety in numbers" (SiN) as an argument against the concern about a potential increase in numbers of accidents resulting from such a policy. The concept of SiN is used to explain the non-linear statistical relationships between the number of pedestrians (or bicyclists) and the number of injuries for the same group (Elvik, 2009; Geyer, Raford, Ragland, & Pham, 2006; Jacobsen, 2003). The concept has been subject to debate, regarding its existence (Bhatia & Wier, 2011), its mathematical characteristics (Brindle, 1994; Elvik, 2013; Knowles et al., 2009) and also related to this, regarding a clear understanding of *the mechanism* behind the safety in numbers effect.

The mechanism that has most frequently been proposed, is that motorists become more attentive, and change their behaviour, when exposed to higher numbers of pedestrians and cyclists (Jacobsen, 2003). Another possible mechanism is improved interplay between road users groups when road users acquire experience with each other, and develop more correct expectations (Phillips, Bjornskau, Hagman, & Sagberg, 2011). Still another suggested mechanism is that the cyclists and pedestrians entering the population at a later stage may be more risk averse and cautious (Fyhri, Bjørnskau, & Backer-Grøndahl, 2012). It has also been suggested that the effect can be a result of safer environmental conditions, including engineering countermeasures or differences in pedestrian norms and behaviours (Bhatia & Wier, 2011). However, these hypotheses have yet to be tested. Knowledge about these mechanisms is essential (Bhatia & Wier, 2011) and is necessary to adopt a safe active transport policy aiming at a shift to increased use of sustainable urban transport.

The Scandinavian countries, and in particular Norway are interesting cases to test the SiN effect, as there is a substantial seasonal variation in bicycle use. The cycle share in winter is in the range of 1 to 2 percent of all trips, and rises to 8 percent in summer (Vågane, Brechan, & Hjorthol, 2011). Pedestrians are a more steady presence in traffic. In fact, the share of pedestrians is somewhat *higher* in winter, around 22 %, and drops to around 18 % in summer (probably due to some bicyclists shifting to walking when conditions are not good enough for cycling). Thus, looking at interplay in traffic as a function of seasonal variation in bicycle use can provide useful insights into the mechanisms involved in the safety in numbers effect.

The seasonal variations is substantial, meaning that every spring there is a dramatic increase in the number of bicycles other road users are exposed to each subsequent week. By studying conflicts and interactions at the same study sites, it is possible to keep a close control with any other potential influencing factors, and only look at the effect of changes in the share of one of the road user groups. In other words, this situation can be used as an experiment of the SiN effect.

In a previous study looking at bicyclists and pedestrians in Oslo in April, June and September, we found that bicyclists experience an improved interaction with car drivers from April to June, and a further improvement from June to September (Fyhri & Bjørnskau, 2013). In particular, the number of times car drivers had not seen them was reduced. Pedestrians, who do not have the same seasonal fluctuation in travel mode, did not have a significant decrease in number of times they are not seen. Hence, this study supported the existence of a safety in numbers effect among cyclists. In the same study we found that there was no significant change in yielding behaviour from motorists through the season. The study could therefore be seen as supporting the mechanism that motorists become more *attentive*, rather than more *considerate*, when exposed to higher numbers of cyclists (Jacobsen, 2003). The study found that, not only the number of cyclists, but also the composition of the cyclist population changed during the season, and we attempted to control for this difference in the regression analysis, by including some of the most relevant background variables. However, such a multivariate analysis cannot take into account all potential variables that might influence people's perceptions about interplay. As an extension of the previous study, we therefore recruited people to take part in a panel study. Thus, we have answers from the same people at three different time stages.

Although the Scandinavian countries (Norway, Sweden and Denmark) are similar in many respects, much is also different. Cycling levels, but also infrastructure design as well as legal contexts differ between these countries. In the current study, we exploit this variation in cycling levels and infrastructure design in order to give a better explanation of the mechanisms involved in the SiN effect. The same interviews that were conducted in Norway were also conducted in Denmark (and will be conducted in Sweden in September 2014).

Traffic accidents are often a result of inadequate road user interaction, but research on the importance of road user interaction for accidents is rather limited. The importance of correct expectations and the ability to predict other road users' behaviour has not been studied much, despite the fact that such abilities are vital in order to avoid accidents (Bjørnskau, 1994; Bjørnskau, 1996; Rothengatter, 1991).

