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DOI
10.1057/s41284-021-00285-3

Publication date
2021

Document Version
Final published version

Published in
Security Journal

Security Journal
https://doi.org/10.1057/s41284-021-00285-3

ORIGINAL ARTICLE

Nudging as a crime prevention strategy: the use of nudges to improve cyclists' locking behavior and reduce the opportunities for bicycle theft

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Accepted: 3 February 2021

Abstract
As policy makers are developing new alternative strategies to prevent bicycle theft, a nudging approach could provide useful insights in this field. In the current study, two different nudges were implemented at a selection of bicycle parking facilities in the neighborhood of a Belgian university campus. To measure the effectiveness of the nudges, a multi-method approach was used with a combination of observations ($n = 3963$) and questionnaires ($n = 197$). The results showed that both nudges had a positive impact on cyclists' locking behavior. Based on these findings, it can be concluded that nudging can be a rather cheap and easy way to improve secure behavior. However, concerns such as the limitations of increased awareness on behavior and the excessive focus on the victim need to be taken into account when implementing nudges in the field of security.

Keywords Nudging · Security · Crime prevention · Bicycle theft · University campus

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Published online: 25 February 2021

Introduction

While for a long time, safety and security policies have been controlled within the framework of penal law, more recent evolutions show that governments are developing new alternative ways to ensure a safe and secure environment (Schuilenburg and Peeters 2015). As crime prevention and social control strategies have become more popular, the concept of nudging could provide useful insights in this field. The nudging approach, which stems from the emerging behavioral research domain, suggests that it should be the aim of policy makers to guide people into making the most positive decisions. In this view, policy makers are considered as 'choice architects' who regulate the environment in which individuals make decisions (Alemanno 2012). Nudges have gained widespread recognition through the book 'Nudge' (2008) by Richard Thaler and Cass Sunstein, who describe nudging as 'any aspect of choice architecture that alters behavior in a predictable way without forbidding alternatives or significantly changing economic incentives' (Thaler and Sunstein 2008, p. 6).

To be qualified as a nudge, it is indispensable that the intervention fully preserves freedom of choice without using any material incentives or disincentives such as taxes, subsidies or a fine (Sunstein 2015). This implies that there always has to be an easily available escape clause for the nudged individual. However, the suggested freedom of choice has been criticized extensively. Wertheimer (2014, p. 10) indicated that there is never a complete freedom of choice as we 'always choose from among a limited set of options.' In this light, Hausmann and Welch (2010) suggest broadening the definition of nudges because according to them, rational agents are not only responsive to economic incentives. The authors define nudges as 'the ways of influencing choice without limiting the choice set or making alternatives appreciably more costly in terms of time, trouble, social sanctions, and so forth' (Hausmann and Welch 2010, p. 126).

Since the first experiment with nudging, the etching of the image of a black housefly in urinals in the men's rooms at Schiphol Airport in Amsterdam, proved to be a major success (Thaler and Sunstein 2008), nudges are frequently used in various domains. Examples can be found in the health sector, where healthy food is placed at eye level in order to nudge people to choose meals low in calories (Thorndike et al. 2012), or in the traffic sector, where the narrowing of the distance between white stripes on the road nudges drivers to limit their speed (Lindhout and Reniers 2017).

Two groups of nudges can be identified, reflecting different underlying brain processes: automatic thinking (system 1), which is associated by fast and instinctive processes, and reflective thinking (system 2), which is characterized by deliberate and conscious processes (Hansen and Jespersen 2013). System 1 nudges have an impact on the automatic thinking or the non-conscious part. Putting food on eye level or narrowing the distance between the stripes on the road are examples of this kind of nudge. System 2 nudges focus on the slow and reflective way of thinking or the conscious processes, such as the alarm that goes off when one is not wearing a seatbelt in the car (Kahneman 2011; Lindhout and

Reniers 2017; Thaler and Sunstein 2008). Additionally, seen from the point of view of the person who is nudged, nudges can be transparent or non-transparent. Nudges such as stickers of footprints placed on the ground leading to a sink or garbage bin are transparent as both the nudge itself and the intention behind it are noticeable by the individual. The inclusion of defaults in a registration form for organ donation is a non-transparent nudge as the intention of the means by which the behavioral change is persecuted is not directly noticeable by the person who is nudged (Lindhout and Reniers 2017).

It can be stated that this nudging approach overlaps with techniques of crime prevention. Reference can be made to Crime Prevention Through Environmental Design (CPTED) approach which has the aim to prevent crime and fear of crime by manipulating the social and physical environment (Cozens et al. 2005). Additionally, nudges can be considered as a form of Situational Crime Prevention (SCP), which has the aim to reduce the opportunities of crime by increasing the risks and difficulties associated with it (Clarke 1995, 1997). Based on the assumption that criminals weigh their costs and benefits before they act, SCP aims to hardening the target and reducing the rewards of crime by changing the physical environment (Clarke 1997). While CPTED and SCP are both grounded in the rational choice theory and target a criminal's ability to make rational choices, nudges are based on the principle that some of the choices that people make are irrational (i.e., not consciously calculated). By manipulating the choice architecture, (system 1) nudges seek to influence the unconscious choices of people. However, (system 2) nudges can also be used to provoke criminals into thinking about the consequences of their decisions before they act. Sharma and Kilgatton (2015), for instance, suggest that theft from shops might be reduced if retailers displayed signs showing how savings made from reductions in losses due to shop-theft, would be donated directly to charity. Additionally, while it is one of the key principles of the nudging approach to preserve full freedom of choice, some of the most effective situational interventions within the CPTED and SCP frameworks involve the removal of choice (Sidebottom and Tilley 2017). For instance, the removal of accessible cash boxes on buses in the United States have led to the near disappearance of bus robberies in the 1960s (Chaiken et al. 1974).

