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Dipping Headlights: An Iterated Prisoner's Dilemma or Assurance Game

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Additional information is available at the end of the chapter

Abstract

When two cars meet in the dark on a rural road, and both drivers use their headlights on full beam, they will both be dazzled. Because of that, we usually dip the lights. However, if modeled as a finite prisoner's dilemma super-game, the standard game theoretic solution would be that both drivers defect and use full lights throughout the super-game. If modeled as an Assurance game, cooperative strategies have better chances of succeeding. Several different strategies are presented and discussed, and in particular whether the strategy most often used by drivers can be invaded by the strategy novice drivers learn in their driver education. On theoretical grounds, one can expect the cooperation to unravel because novice drivers are taught to defect both in the beginning and at the end of the super-game. However, empirical results from three different surveys reveal that novice drivers change their behavior and adapt to normal practice with experience in real traffic. Hence, cooperation has sustained because cooperative and retaliating strategies dominate in the population. In addition, when drivers retaliate by flashing their headlights, it is probably perceived as a negative penalty which causes the inexperienced drivers to adjust the behavior to normal practice.

Keywords: car driver, dipping headlights, Prisoner's dilemma, assurance game, cooperation

1. Introduction

When two cars meet in the dark on a rural road, and both drivers use their headlights on full beam, they will both be dazzled. Because of that, we usually dip the lights. This is, however, not a good explanation, because for each driver it may be individually preferable to continue with full lights, regardless of what the driver of the oncoming car does. If he dips his lights,

I can proceed with full lights without being dazzled. If he does not dip his lights, the worst thing for me to do would be to dip my own lights, being both dazzled and not able to see the road ahead because of low lights.

The situation can be considered as a game of conflict and cooperation. The result might be conflict (both use full lights), cooperation (both use low lights), or a mix of conflict and cooperation. If the drivers have the aforementioned preferences, they are engaged in the most famous of all games: The prisoner's dilemma (PD). However they might value mutual cooperation as the best outcome with preferences according to the assurance game (AG) (aka stag hunt).

Normally, situations of road-user interaction that can be considered as games in a game theoretic sense will be games that consist of very few moves, or games where the actors move simultaneously, but where each game is frequently repeated with new actors [1–5]. The situation when car drivers meet in the dark on a rural road may, however, be viewed as a supergame, that is, a game stretched out in time where the same actors play several constituent or static games against each other.

In this chapter, the game theoretic model will first be outlined both as a PD game and as an AG game. Why there has been established a convention of mutual cooperation in the dipping headlights game will briefly be discussed. We will then present possible strategies in the dipping headlights game and discuss if these strategies are evolutionary stable strategies. A particularly interesting attempt of invasion is the strategy that novice drivers learn during their driver education; they are taught both to keep full lights longer than what is normal and to switch back from low lights to full lights at an earlier stage than what is normal [6]. We will discuss whether this attempt of invasion will succeed. We will proceed by presenting empirical results revealing the distribution of strategies in the driver population and how behavior in the dipping headlights game has changed over time and discuss why cooperation in this game has survived.

2. The model

We start by presenting the dipping headlights game as an ordinary two-person one-shot game. This is depicted in **Figure 1**.

		B	
		Low lights	Full lights
A	Low lights	R, R	S, T
	Full lights	T, S	P, P

Figure 1. The dipping headlights game as a two-person one-shot game.

When meeting in the dark, both actors (drivers) have two choices, either to put on full lights or to use low lights. Each of the four cells in the matrix represents an outcome of the game, giving one payoff to A and one payoff to B. The letter on the left-hand side of each cell represents the payoff to A, and the letter on right-hand side represents the payoff to B.

For each actor, there are four possible payoffs. If they have PD preferences, the ranking of the payoffs is as follows: $T > R > P > S$. T represents "Temptation," that is, the temptation to defect while the other cooperates, R stands for Reward, that is, the reward for mutual cooperation, S symbolizes sucker's payoff, that is, the worst payoff resulting from playing cooperatively while the opponent defects, and P represents punishment, that is, the outcome of mutual defection [7]. In addition it is often assumed that $2R > T + S$, that is, that each player values the cooperative solution as better than alternatively to receive T and S in subsequent rounds (if played several times). If the drivers have AG preferences they rank the outcome as $R > T > P > S$.