When the proportions of different road user groups change, for instance through an increase in soft transport modes, interaction patterns may also change. Bjørnskau (2007) has documented how road user interaction can change over time as a result of dynamic interplay. One example is pedestrian crossings, where cars yield to cyclists contrary to the traffic rules (Bjørnskau, 2007). Another is how novice drivers change their use of the headlights and adapt to the dominant practice of dipping, contrary to what is prescribed in driver education (Bjørnskau, 1994).

1.1 Objectives

The objective of the current study is to investigate if bicyclists experience an increased quality of interplay with cars when more bicyclists enter the streets throughout the cycling season. Specifically we hypothesize that

1. The number of times bicyclists are not seen by cars is reduced, from April to June and from June to September, when we control for population differences in the three time periods.
2. The number of times car drivers are surprised by a bicyclist is reduced from April to June and from June to September, when we control for population differences in the three time periods.

Further, we expect that there will be a difference between Norway and Denmark in that

3. Norwegian bicyclists more often than Danish bicyclists experience not to be seen by cars
4. Norwegian car drivers more often than Danish car drivers experience to be surprised by a bicyclist, relative to the number of bicyclists one has encountered.

2. METHOD

Data were collected in a series of field surveys among road users in some preselected streets and parking lots in Oslo, Norway and in Aalborg, Denmark. The surveys were conducted at three time-points in Oslo (April, June and September 2013) and at one point in time in Aalborg (October 2013). The data collection period spanned over two weeks at each time point. Interviews were conducted on weekdays, and during daytime. Most interviews were conducted in the morning and afternoon, during rush hours, in order to recruit enough respondents at each location.

Pedestrians and bicyclists were interviewed at three different locations in both cities. The locations were selected so that we would recruit «average" road users, have enough traffic, and to ensure that those interviewed would have had sufficiently long travels so that they could have experienced interactions with other road users. The interviewers were in principle asked to

stop any pedestrian or bicyclists approaching them. However, as we were mostly interested in bicyclists' perceptions, on some days the interviewers were asked to recruit twice as many bicyclists as pedestrians. The interview took approximately 4-5 minutes to complete, and data were registered using table PCs. All who participated were promised a ticket in draw for a prize worth 5000 NOK (approx. 600 €) in Oslo, and ticket for 1000 DKK in Aalborg.

Respondents were asked a range of questions regarding the trip they just had made (or were in the process of undertaking):

- Trip length in minutes
- Number of times they had experienced different types of conflicts
- Assessment of interplay with cars and pedestrians (bicyclists for pedestrians)
- Experiences of near-accidents.
- Feeling of safety

In addition, background questions about amount of cycling, seasonal variation in cycling and age were asked. The interviewers registered gender, bicycle type and type of equipment.

Car drivers were interviewed at parking lots outside commercial centres and at street side parking lots in the city centre.

Respondents (bicyclists, pedestrians, and car drivers) who completed the interview were asked if we could contact them anew, and those who said yes, were asked to leave their email address. One week after the field interviews the respondents received a survey at home were they were asked some further questions about their experiences with being in traffic during the last week, and about interplay with other road users. In order to establish a panel survey design (only in Norway), those who completed this survey in Oslo, were asked if we could contact them again at the next phase of the survey (In June or September). Response rates for each phase is presented in table 1 (drivers) and table 2 (bicyclists). Pedestrian interviews are not presented in this article.

Table 1 reveals that of the 222 drivers who were surveyed in the field in April, 59, or 27 % answered the web survey at home in addition. I June 32 of the 222 drivers surveyed in the field in April answered, i.e. 14 %, and in September the number was reduced to 17, i.e. 8 %.

Table 1 Response rate and retention rate for drivers. N (per cent)

	April		June		September		June to September
	Field	Home	Field	Home	Field	Home	
April	222	59 (27)	-	32 (14)	-	17 (8)	22 (19)
June	-	-	246	45 (18)	-	26 (11)	26 (11)
September	-	-	-	-	203	45 (22)	-
Denmark	-	-	-	-	158	70 (44)	-

Table 2 Response rate and retention rate for bicyclists. N (per cent)

	April		June		September		June to September
	Field	Home	Field	Home	Field	Home	
April	327	199 (61)		152 (46)	-	103 (31)	109 (33)
June	-	-	284	147 (52)	-	93 (33)	93 (33)
September	-	-	-	-	463	205 (44)	-
Denmark	-	-	-	-	266	125 (47)	-

As can be seen from the tables, the response and retention rates were highest among the bicyclists. Here, we have not taken into account the number that responded "yes" for participation in the panel survey, but merely a percentage of how many from the field we were able to retain. Hence, the *actual* response rate for the each panel phase is somewhat higher than given in the table. For example, of the 327 cyclists recruited in the field in April 263 said yes to receive a follow-up (a response rate at 76 percentage).