In the current study, system 2 nudges are used to provoke cyclists into thinking about the consequences of their decisions. By implementing contextual cues, it is the aim to reduce the number of opportunities for bicycle theft and increase the efforts for criminals. Due to the unavailability of official police statistics, the number of bicycle thefts before and after the nudging experiment is unknown. While these data cannot be included in the evaluation of the nudging approach, changes in cyclists' preventive locking behaviors will be assessed by carrying out observations. First, an overview of earlier experiments with nudges in the field of security will be provided. Additionally, the methodological approach of the current study will be presented. After the presentation of the results, the most remarkable conclusions are discussed. At the end of the paper, some limitations of the current research and recommendations for future studies will be presented.

Nudges in the field of security

Although some nudging techniques are already sporadically used in cyber security environments (see Almuhimedi et al. 2015; Balebako et al. 2011; Turland et al. 2015), examples in the field of physical security are scarce. Only a limited number of researchers have carried out experiments to examine whether nudging can be effective in the reduction of criminal offenses or individuals' fear of crime. A first example can be found in the prevention of crimes occurring around cashpoints. Drawings of colored boxes on the pavement right before the cashpoint operates to deliver greater distance between the users of the cash points and the pedestrians on the street behind them. This 'safety spot' has the aim to increase the privacy of the cash point user and to ensure greater social control. As previous experiments proved to be effective, this type of nudge has already been implemented in some cities in the United Kingdom and the Netherlands (Gamman and Willcocks 2010; Kuiper et al. 2016).

In May 2008, the airports of Schiphol and New York started a nudging experiment with biometric data from American and Dutch travelers with a low security risk. Travelers who agreed to participate in this project were screened for extra security risks. In case they were considered safe, they received a chip card with their identity data, fingerprints, and iris scan. With this pass travelers could cross the border without any delay due to the interrogation by security guards at the airport. This way, travelers were 'rewarded' with speed and ease if they are willing to share some personal data (Romein and Schuilenburg 2008).

In 2015, the municipality of Hilversum, a town in the Netherlands, rolled out a red carpet with mirrors next to it to reduce crime in the main entertainment street of the city. While the red carpet referred to a high status, the mirrors ensured that passers-by saw a reflection of themselves. The two interventions had the aim to suppress the tendency towards aggressive behavior. A survey indicated that passers-by felt much safer after the implementation of the red carpet and the mirrors (Kuiper et al. 2016). In Roermond, another town in the Netherlands, portrait photos were placed behind the benches of the train station, and quiet music sounds were provided in the waiting area of regional transport. While the placement of several eyes on the walls had the aim to create the feeling that people are watched, the music offered people a warm and welcome feeling. As a result, individuals unconsciously showed socially desirable behavior and the train station was perceived as more atmospheric, colorful, and safe (Kuiper et al. 2016). In the study of Nettle et al. (2012), posters with watching eyes were placed in bicycle parking facilities to reduce bicycle theft which caused a reduction of 62% of bicycle thefts. Unfortunately, a displacement effect took place as the amount of theft increased at other parking facilities in the neighborhood by 65%.

In order to prevent vehicle theft in Durham in the United Kingdom, Roach et al. (2017) developed a leaflet campaign to nudge vehicle owners into locking their vehicle when leaving it unattended. Results showed that the number of thefts committed against insecure vehicles in the treatment areas was reduced significantly in comparison with the control areas where no nudges were implemented.

In a more recent study, Roach et al. (2020) developed a questionnaire to raise awareness among the residents of the twelve most victimized streets of Durham. It was the second aim of the survey to nudge the residents into reflecting on their preventing behavior. The experiment led to a decrease in recorded burglaries during and soon after the distribution of the survey. Moreover, the authors indicated that the questionnaire had a positive nudging effect on residents' preventive behavior regarding burglary.

In the current study, nudges were implemented to improve cyclists' locking behavior to reduce the opportunities for bicycle theft. While worldwide bicycles are promoted as an alternative and sustainable way of transport, the widespread use of bikes creates a large number of challenges, not only for traffic safety but also seen from a criminological perspective. An increase in bicycle use raises the opportunities for potential perpetrators of bicycle theft. While over the past years, international crime rates show a decrease of criminal offenses, this is not the case for registered bicycle thefts (Swanepoel 2017). Previous research has shown that the most attractive locations for bicycle thieves are in or around the home, at railway stations and in the neighborhood of educational institutions (Mercat and Heran 2003; Nicholas et al. 2005; Zhang et al. 2007). Additionally, it is shown that bicycle theft and the fear of theft could discourage cycle use (Sidebottom et al. 2009). Moreover, the abundance of not properly locked bikes not only facilitates bicycle theft, but it also encourages it (Felson and Clarke 1998).