In one-shot prisoner's dilemma (PD), the dominant strategy is to defect and hence P, P is the only Nash equilibrium. In the assurance game (AG) there are no dominant strategies and two Nash equilibria: that both cooperate (R, R) and that both defect (P, P).

When the dipping headlights game is modeled as a two-person PD or AG, the choice of full lights equals defection and the choice of low lights equals cooperation. In the dipping headlights game the dominant strategy is accordingly to use full lights if the drivers have PD preferences but not if they have AG preferences. However, also in the AG, the best option is to use full lights if the opponent uses full lights. Thus, also if the game is an AG, mutual defection may be the result.

When, however, the PD game is repeated, that is, the same two players play the same game in a number of trials, the outcome will not necessarily be mutual defection. And in the real-life dipping headlights game, when two drivers meet in the dark, the game can be viewed as an iterated PD game with a certain number of single games, that is, a PD super-game. At any point in time from the game starts (when full lights dazzle the driver of a meeting car) until it ends (when the cars pass each other), both drivers have chosen either full lights or low lights.

In such repeated games, cooperative strategies can survive if they are conditionally cooperative, that is, adapted to what the opponent has chosen in the previous sub-game of the super-game. One such strategy is tit-for-tat (TFT) which chooses to cooperate in the first game, and then continues to cooperate, if the opponent has cooperated in the previous game, and to defect if the opponent defected in the previous game. Thus TFT achieves cooperation against cooperative opponents and it avoids the sucker's payoff against defecting opponents. In a simulation of iterated PDs with a number of different strategies, Robert Axelrod [8] found that TFT was the most successful strategy in the long run.

Normally, in dynamic game theory, it is assumed that future payoffs are discounted by some factor, the logic being that the payoff you receive immediately is valued higher than the same value received later in the game. This will however not be the case in the dipping headlights game. On the contrary, as this super-game approaches its end, the payoff for each driver

will normally be higher than in the beginning of the game; you will be more dazzled by an oncoming car the closer it is, and your own full lights will be the sole source of lighting for a longer stretch of road the closer you are to the oncoming car. So it is reasonable to consider the payoffs at the end of the game to be higher for both drivers, regardless of what the outcome is. Thus, in this game, instead of having a discount factor in the repeated game, we will introduce the opposite, a premium factor.

In order to analyze the dipping headlights game we must make some assumption. First we assume that the super-game starts when the cars are about 300 m apart and that the super-game ends when the cars pass one another. We assume that the players play simultaneously, that is, at each moment in time, they have both made a move, either full or low lights. Each move takes place during a short time interval, depending on how quickly the drivers are able to change between full lights and low lights. We assume that each move lasts for 0.5 s and that the game begins when the distance between the cars is 310 m. Given the distance, it will take 7 s before the cars meet, giving 14 sub-games or moves for each driver in the game.

3. Strategies in the dipping headlights game

In the dipping headlights game, there are probably different strategies in different countries, and they may also differ among drivers in each country. Below, five strategies are outlined.

3.1. Strategy 1: "Custom"

In Norway, probably the most common strategy, which we will call "Custom," is to play cooperatively and to dip the lights when driver A meets driver B in the dark (at approximately 300 m) and to keep low lights until the cars pass one another.

If driver B does not dip the lights when the game has started (according to driver A), driver A will flash his lights. The normal process will then be that driver B dips his lights and that both keep low lights until the cars pass one another.

The flashing of lights from A can be considered to play cooperatively (C) in the first game, then to defect (D) in the second, then to play C in the third game (the sequence DC being the flash), whereas B plays consistently D, D, D in these three games. Then, after the third game, if B does not dip his lights in the fourth game, A will normally play TFT for the rest of the game.

When both players play custom, B will immediately dip his lights after A has done so, and the time interval between the two drivers who have dipped their lights is microscopic. When both play custom, they will both receive R throughout the game. Custom players will not engage in any defection in the last move(s) and will receive RR also in the last game.

3.2. Strategy 2: "School-strat"

In Norway, both the road authorities, the traffic police and the driving schools, recommend using full lights more often than what is normal. Different editions of the textbook used

in the Norwegian driver education state that the current practice is not optimal and they recommend to keep full lights until the distance to the oncoming car is around 200–250 m, then switch to low lights and to switch back to full lights when the distance to the oncoming car is about 10–20 m. They recommend this practice regardless of what the driver of the oncoming car does. The logic behind is that full-beam headlights do not actually dazzle oncoming drivers at distances greater than 200 m, nor when cars are 10–20 m apart. This strategy, which learner drivers are taught in the driving schools, is called school-strat.