2.1 Sample

Table 3 shows the sample characteristics of the Norwegian bicycle interviews in April, June and September, as well as the Danish bicyclists.

Table 3 Sample characteristics of bicyclists. Percent (except for age).

	April	June	September	Danish bicyclists
Mountain bike	44	34	37	9
"Hybrid bike" (city bike)	39	38	33	39
Racer bike	5	7	9	8
Rented bike	1	1	1	2
Classical bike	10	19	19	42
Other types	1	1	1	1
5 days / week or more	73	72	73	81
2-4 days /week	24	26	25	18
1 day/week	2	1	1	1
1-3 days /month	0	0	0	0
Rarely	0	0	1	0
Whole year bicyclist	46	33	36	88
Male	57	58	53	44
Mean age	*44.6*	*43.8*	*43.1*	*35.5*
N	212	288	480	265

Notably, many of the Norwegian bicyclists use mountain bikes. This share is as high as 44 percent in spring, and falls to 34 percent in mid-summer. This is typical of the Norwegian cycling

population where mountain bikes for a while has been the most popular cycle type, even for urban cyclists. The share of those using a hybrid bike[1] is similar in Denmark and Norway (39 percent), whereas the classical bike and the mountain bike have opposite shares. In Denmark 42 percent uses a classical bike. In addition, we can see that many of those who are interviewed are quite accustomed bicycle users. In Norway, as many as 73 percent cycle "every day" (i.e. five or more days a week). This share is quite stable throughout the season. The Danish cyclists are even more accustomed bicycle users (81 percent cycle "every day"), and 88 percent are whole year bicyclists. Pedestrian interviews are not presented in this article.

3. RESULTS

3.1 Norwegian bicyclists experience of interplay with car drivers through the season

In order to test seasonal effect on bicyclists' experiences with conflicts and interplay with other road users, the panel data was analysed, using paired samples t-test, with on pair being responses from April and June, and one being from June and September. The number of participants taking part in all three surveys was rather low, and we decided that paired samples would suffice for the scope of this analysis.

After a short introduction asking the respondents to think back to their last week in traffic, they were asked, "Think back to your encounters with cars last week. Imagine that you have met 100 such car drivers during the past week. Approximately how many of these will have…." "not yielded for you at an intersection" etc. (five items). Responses were to be given on a sliding scale with 11 intervals ranging from "none" via 10, 20 etc. to "all".

Table 4 shows the mean number of times bicyclists have experienced not being seen by a car, and that a car has been placed in the roadway so they were hindered in April, as well as the change from April to June, and from June to September.

Table 4 Number of times bicyclists have experienced not being seen by a car, and that a car has been placed in the roadway so they were hindered in April, and change from April to June, and from June to September. Significant changes in bold.

	April	*Change from April to June*	*Change from June to September*
Not seen by car	15.51	**-1.99**	-.92
Car hindering	16.47	-2.72	**-2.53**
N		136	172

There is a drop in the number of times bicyclists are not seen by cars from April to June and from June to September. Only the drop from April to June is significant (p=0.094). There is also a drop in the number of times bicyclists are hindered by cars because of the way they are placed in the roadway for both time intervals, but only the drop from June to September is significant (p=0.05).

[1] A hybrid bike is a typical commuter's bike, and is a mix between a mountain bike, and a road bike. It will typically have larger, slimmer wheels, and more efficient mudguards than the mountain bike.

3.2 Norwegian car drivers experience of interplay with bicyclists through the season

The car drivers were asked to think about the trip they had made on the day of the field interview. The first question they were asked was to estimate how many cyclists they had encountered. They were then asked how many of these had appeared suddenly or surprisingly to them. Based on this a surprise per bicycle ratio can be calculated. The number of bicyclists, surprises and the ratio is presented in table 5.

Table 5 Number of bicyclists encountered on current trip, number of times surprised and surprise per bicycle, reported by drivers. Means

	Number of bicyclists	*Number of times surprised*	*Surprise/ bicyclist*
April	4.81	.34	.07
June	6.33	.31	.05
September	5.86	.42	.07

There is an increase of bicyclist from April to June. At the same time, the number of surprises is constant. From June to September the number of bicycles encountered drops and the number of times surprised increases, giving the same ratio (.07) in September and April.