In this light, Sidebottom et al. (2009) examined the use of targeted publicity to limit the opportunities for offenders of bicycle theft in public bicycle parking facilities. Although not badged so, the targeted publicity approach can be considered as an example of nudging. Stickers with a short advisory tag line and an illustration were placed on cycle parking furniture. At the end of the experiment, the authors concluded that the stickers did have a positive impact on the locking practices of cyclists. Similar to this study, the current research has the aim to examine whether the use of nudges can have an impact on cyclists' locking behaviors. Different from the study of Sidebottom et al. (2009), the impact of two different nudging interventions will be measured in the neighborhood of a university campus in Antwerp (Belgium). Additionally, a multi-method approach will be used with a combination of observations and a survey. Focus lies on a measurement of the change in cyclists' locking behaviors instead of the reduction in the amount of bicycle thefts.

Methodology

Research design

In the current study, focus lies on the improvement of cyclists' locking behaviors to reduce the opportunities for crime. A multi-method design was used in which observations and questionnaires are combined. In a first research stage, observations were carried out to examine the impact of the nudges on the locking behavior of cyclists. In a second stage, a quantitative survey was conducted to verify to what extent a change in locking practices could be attributed to the implementation of the nudges.

In order to set up the nudging experiment for this study, the guidance of Lindhout and Reniers (2017) for the development, implementation, and evaluation of a safety nudge was used. Based on their literature review, six steps were identified for the design and development of a nudge in practice: (1) assessment of the situation, (2) focus on the individual behavior, (3) selection of a nudge type, (4) design, construction, and pre-test of the nudge, (5) implementation of the nudge and (6) evaluation of the nudge.

Assessment of the situation

The most recent Belgian crime statistics show that for several years, the number of bicycle thefts has been around 35,000 offenses per year (Federale Politie 2019). In 2018, 3672 bicycle thefts were registered in Antwerp, the second largest city of Belgium. The Safety Monitor, a national population survey on various safety topics, showed that 17,23% of respondents ($n = 1538$) indicated that they had become a victim of bicycle theft in the city of Antwerp in 2018. Additionally, in the same year, 40,44% of respondents ($n = 183$) indicated that they reported bicycle theft to the Police Department (Federale Politie 2018). National crime statistics show that the total amount of bike thefts is much higher in the vicinity of universities. In the whole city of Antwerp, 6.27 bikes per 1000 inhabitants were stolen in 2018 in comparison to 25.11 bikes per 1000 inhabitants in the vicinity of the university campuses (Lokale Politie Antwerpen 2019). These findings are similar to conclusions based on international crime statistics where the environment of educational institutions is considered as an attractive location for perpetrators of bicycle theft (Van Dijk et al. 2005). In this light, the bicycle parking facilities in the neighborhood of a university campus in the city of Antwerp were selected for carrying out the nudging experiment.

Focus on the individual behavior

Nudges affect the psychological processes that determine the individual's automatic or choice behavior. As this study has the aim to urge cyclists to lock their bike in a secure way, the choice behavior of individuals has to be influenced. At the moment, they park their bicycle, cyclist choose whether they lock it decently or leave the bike behind in an unsecure way. Based on the instructions of the Belgian police department, opportunities for bicycle theft can be reduced by ensuring that bicycles are secured with attaching the frame and (one of) the wheels to the parking furniture. Therefore, it is the aim of this study to stimulate cyclists to make the effort to secure their bike with two locks.

It should be mentioned that while it is the goal of the interventions of the current study to influence cyclists' decision process, the nudges cannot have any impact on situational factors. For instance, it is possible that a student, who has noticed the nudge, needs to be on time in class to follow a course and decides to leave their bike unsecured in a rush. In another situation, it is possible that there are no available parking spots left which hinders cyclists to lock their bike to the bicycle stand. In order to obtain a more clear view on the impact of situational factors in this

study, the nudges will be evaluated by making use of a multi-method approach (see Sect. 3.1.5.).

Selection of a nudge type

In the current study, the nudges have to stimulate the 'system 2' or reflective behavior of individuals as it is the aim to make cyclists aware of the potential risks of leaving their bike in an unsecure way in order to stimulate them to improve their locking behavior. One strategy to guide behavior in a certain direction can be found in theories and research about normative social norms (Cialdini 2003). Although there exists little research involving the use of social norms to promote more secure behavior, their ability to stimulate human behavior has been demonstrated in other contexts (Aldrovandi et al. 2015; Lehner et al. 2016). Recent literature has distinguished two different types of social norms: injunctive norms, which involves the individuals' perceptions of which behaviors are approved or disapproved, and descriptive norms, involving the individuals' perceptions of which behaviors are typically performed (Loschelder et al. 2019). Previous research showed that both kinds of norms motivate human behavior as people tend to do what is socially approved as well as what is popular (Dolan et al. 2012; Lindhout and Reniers 2017; Ponnet et al. 2015). As a consequence, a combination of injunctive (intervention 1) and descriptive (intervention 2) norms may be the most effective way to induce normative behavior (Cialdini 2003).