3.3. Strategy 3: "Tit-for-tat"

We assume that tit-for-tat (TFT) equals custom in that it initiates cooperation at around 300 m by dipping the lights. If the oncoming car does not dip his lights, TFT switches to full lights and keeps full lights until the oncoming car has dipped his lights. In the last game TFT will copy the move of the opponent in the next-to-last game.

3.4. Strategy 4: "All D"

In All D, the driver chooses full lights throughout the game, regardless of what the driver of the oncoming car does.

3.5. Strategy 5: "All C"

In All C, the driver chooses low lights throughout the game, regardless of what the driver of the oncoming car does. We assume that the game starts at the similar point as for drivers playing custom and TFT, that is, when the distance between the cars is approximately 300 m, and that it ends when the cars pass one another.

4. Evolutionary stable strategies

In a population with several encounters like in road traffic, the strategies that will survive in the long run must be evolutionary stable strategies (ESS). The concept of ESS was introduced by John Maynard Smith [9] and outlined as follows by Robert Sugden (p. 27–28) [5]:

Let E(I, J) symbolize the expected utility derived by any player from a game where he plays strategy I and the opponent plays strategy J. For a strategy I to be ESS, the expected utility of playing I against itself must be at least as high or higher than any other strategy J (pure or mixed) against I:

$$E(I, I) \geq E(J, I) \tag{1}$$

If this condition holds, it follows that if every driver plays strategy I, no single driver can gain by switching to another strategy. According to this condition, there is however the possibility that there are other strategies that are equally good against I as I itself. Thus in addition to (1) the following criteria must be met:

For all strategies J (pure or mixed) where J ≠ I,

$$\text{Either } E(I, I) > E(J, I) \text{ or } E(I, J) > E(J, J) \tag{2}$$

If conditions (1) and (2) are satisfied strategy I is an ESS and a stable equilibrium.

4.1. Evolutionary stable strategies in the dipping headlights game

We have identified five different strategies in the dipping headlights game. Of these there are three that will cooperate against each other throughout the game: custom, TFT and All C. They will all receive R in every sub-game. Hence, the interesting cases are when these cooperative strategies meet school-strat and All D.

It seems quite obvious that All C will easily be invaded by both school-strat and All D. Against All D, it will lose and receive S throughout the game. All C will also loose against school-strat, who uses full lights in the beginning of the game (until the distance is 200–250 m), and also full lights at the end.

The more interesting cases are when the strategies custom and TFT meet school-strat and All D.

4.1.1. Custom against All D

When custom meets All D in one super-game, All D will win. Custom will play C, D, C, C, and then D for the rest of the game against All D. We assume that after the flashing of the light (D, C in the second and third game), custom holds low lights also in the fourth game. If the opponent has not cooperated in the fourth game, custom plays D in the fifth. Against All D custom will continue to play D from the fifth game onward. Thus, All D will receive T and custom will receive S in the three games when custom plays C (and All D plays D). In the rest of the game they will both receive P. If there is equal distance between payoffs T, R, P, and S, it is easy to see that custom will receive a better outcome against itself than All D will against custom. Against itself custom will receive R throughout, whereas All D will receive $3T + Pn$ (where n symbolizes the number of remaining sub-games in the sub-game). If we also include a premium that raises the value of the payoffs throughout the game, the values of the losses to custom in the beginning of the game against All D (3S) will easily be outweighed by the gain received later in the game when custom plays against itself. Thus, E(Custom, Custom) > E(All D, Custom).

4.1.2. TFT against All D

Against TFT the same logic will apply: All D will receive a higher payoff than TFT in one single super-game, since TFT starts by cooperating, but TFT is better against itself (and against custom and other cooperative strategies) than All D is. Thus, in a population where everybody else plays TFT (or custom), E(TFT, TFT) > E (All D, TFT).

4.1.3. Custom against school-strat

The prescribed behavior in the driver education is school-strat, and this is perhaps the most interesting case to consider against custom and TFT. If we assume that player A uses custom against a player B using School-strat, the sequence may be as follows:

A. C, D, C, C, C, … C, C.

B. D, D, D, D, C, … C, D.

It is obvious that B will receive a higher payoff than A: $4T + P + Rn$ vs. $4S + P + Rn$. Hence in one single game against custom, school-strat will perform better. School-strat will also perform better against custom than custom performs against itself ($T > R$).