3.3 Norwegian and Danish bicyclists perception of interplay

In order to investigate if bicyclists' immediate experience of interplay with car drivers differed in Norway and Denmark, we compared field survey results from Norway in September with those collected in Denmark in October.

In Norway bicyclists experienced to not have been seen by a car driver 0.24 times on their recent trip, whereas in Denmark this figure was 0.31 ($p<0.01$). In addition, the number of times they were hindered was higher in Denmark (0.55) than in Norway (0.39).

We conducted a linear regression analysis with "number of times not being seen" as a dependent variable. Independent variables were country (Norway vs. Denmark) gender, age, time of day (categorical, morning as contrast) and distance cycled. Table 6 shows the parameter estimates and significance levels of the dependent variables.

Table 6 Linear regression model predicting bicyclists not being seen by cars on current trip (Field survey data). Parameter estimates and significance levels of the dependent variables.

	Beta	*P*
Country=Denmark	.15	.00
Gender	-.06	.10
Age	-.05	.16
Mid-day	.04	.36
Afternoon	-.07	.09
Distance cycled	.17	.00

The results of the linear regression analysis shows that even when controlling for other background variables, Danish cyclists experience not to be seen far more often than Norwegian cyclists do.

In order to further test this difference in experience of interplay, the responses from the home survey was also investigated. Here the situation was the opposite from what we found in the

field survey. On average, Norwegian cyclists reported to not having been seen by 12.8 percent of the cars they had met, whereas the figure in Denmark was 8.7.

A linear regression analysis was conducted with "percentage of times not being seen during last week" as a dependent variable. Independent variables were country (Norway vs. Denmark) gender, age, and weekly distance cycled. Table 7 shows the parameter estimates and significance levels of the dependent variables.

Table 7 Linear regression model predicting bicyclists not being seen by cars during last week (Home survey data). Parameter estimates and significance levels of the dependent variables.

	Beta	*P*
Country=Denmark	-.11	.01
Gender	-.12	.01
Age	-.10	.02
Weekly distance cycled	.10	.03

The results of the home survey data also show an adjusted effect of country. Contrary to the field survey data it was the Norwegian cyclists that were most often ignored by car drivers.

3.4 Norwegian and Danish Car drivers perceptions of interplay

Table 8 shows the number of bicycles that Norwegian and Danish car drivers encountered bicyclists on their current trip, the number of times they were surprised, and the ratio of surprise per bicycle.

Table 8 Number of bicyclists encountered on current trip, number of times surprised and surprise per bicycle, reported by drivers in Denmark and Norway. Means and F-values

	Norway	*Denmark*	*F*
Number of bicycles encountered	5.8	19.6	108.4***
Number of times surprised	.46	.17	11.2***
Surprise/bike	0.074	0.018	8.1**
N	204	158	158

** p<0.01
*** p<0.001

Danish car drivers encountered on average 19.5 bicyclists on their trip, compared to 5.8 for Norwegian car drivers. Quite a few (66) of the Norwegian car drivers had not encountered any bicyclists on their current trip (none of the Danish reported this). The remaining car drivers had been surprised by a bicyclist 0.46 times, compared to 0.17 times in Denmark. The ratio of surprise per bicycle was four times as high in Norway (0.074) as in Denmark (0.018). All differences were significant.

4. DISCUSSION

The aim of this study was to prove the existence of a Safety in Numbers effect expressed as a short-term seasonal change in number of cyclists, and as a long-term effect represented as cross-national differences. In order to achieve this, two different approaches were applied, a panel survey design, and a cross sectional design with multivariate analysis. In case of short-term effects, differences in time due to increasing cycling shares in Norway are to be expected. In case of long-term effects, we expected to find differences in cyclist-car interaction between Denmark and Norway.

Our first hypothesis was that the number of times bicyclists are not seen by cars is reduced, from April to June and from June to September, when we control for population differences in the three time periods in Norway. This hypothesis was clearly confirmed. In the panel survey there was a significant drop from April to June, and the drop from June to September was also large, although not statistically significant. These results confirm our previous findings that bicyclists in a cross sectional field study report to be seen more often in June than in April, even when controlling for background variables (Fyhri & Bjørnskau, 2013).