Design, construction, and pre-test of the nudge

For the first intervention, a nudge including an injunctive social norm was developed (see Fig. 1). With a very clear and transparent visual sign of both a poorly secured and a good secured bicycle, cyclists were informed about the expected norm of their locking behavior. A green satisfied smiley emoticon was placed next to the secured bike to show that this behavior is approved. A red unsatisfied smiley emoticon was added next to the poorly secured bicycle to disapprove this behavior. In order to make the nudge more transparent, the slogan (in Dutch and English) 'Lock your bike twice… and don't suffer from theft' was added next to the images of the bicycles.

Fig. 1 The first nudging intervention (110×45 mm)

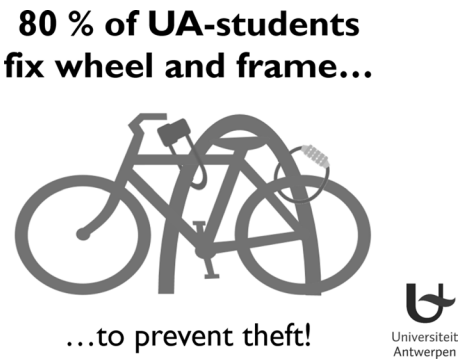

Fig. 2 The second nudging intervention (297 × 210 mm)

Fig. 3 Example of the implementation of the sticker and poster at treatment site

A descriptive social norm was included in the second nudge (see Fig. 2). The same visual sign of a good secured bicycle, which was used in the first nudge, was developed in a larger format. Additionally, the message (in Dutch and English) that '80% of students of the University of Antwerp fix wheel and frame… to prevent theft' was placed above and beneath the image in order to influence their perception of which behavior is typically performed by other cyclists.

While the first intervention involved a sticker, the second nudge was presented in the form of a poster. Both were developed in a format that could easily be attached to the bicycle parking furniture. For the sticker and the poster, three possible designs were developed and presented to a panel of researchers, students, and staff members of the university. In total, 21 respondents were asked to draw up a ranking of the six designs, based on three criteria: (1) the design of the sticker and poster, (2) the clarity of the message, and (3) the perceived effect of the included social norm. Based on their ranking, two designs were selected and printed on stickers and posters.

Implementation of the nudge

After the development of the two nudges, the stickers and posters were attached in the bicycle parking facilities (see Fig. 3). In order to select the bicycle parking locations, a couple of choices had to be made. First, based on the crime statistics,

it became clear that the environment of educational institutions is a very attractive location for perpetrators of bicycle theft. This means that only bicycle parking facilities in the close neighborhood of the campus were selected. Second, based on the differences in infrastructure of these parking facilities, a selection was made of parking spots that only contained bicycle stands between each bicycle. This criterion was necessary to attach the stickers. In total, six bicycle parking facilities were selected. The maximum capacity of the parking facilities varied between 86 and 164 bikes. All parking locations are public, which implies that they are accessible not only to students and staff members of the university, but also for external people such as inhabitants of Antwerp or tourists. Third, the selected bicycle parking locations were randomly split up in three control sites and three treatment sites. The maximum number of parking options per site was taken into account when randomizing the parking facilities. It was the aim to create two groups that consisted of, to the extent possible, an equal number of available parking spots.

As the timeline of the experiment indicates (see Fig. 4), no stickers or posters were attached in the parking facilities belonging to the control group. At the treatment sites, no nudges were implemented in the first four weeks. In the fifth week, the stickers were attached to every bicycle stand between two bikes, which made it very easy for cyclists to read the message when they parked their bike. In the ninth week, the stickers remained and posters were attached to the walls or railing of the parking infrastructure. Depending on the surface of each bicycle parking, minimum three and maximum eight posters were attached.

Evaluation of the nudge

Similar to the research of Sidebottom et al. (2009), weekly observations were carried out in order to observe the locking practices of cyclists ($n = 3963$) at both treatment ($n = 2271$) and control ($n = 1692$) sites. In total, an average number of 329 bicycles were observed each week. This made it possible to examine whether cyclists improved their locking practices before and after each intervention at the treatment sites. Importantly, the observations were carried out in a way that the observers