School-strat will, however, perform worse against itself than custom does against custom. Against itself school-strat will receive $5P + Rn$, whereas custom receives R throughout the game against itself. Nevertheless, school-strat may invade a population of custom-players. If school-strat meets custom it outperforms custom, if it meets itself it is better to play school-strat than Custom. Hence, E(School-strat, Custom) > E (Custom, Custom).

4.1.4. TFT against school-strat

Against TFT school-strat will not perform as well as against custom, since TFT retaliates earlier in the game than Custom does. If A plays TFT and B plays school-strat, the sequence will be as follows:

A. C, D, D, D, D, C … C, C.

B. D, D, D, D, C, C … C, D.

We see that TFT and school-strat will perform equally well during the first five moves of the game, both receiving $T + 3P + S$. As mentioned, in the dipping headlights game, it is reasonable to include a premium that raises the payoffs as the game progresses. Hence, the payoff of playing D against C (giving value T) in the fifth game is valued higher than the payoff of D against C in the first game. But since school-strat plays D in the last game, it nevertheless scores better than TFT when they meet. Hence E (school-strat, TFT) > E (TFT, TFT).

4.2. Developments over time

So far, we have just considered what strategies will be best against each other, without considering the developments over time. We have seen that school-strat will score better both against custom and against TFT. Against the latter, school-strat scores better since it defects in the last game. Thus, a moderated TFT (TFTm), also playing defect in the last game, would win against school-strat. Against each other both school-strat and TFTm would receive $T + 4P + S$. If we introduce a premium TFTm wins since the T received in the fifth game is more worth than the T school-strat receives in the first game. Even without a premium, TFTm will outperform school-strat since TFTm scores better against itself compared to school-strat against itself.

A moderated custom strategy, also defecting in the last game, will however not be able to resist invasion from school-strat.

TFTm, which uses full lights in the last game, will outperform school-strat. The reason is that it manages to cooperate with other cooperative strategies in the beginning of the game. However, such a moderated TFT strategy will lose against another cooperative strategy that uses full light also in the next-to-last game. Hence, if all players copy this strategy, using full lights in the two last rounds, a cooperative strategy defecting in the third-to-last game will outperform the existing strategies and so on.

This is the standard logic in the finite prisoner's dilemma super-game. Each actor will choose to defect in this last game because in the last game to defect will be a dominant strategy just as in a one-shot game. Given this result in the last game, the same will happen in the next-to-last game because now the last game cannot be used to sanction the other player's action in the next-to-last game. But, the same will then also be true in the third-to-last game and so on all the way to the first game. If, however, it is not known when the last game is in play, or the super-game is one of infinite horizon, conditional cooperative strategies may be successful because the actors may realize a cooperative solution, which is better for both parties than mutual defection.

However, it has been shown that even when the game has a finite number of moves, conditional cooperative strategies may be equilibrium strategies, if there is incomplete information [10]. The reasoning behind this result is that if you for some reason suspect your opponent not to play defect in every sub-game, you might be better off yourself by choosing to cooperate in one or more sub-games. Thus, if there are some drivers in the population who chooses always to cooperate, and/or there are drivers with assurance game preferences ($R > T > P > S$), conditional cooperation can be a viable strategy even in the finite number prisoner's dilemma super-game.

5. Strategies and behavior in real traffic

So far, the dipping headlights game has been discussed theoretically. In this section we will report results from three different data sets of self-reported behavior in the dipping headlights game. The data sets are all surveys to driver populations in Norway.

5.1. Survey 1 to car drivers

In 1991, Bjørnskau [1] surveyed Norwegian car drivers with a rather detailed questionnaire about behavior in the dipping headlights game. The questionnaire was administered to 12,000 car owners in the Oslo region. The reply rate was 29.2% giving a net sample of 3.505 car owners.

The drivers were asked whether they usually dipped before or after the driver of the oncoming car did so, when driving in the dark, how they reacted if the driver of the oncoming car did

not dip his lights, and when they changed back to full lights. They were also asked if they had received special education in driving in the dark, in their driver education. Such special education in driving in the dark was introduced in the driver education in Norway in the late 1970s.