Our second hypothesis was that car drivers would be less surprised by meeting a bicycle through the bicycling season. This hypothesis was not confirmed. The car drivers, when interviewed in the field, did not report any change in being surprised by bicyclists, through the season. No appropriate measure existed to test this hypothesis with the panel data.

Our third hypothesis was that Norwegian bicyclists would have experienced poor attention from car drivers more often than Danish bicyclists would. This hypothesis was only partly confirmed. It appeared that Danish bicyclists had experienced inattentive car drivers more often than Norwegian cyclists, on their current trip (field survey data). This difference could only partly be explained by the fact that there were more young and male cyclists in the Danish sample. However, the responses on the home survey indicated that Norwegian cyclists were in fact more often neglected by cars, thus supporting our hypothesis.

Our fourth hypothesis was that Norwegian car drivers more often than Danish car drivers would be surprised by seeing a bicycle in traffic. This hypothesis was strongly confirmed. The Norwegian car drivers were in fact four times as often surprised by a bicyclist, when we control for the number of times they had encountered a bicyclist.

Regarding our second hypothesis, a possible reason for the lack of support could be that there *is* a population change through the bicycle season, but that this change is opposite of what we expected. We argued above that an apparent SiN effect could result from a population change where more risk aversive cyclists enter the cyclist population at later stages of the season. However, when we look at the seasonal changes the opposite might in fact be at least equally true. Those bicyclists that cycle all year around, are in general very experienced, often middle-aged and quite law-abiding cyclists, whereas in the summer time there will be an entry of lots of young cyclists on city-cycles who perhaps behave in more unexpected ways.

Regarding our third hypothesis, it is hard to reconcile the flip of results from the field survey, where the Danish cyclists experience to be overlooked most, with the home survey results, where the Norwegian cyclists are most often overlooked. A closer inspection of the data indicate that most of the difference in results is due to five outlier cases in Denmark, who report to have been overlooked five times or more during their recent trip. In Norway, only one person reported this. If we treat this variable as dichotomous, there is no difference between Norway and Denmark. Still, the analysis of the field survey does not confirm our hypothesis that Norwegian car drivers are less attentive to bicyclists than Danish car drivers are.

The data presented here are part of a larger study, involving a range of different research designs. Method triangulation is an ideal in academic research that is often called for, but that is rarely adhered to. As such, this study is unique in its kind. It gives us the possibility to cover the issue of Safety in Numbers with broad variety of data. However, this benefit also involves a challenge, since the complexity and wide array of data potentially can give conflicting results. If all our four hypotheses had been verified, we could state with a certain confidence that increasing numbers of cyclists leads to increasing levels of attention from car drivers. As it is, two of our hypotheses were confirmed, one was only partly confirmed and one was rejected. So, the balance of evidence leans towards a SiN mechanism as has been often suggested, that motorists become more attentive, and change their behaviour, when exposed to higher numbers of cyclists.

One limitation of the current study is that we only use self-report data. To counter this limitation we have designed the questions in a way that should remove as much of interpretation as possible from the respondents. Therefore, we have asked about number of occurrences of given situations, rather than general assessments of interplay etc. Even though respondents have trouble with remembering the exact figures for such events, we believe that these measures, when aggregated to a group, gives a valid and reliable estimate of the quality of interplay among road users. Future analyses will verify if this assumption is true, since we also have access to objective data though video observations in the same time/space dimension that we have covered here.

The hypotheses that we have worked with in this paper, are all based on the assumption that car drivers are more attentive the more bicyclists there are on the road. However, it can be argued that this assumption is not enough to create the purported SiN effect. If the linear relationship between exposure and accidents is to be broken, there should be a *higher than proportional* increase in attention as the number of bicyclists increases. We did in fact see this difference between Norwegian and Danish car drivers, but not observed in any of the other comparisons we made. Future studies should aim to further discuss the theoretical assumptions associated with a SiN effect, and what kind of operationalization that should be made in order to prove this effect further.

5. CONCLUSION

Norwegian bicyclists experienced poor attention from car drivers far more often in the start of the cycling season (April) than towards the end (September), but there was no change in how often car drivers reported to be surprised by bicyclists. There does not seem to be a large difference in Norwegian and Danish bicyclists' experience of interplay with car drivers, but the Norwegian car drivers are far more often surprised than the Danish are. In sum, these results give a certain support to the hypothesis that car drivers are more attentive to bicyclists, when the number of bicyclists increases. However, we need more, preferably objective data, in order to conclude about this with a sufficient degree of certainty.

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