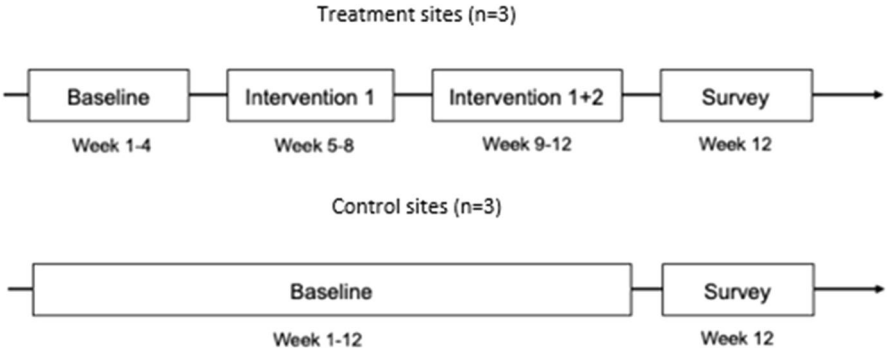

Fig. 4 Chronological timeline of the experiment at treatment ($n = 3$) and control ($n = 3$) sites

attempted to remain unnoticed in order to minimize the impact of their presence on the behavior of cyclists. During the experiment, three researchers operated as observers and registered cyclists' locking practices. By making use of a rotation system, at each observation moment, two of three observers were responsible for the registration of bicycles. During 12 weeks, observations were carried out one day a week and two times a day, starting between 9.00 am and 10.00 am in the morning and between 3.00 pm and 4.00 pm in the afternoon. Before the experiment started, different observations days were picked randomly, which means that, for instance, observations took place on Monday in the first week and on Wednesday in the second week. All observations were carried out before the outbreak of the COVID-19 pandemic. Moreover, during the 12 weeks of observations, there were no holiday periods or other interruptions in students' class schedules. Each researcher was assigned the same three parking facilities in the morning and the afternoon. At the first observation moment, the three observers registered all the bicycles at the six parking spots together in order to adjust the observation criteria and to minimize observer bias.

In order to register the observations as uniform as possible, the researchers used a standardized observation sheet to categorize the locking practices according to three criteria:

- Good: The use of two locks; or the frame and one (or both) wheels are attached to the bicycle stand.
- Acceptable: The use of a single lock; or the frame or one wheel are attached to the bicycle stand.
- Poor: The use of no lock or a single lock; neither the frame, nor one wheel are attached to the bicycle stand.

In order to decide whether or not an improvement in cyclists' locking practices took place, the researchers decided that at least one out of three criteria had to be fulfilled: (1) an increase in good locking practices, (2) an increase in acceptable locking practices, and/or (3) a decrease in poor locking practices.

Besides the locking practices, seven other characteristics of the bicycles were registered on the observation sheet: (1) whether it is a male or female bike, (2) the brand of the bike, (3) the color of the bike, (4) the color of the lock, (5) whether the bike has bicycle bags, (6) whether the bike is marked, and (7) other remarkable characteristics, such as the presence of a child's seat or a remarkable color of the saddle. The inclusion of these extra categories made it possible to identify duplicate observations as counting the same bike would distort the results and would lead to the wrong conclusions. Therefore, registered bicycles with exactly the same characteristics were removed out of the data collection. For instance, if a particular bike was poorly locked in the morning and the bike is still there in the afternoon, only the first registration was retained. Additionally, observers were instructed to leave clearly abandoned bicycles out of the data collection.

In order to find out whether a possible change in behavior was caused by the interventions or whether or not other factors had an impact on the behavior of cyclists a survey was carried out. Two days after the last observations took place

in the 12th week of the experiment, five researchers orally questioned arriving and departing cyclists at the six bicycle parking facilities. Two very similar surveys were developed, one directed to cyclists who used the bicycle parking facilities on the control site, and one directed to cyclists who used one of the treatment sites to park their bike. In order to not disturb the cyclists before or after they went to class or work, the surveys were very short.

Results

Observations

Figure 5 presents an overview of the locking practices at both the control and treatment sites before and after the two interventions took place. Based on the results, it can be noticed that in the baseline condition, locking practices at both control and treatment site are quite similar: around 30% of cyclists locked their bicycle in a poor way, around 30% in an acceptable way and around 40% in a good way. After the first intervention, a small increase in good locking practices of 4.1% and a small decrease of acceptable locking practices of 3.8% at the control sites can be noticed. For the poor locking practices, the results remain almost the same. At the treatment sites, a decrease in poor and acceptable locking practices of, respectively, 6.4% and 3.8% can be noticed. This decrease is accompanied with a large increase of 10.2% in good locking practices. After the second intervention, the locking practices at the control sites are quite similar with the baseline condition. At the treatment sites, a

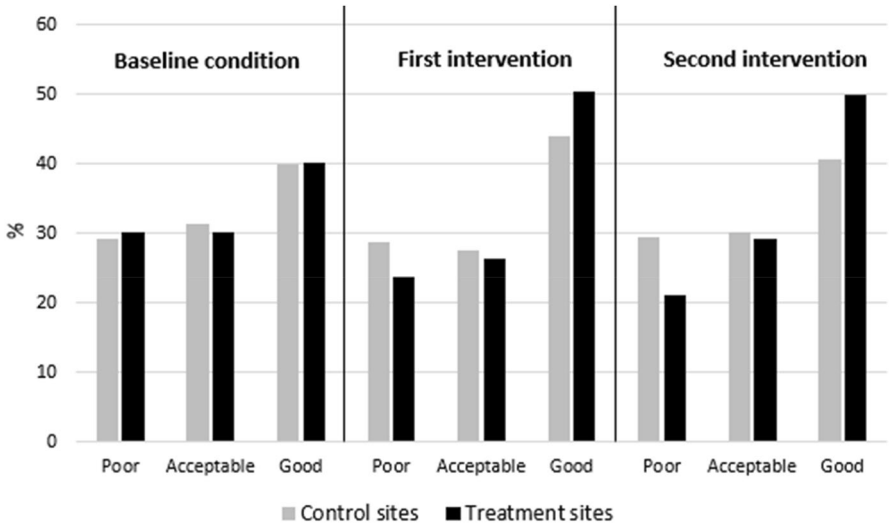

Fig. 5 Overview of the locking practices at control and treatment sites at baseline condition, after the first intervention and after the second intervention ($n = 3963$)

further increase of 2.8% in acceptable locking behavior can be noticed after the second intervention, compared with the first intervention.