The results revealed that cooperative strategies were in a clear majority among drivers. The strategies most often used were even more cooperative than the strategy custom described above. Among the drivers 17% used All C, 6% used TFT, 16% used custom, and 55% used a more forgiving version of custom in the first moves of the game (either they flashed more than once and/or they did not switch to full lights after flashing if the opponent did not change to low lights). Interestingly, 72% of the drivers said they would flash the lights one or more times if the driver of the oncoming car did not dip the lights (in time).

At the end of the game, only 3% said they switched back to full lights when the cars were 10–20 m apart. Another 17% said they changed back when the distance was 5–10 m, 28% when it was 1–5 m, and 52% when cars passed one another or after passing the oncoming car.

Given these large proportions of cooperative strategies in the driver population, school-strat should not have had any difficulties in invading the population. At the time of the survey (1991), the school-strat behavior had been taught at driving schools for about 15 years. Thus, there should have been ample time for the behavior to change.

Also among drivers in the sample who had been given lessons in dark driving (21.4% in the sample), a clear majority did not behave according to the school-strat strategy, neither in the beginning nor at the end of the game. However, those who had recently conducted the driver's test and received training in dark driving behaved more in accordance with the school-strat strategy than those with longer driver experience. In general those with dark driving lessons behaved somewhat more according to the prescribed practice at the end of the game than in the beginning. There were however no tendencies toward changing back to full lights at earlier stages in the end game with time or with experience.

It was concluded that the behavior drivers are taught at the dark driving course in the driver education are abandoned in real life.

5.2. Survey 2 to car drivers

In a study of driver attitudes and behavior, Sagberg and Bjørnskau [11] sampled novice drivers with 1, 5 and 9 months of experience, respectively, together with a smaller group of experienced drivers. The drivers answered a version of the driver behavior questionnaire (DBQ) together with questions about behavior when meeting other cars in the dark. Results on the DBQ questions are given by Bjørnskau and Sagberg [12].

Figure 2 gives the distribution of answers to the question of when drivers normally change to low lights upon meeting in the dark, among drivers with dark driving education, in survey 1 and survey 2.

The results reveal clearly that there is only a very small proportion of drivers who say they normally switch to low lights after the driver of the oncoming car has switched to low lights.
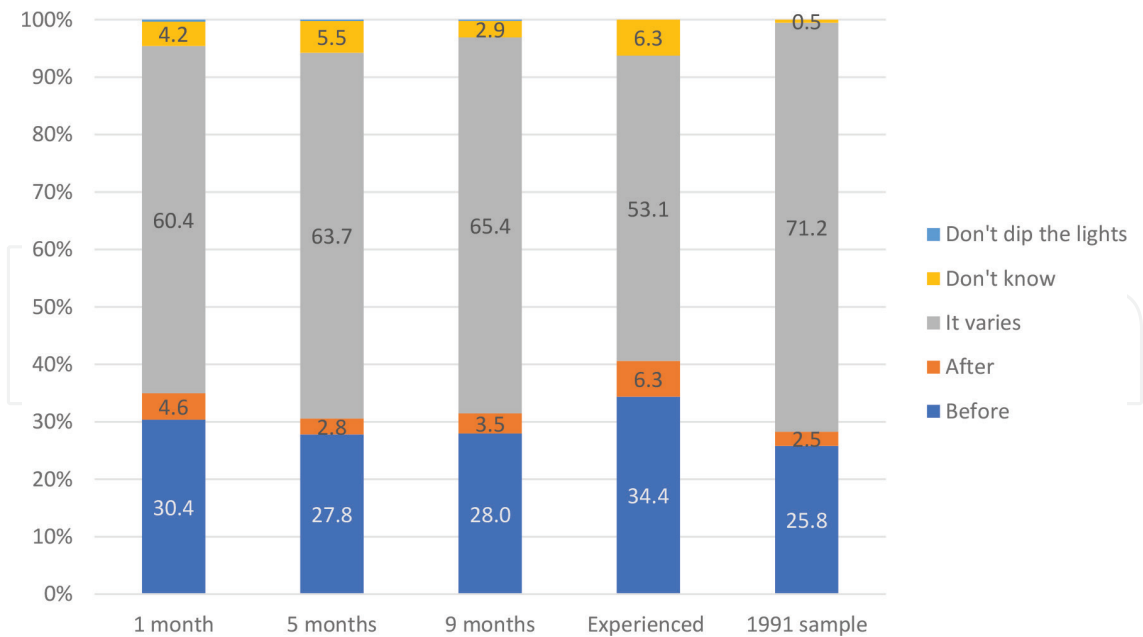
Figure 2. Drivers' self-reported answers to when they switch from full lights to low lights when meeting another car at night. Sample from 2001 to 2002 (survey 2), distributed by driving experience (N = 1433) and sample from 1991 (survey 1) (N = 3421). Percentage.

The share among the inexperienced drivers is not higher than among the experienced drivers. If school-strat had been adopted by novice drivers, we should expect these shares to be considerably higher. Most drivers say it varies whether he/she or the driver of the oncoming car changes to low lights first. However, quite a few say they normally change before the driver of the oncoming car has done so.

An interesting result is that there seems to be no clear development in behavior over the 10 years that have passed from survey 1 (1991) to survey 2 (2001–2002) nor with increased experience among novice drivers. According to the theoretical analysis we could have expected less cooperation over time. We also argued that the cooperation in the game could unravel given the fact that it is a finite super-game, but this has clearly not happened. In fact almost no one says they keep full lights throughout the game.

Figure 3 gives the results about when drivers change back from low lights to full lights upon meeting in the dark among drivers with lessons in dark driving in survey 1 and survey 2.

A very small fraction says they change back to full lights when cars are 10–20 m apart, which would be the correct behavior according to school-strat. A majority of the inexperienced drivers (1–9 months) say they switch back before the cars meet and also in the 1991 sample this is the case. An interesting result is the clear tendency to switch later as novice drivers gain experience. Thus, there seems to be a clear tendency that novice drivers change their behavior toward normal practice as they gain experience during the first months of driving. The difference between the three groups of novice drivers (1, 5 and 9 months of driving experience) is
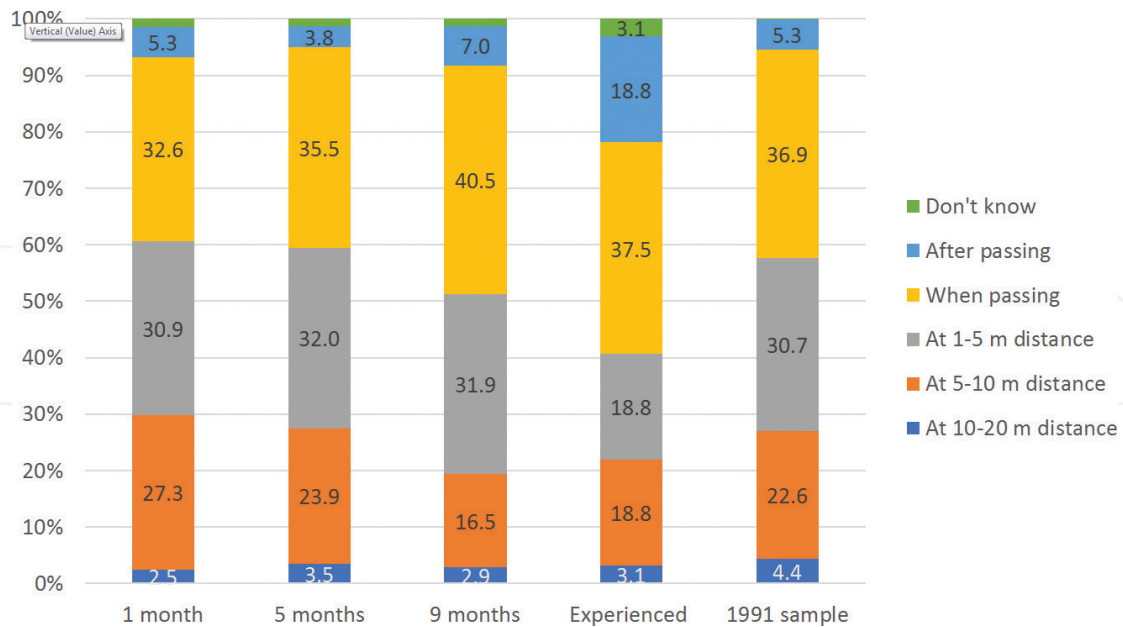
Figure 3. Drivers' self-reported answers to when they switch back from low to full lights when meeting another car at night. Sample from 2001 to 2002 (survey 2), distributed by driving experience (N = 1433) and sample from 1991 (survey 1) (N = 3435). Percentage.

statistically significant (χ^2 = 19.4, df = 10, p < 0.035). Also the difference between all four groups in the 2001–2002 sample is statistically significant (χ^2 = 31.1, df = 15, p < 0.008).