In order to measure the impact of the nudges on the locking behavior of cyclists, a Pearson Chi-square test was used. In order to know which specific categories differ significantly from each other, partitioned Pearson Chi-square tests were carried out.

When comparing cyclists' behavior at control and treatment sites in the baseline condition, the Pearson Chi-square test showed that there were no significant differences in locking practices ($\chi^2(2)=0.274$, $p=0.872$). After the first intervention, no significant differences were found in poor, acceptable, or good locking practices at the control sites ($\chi^2(2)=2.396$, $p=0.302$). At the treatment sites, significant differences were observed in locking practices after the attachment of the stickers ($\chi^2(2)=15.928$, $p<0.001$). A partitioned Pearson Chi-square test (see Table 1) showed a significant increase in good locking practices compared to poor locking practices ($p<0.001$). Additionally, a significant decrease was observed in acceptable locking behavior compared to good locking behavior ($p=0.004$). Poor locking practices were found to be less frequent compared to acceptable locking behavior, but non-significant before and after the implementation of the first nudge ($p=0.484$).

After the second intervention, a Pearson Chi-square test showed non-significant increases in poor and acceptable locking behavior and a non-significant decrease in good locking behavior at the control sites ($\chi^2(2)=1.394$, $p=0.498$). At the treatment sites, also only non-significant changes were observed as poor and good locking conditions decreased and acceptable locking behaviors were more frequent ($\chi^2(2)=2.083$, $p=0.353$).

When comparing the locking behaviors of the baseline condition with these of the period after the second intervention, no significant changes were found at the control sites in poor, acceptable, and good practices ($\chi^2(2)=0.186$, $p=0.911$). At the treatment sites, significant changes in cyclists' locking behavior were observed ($\chi^2(2)=21.578$, $p<0.001$). A partitioned Chi-square test (see Table 2) showed a significant decrease in poor locking practices in comparison to acceptable locking practices ($p=0.018$), while a significant increase was found in good locking behavior compared to poor locking behavior ($p<0.001$). Additionally, a significant decrease in acceptable locking practices was observed in comparison with good locking practices ($p=0.030$).

Table 1 Partitioned Pearson Chi-square comparisons of locking practices in the baseline condition and after the first intervention at the treatment sites

	Baseline condition (%)	First intervention (%)	Total *n*	X^2	*p*
Poor	49.8	47.3	841	0.490	484
Acceptable	50.2	52.7			
Acceptable	43.0	34.4	1089	8.432	0.004*
Good	57.0	65.6			
Good	57.2	68.0	1079	13.124	<0.001**
Poor	42.8	32.0			

*$p<0.01$, **$p<0.001$

Table 2 Pearson Chi-square comparisons of locking practices in the baseline condition and after the second intervention at the treatment sites

	Baseline condition (%)	Second intervention (%)	Total *n*	X^2	*p*
Poor	49.8	41.9	906	5.577	0.018*
Acceptable	50.2	58.1			
Acceptable	43.0	36.9	1214	4.702	0.030*
Good	57.0	63.1			
Good	57.2	70.4	1150	21.367	< 0.001**
Poor	42.8	29.6			

*$p < 0.05$, **$p < 0.001$

Table 3 Differences in locking practices at the control and treatment sites after the second intervention

	Control sites (%)	Treatment sites (%)	Total *n*	X^2	*p*
Poor	49.3	41.9	739	4.092	0.043*
Acceptable	50.7	58.1			
Acceptable	42.7	36.9	1026	3.523	0.061
Good	57.3	63.1			
Good	58.0	70.4	959	15.874	< 0.001**
Poor	42.0	29.6			

*$p < 0.05$, **$p < 0.001$

At the end of the experiment, significant differences were found between cyclists' locking behavior at the control and treatment sites ($\chi^2(2) = 16.018$, $p < 0.001$). A partitioned Chi-square test (see Table 3) showed that significantly less poor locking practices in comparison to acceptable locking behavior were observed at the treatment sites ($p = 0.043$). Additionally, more good locking practices in comparison to poor locking practices were found at the treatment sites ($p < 0.001$). Finally, at the control sites, more acceptable locked bikes in comparison to good locked bikes were observed. The differences between the control sites and treatment sites were, however, non-significant ($p = 0.061$).