As already mentioned, we saw in survey 1 that a large majority of drivers said they flashed the headlights if the oncoming driver did not dip the lights (in time). Hence, we would expect novice drivers, who have recently been taught to use school-strat, to have experienced oncoming cars to flash their headlights to a greater extent than experienced drivers. We would also expect that the less experienced you are, the more often this would happen.

In survey 2, drivers were asked as to how many times during the last month they had experienced other drivers to flash the headlights against them. The results are given in **Figure 4**.

There is a quite clear tendency in the expected direction. Drivers with 1 month driving experience have been flashed at more often than drivers with 5 and 9 months experience. The most experienced drivers in the sample have experienced this even less often. There seems to be a clear tendency, but it is not statistically significant at the standard 5% level (χ^2 = 11.8, df = 6, p < 0.067).

5.3. Survey 3 to car drivers

The third survey we report results from is a panel study where a Norwegian sample of 982 young novice drivers aged 18–20 responded to a questionnaire on attitudes, errors, behavior and so on in 2007/2008 (study A) and then again in 2010 (study B) [13]. Hence we will be able to see whether the same drivers change behavior during the two first years of driving.
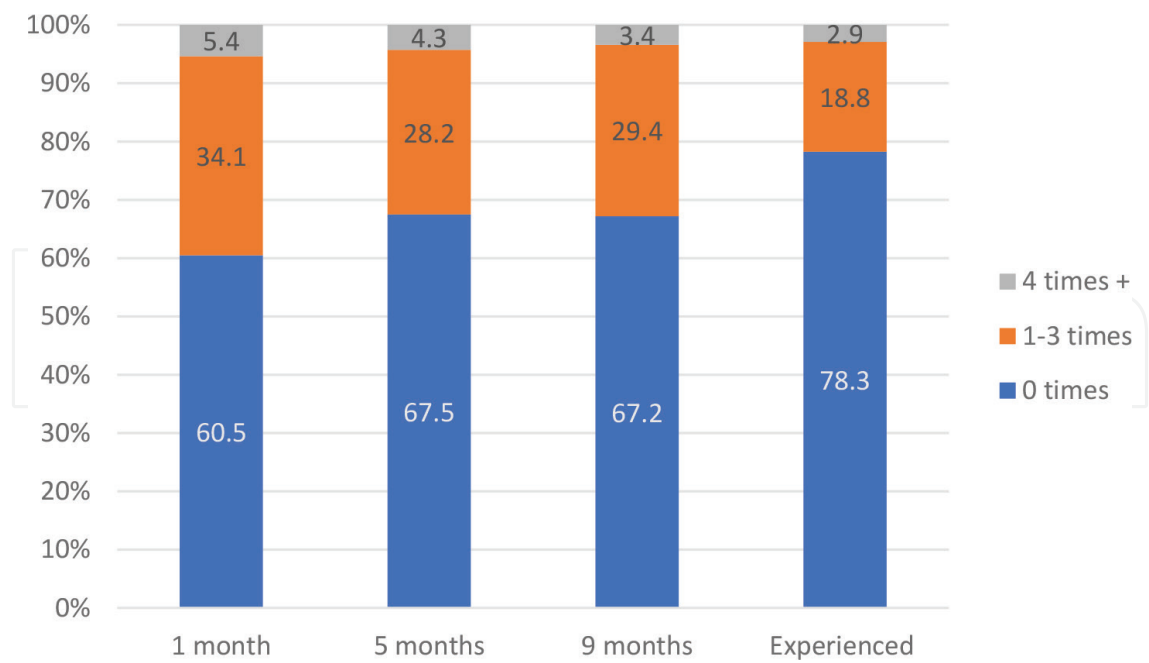
Figure 4. Drivers' self-reported answers to how many times during the last month they have experienced to be flashed at by other drivers. Sample from 2001 to 2002 (survey 2), distributed by driving experience (N = 1433). Percentage.