Survey

Demographic characteristics of respondents

In total, 197 cyclists were surveyed at the bicycle parking facilities at the control and treatment sites. Table 4 shows the demographic characteristics of the respondents at both sites.

Table 4 Overview of demographic characteristics of respondents at treatment ($n = 139$) and control sites ($n = 58$)

	Treatment sites number (%)	Control sites number (%)
Gender		
Man	66 (47.5)	30 (51.7)
Women	70 (50.4)	28 (48.3)
Missing	3 (2.2)	0 (0.0)
Age		
< 20	20 (14.4)	10 (17.2)
20–29	84 (60.4)	30 (51.7)
30–39	16 (11.5)	6 (10.3)
40–49	10 (7.2)	6 (10.3)
> 49	9 (6.5)	6 (10.3)
Position		
Student	112 (80.6)	34 (58.6)
Staff member	18 (12.9)	18 (31.0)
External	9 (6.5)	6 (10.3)

Awareness and effectiveness of nudges at treatment sites

At the treatment sites, 77.7% of cyclists ($n = 108$) indicated that they had noticed the sticker, while 59% of cyclists ($n = 82$) indicated to be aware of the poster, and 84.9% ($n = 118$) had noticed the sticker and/or the poster. Remarkably, while many people at the treatment sites were aware of the interventions, only 11.5% ($n = 14$) of them indicated that the sticker had an impact on their locking practices in the last couple of months, and only 7.2% of cyclists ($n = 9$) confirmed that their improvement in locking practices is due to the second intervention or poster. 8.6% ($n = 12$) gave other explanations for an improvement in their locking practices. An earlier experience with theft ($n = 4$) and the risk of the public character of the bicycle parking ($n = 3$) were the most common reasons.

Awareness and effectiveness of nudges at control sites

At the control sites, cyclists were asked if they ever park their bike at other parking locations in the neighborhood of the university. If they confirmed, they were asked whether they had noticed stickers or posters at one of the locations of the treatment group. In total, 60.4% cyclists ($n = 35$) indicated that they sometimes park their bike at another location. 22.4% of them ($n = 13$) did park their bike in the last couple of months at one of the treatment sites. Eight of them had noticed the sticker, and two of them had noticed the poster. Additionally, four individuals indicated that they had noticed the sticker without parking their bike at one of the parking facilities of the treatment group. We could observe a significant difference between cyclists' awareness of stickers or posters and

their locking practices ($p = 0.031$), which implies that cyclists who indicated to be aware of the nudges locked their bike in a more secure way. Of the 14 individuals that noticed the sticker and/or poster, only one individual confirmed that the sticker had an effect on his/her locking practices. The other 13 cyclists gave other explanations, such as an earlier experience with theft ($n = 9$) or theft warnings by their parents ($n = 2$).

Discussion

The relationship between awareness and conscious behavior

The nudging interventions of the current study had the aim to improve cyclists' locking practices and, therefore, to reduce the opportunities for bicycle theft. By developing a sticker and poster, cyclists were stimulated to think consciously about their locking practices and the potential risk of bicycle theft. After the first intervention, the observations showed an improvement in locking practices as significantly more cyclists locked their bike in a good way after implementing the stickers. Based on the results of the survey, it became clear that almost 80 per cent of cyclists indicated that they had noticed the stickers at the treatment sites. Remarkably, only 12% of them confirmed that the sticker had an impact on their behavior, while almost 9% indicated that other factors influenced their locking practices.

Although it was the aim of the nudges to influence the conscious and reflective thinking of cyclists, these findings suggest that almost 80% of cyclists who noticed the sticker, changed their locking behavior apart from the intervention or other factors. An explanation could be that the cyclists improved their locking practices in an unconscious way. This would imply that the stickers served more as a system 1 nudge, which influences the automatic thinking of people, instead of a system 2 nudge, which aims to impact the reflective decision process. Following this explanation, cyclists unconsciously could have paid more attention their locking practices after they noticed the first intervention. As the results of the current study cannot confirm whether these assumptions are correct, further research is needed.

More awareness does not directly lead to better behavior for everyone

At the beginning of the experiment, it was expected that an increase in awareness would cause a change in behavior. Based on the results of the survey, almost 85% of cyclists indicated that they were aware of one or both interventions. While the results show that the nudges led to a significant improvement in good locking practices, almost 20% of cyclists still locked their bike in a poor way at the end of the experiment. This finding may support the findings of other studies that an increase in the awareness of individuals does not always lead to a change in behavior for everyone. For instance, Reniers et al. (2014) concluded in their study that lab safety interventions within higher educational chemical labs did change the safety

knowledge of students but did not change student's safety behavior. Kempton et al. (1995) examined the relationship between the awareness of environmental issues and pro-environmental behavior and concluded that environmental knowledge is not a prerequisite for behaving in a good environmental way. Yet, the majority of the existing policy tools for changing rational behavior are often guided by the assumption that availability of information is needed to make rational choices.