The question about experiencing other drivers to flash their headlights was asked in two versions, a general question like the one used in survey 2 and reported in **Figure 4** and a specific one about being flashed at by an oncoming car in the dark. On both questions, answers were given on the following scale: 1 = 0 times, 2 = 1–3 times, 3 = 4–6 times, 4 = 7–9 times, and 5 = 10 or more times. The results are presented in **Table 1**.

Both among men and women there are statistically significant changes in the expected direction over time, on both questions. In the B study, when respondents are 20–22 years old, they experience to be flashed at to a lesser extent than in the A study when they are 18–20 years old. There is also a significant difference between men and women. On both questions men are more often flashed at than women are. There is no interaction between time and sex.

	Study	Average scores		p-value		
		Women	Men	Time	Sex	Interaction
Been flashed at by other road users	A	1.23	1.42	0.001	0.001	ns
	B	1.17	1.30			
Been flashed at by an oncoming car in the dark	A	1.20	1.29	0.001	0.001	ns
	B	1.10	1.15			

Two-way ANOVA. N_{women} = 533, N_{men} = 393.
p-values for differences in time, sex, and the interaction between time and sex.

Table 1. Average scores on driver-behavior questions distributed by sex and study (A and B).

6. Discussion

We have seen that the data from three different data sets clearly indicate that the strategies taught in the Norwegian driver education is abandoned over time when drivers gain experience in traffic. Novice drivers who recently have passed they driver test use full lights more than more experienced drivers, but over time they adjust to the normal practice, which is to use low lights more than what is optimal according to the driver education textbooks. This problem is described similarly in the current edition of the driver education textbook as in the editions from 1976, 1990 and 1996 [6, 14, 15]. In this period thousands of new drivers have entered the roads, being taught the same lesson, but according to the textbooks, the problem remains the same: lights are used less than optimal.

Thus, cooperation has survived in the dipping headlights game even though we, both on theoretical grounds and due to the driver education, could expect it to unravel. Why is it so?

The analyses and empirical results presented here can provide some tentative answers to why the cooperation in the dipping headlights game has survived. There are mainly two mechanisms that may have produced the result:

a) The majority of drivers are more cooperative than assumed in the prisoners' dilemma game.

We have seen that in the driver population, there was a substantial proportion (17%) of drivers who said they would always cooperate, regardless of what the oncoming driver did. In addition, many drivers showed more cooperative behavior than prescribed by TFT and custom. If enough drivers in the population value cooperation as the better solution (e.g., they have AG preferences), and there are at the same time a substantial number who retaliate against defection early in the game, cooperative strategies can give higher payoffs. And, if many drivers indeed have AG preferences, the unraveling of cooperation from behind may not happen: the drivers value cooperation in the last game as better than to use full lights single-handedly.

b) The flashing of lights to oncoming cars who do not dip their lights is interpreted as a sanction.

Nearly 80% of the drivers participating in the first survey said they retaliated when drivers of oncoming cars did not dip the lights. A large majority flashed with the lights, and some used TFT, that is, full lights, until the oncoming driver dipped his lights. Thus, if drivers try to use the lessons learned in the driver education, and keep full lights longer than normal, they will meet strong reactions by almost every driver they meet. In the modeling of the game, we have only considered the values of full and low lights and not included any additional valuation of the sanctions the flashing headlights of an oncoming car represent.

Most novice drivers will try to adjust to normal behavior in traffic. Many studies reveal that they adapt to what they perceive to be normal practice during the first months of driving [12]. Thus, when flashed at by oncoming cars, they will probably interpret this as a sanction and hence the flashing is valued more negatively than just the glaring it provides. In addition,

when heavily sanctioned at the beginning of the game for using full lights, it might also result in less use of full lights at the end of the game.

The invasion from upfront fails because the practice is heavily sanctioned by other car drivers. The invasion from behind, which could unravel the cooperation if drivers have PD preferences, fails because there are many (enough) drivers who have more cooperative preferences, for example, AG preferences.

The driver education tries to teach drivers to use full lights more than what is normal. It can be argued that this is a dangerous practice since it might give rise to defections in the last games unraveling the cooperative solution. These attempts have not succeeded because the novice drivers entering the driver population at any moment of time will constitute a small minority of drivers, and hence they will be sanctioned by flashing headlights on the roads and change their behavior over time. If large numbers of novice drivers had entered the population at the same time, constituting a large proportion of the drivers in the population, the established cooperation in the dipping headlights game might unravel.

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