According to Sidebottom et al. (2009), the distinction between an improvement in awareness and behavior is caused by an 'incubation period,' or a sort of acclimatization time for people to adapt to the changes in the environment. For instance, if cyclists decide at a certain moment to change their behavior, it is possible that they still have to buy an extra lock or take other precautions. In the current study, it was not possible to examine the effect of the incubation period as the experiment was only limited to 12 weeks. Previous research on the long-term effects of nudging provides mixed evidence (see Dupas 2012; Gneezy et al. 2011). Therefore, more research is needed to examine whether it is suggested that policy makers make use of nudges as a long-term intervention tool (Marchiori et al. 2016).

Careful with blaming the victim

In contrast to the study of Nettle et al. (2012), the interventions in this study did not focus on perpetrators but on the responsibility of potential victims of bicycle theft. The nudges had the aim to empower cyclists by providing them with information about the risk on bicycle theft and a possible way to avoid this risk. In previous research, these victim-oriented strategies have received some criticism. In the most extreme example, women are considered responsible for rape for wearing short skirts or other 'sexually provocative' clothing. However, in other situations, people are happy to receive some advice about possible ways to minimalize their risk on crime. For example, informing car owners that it is best to park their vehicle in their garage at night could reduce the risk of vehicle crime by 20-fold. Based on this information, they can decide for themselves whether the risk is worth the effort of parking the car in the garage (Clarke and Mayhew 1998).

Additionally, providing information to potential victims could unintentionally cause some side-effects, such as increased fear of crime. Depending on the used strategy, preventive communication can result in inflated estimates of victimization risk or a strengthening of the perceived negative impact of victimization (Winkel 1991). However, in the study of Davis and Smith (1994), the authors found that encouraging people to take responsibility for their own safety did not lead to higher levels of fear of crime. Winkel (1991) concluded that an adaptation of the communication strategy to the target population can control these negative side effects. According to Barthe (2006), information given to potential victims should always be complemented by initiatives by the police or government. Publicity campaigns proved only to be successful in the context of a broader response to the problem. In this light, it can be useful for this experiment to combine the nudging techniques that focus on the responsibility

of the potential victims with security measures that improve the bicycle parking facilities or discourage perpetrators. In this way, the responsibility is shared between the potential victim and the law enforcement institutions.

Limitations and further research

As this study was not carried out in a laboratory but in a natural setting, there are some limitations to the research design, which can create opportunities for future research. First, the presence of observers at the busiest hours of the day may have caused an impact on the locking behavior of cyclists. Although the observers received the instructions that they had to stay on the background, it is still possible that cyclists were aware that their behavior was observed and that they locked their bicycle in a better way. Especially at the treatment sites, where stickers and posters were attached, the combination of these interventions with the presence of the observers could have led to a change in behavior.

Second, the locations of the bicycle parking facilities may have caused a contamination on the effect of the interventions. As all parking facilities were located in the same neighborhood, they are within walking distance of each other. This means that it could be possible that cyclists who normally park their bike at one of the control sites, for once choose to store it at a treatment site and noticed the interventions. These cyclists could have experienced an effect of the nudges and, therefore, decided to lock their bicycle in a better way. In order to examine the impact of this limitation on the results, a survey was carried out at the end of the experiment. Based on the answers of the respondents, it became clear that only a very small number of cyclists at the control locations had noticed the interventions on the treatment sites. It should be interesting for further research to select parking facilities spread over a whole city or region in order to eliminate the contamination. In case of the university context, it could be interesting to include parking facilities of different campuses or universities in the experiment.

Third, a major limitation of this research is the limited time frame. As the experiment only lasted for 12 weeks, it was not possible to examine the long-term effect of both interventions. For future research, it should be interesting to test the nudges over a longer period. This way, some interesting hypotheses could be framed which could explore what nudges may and may not be able to do. For example, one conjecture could be that nudges are good for altering behavior of the moment (although not changing longer-term habits or reasoning). Another could be that nudging is educative and leads those nudged to change their longer-term intentional behavior in the preferred direction. A third could be that novelty nudges are noticed at first and then lose their saliency over time. Each would lead to rather different outcome patterns, but an experiment on long term would need to be designed to allow those outcome patterns to emerge (or not to do so).

Fourth, based on this study, it was not possible to ascertain the impact size of the second intervention on itself. As the attachment of posters took place four weeks after the stickers were applied, only the impact of the first intervention and the effect

of both interventions together could be measured. Based on the results, it can be concluded that the impact of the posters was smaller than the influence of the stickers. However, in this study, it was not possible to find out whether the poster on itself did have little impact on the cyclists' behavior or whether it can be assumed that one intervention is more effective than a combination of two nudges. Therefore, it should be interesting for further research to focus on the effectiveness of this second intervention on itself.

Finally, it was not possible to examine whether the interventions caused a reduction in bicycle theft at the parking facilities that were included in the experiment. Due to the unavailability of official crime statistics for this specific neighborhood of the university, the number of bicycle thefts before and after the experiment is unknown. This also means that it was not possible to examine whether the interventions caused a displacement effect. Previous research on place-based crime prevention strategies has raised concerns that the interventions displace the offenses to other places (Gabor 1990). In about 25 percent of evaluation studies on place-based security measures, a displacement effect was found (Guerette and Bowers 2009). Also Nettle et al. (2012) concluded in their study that a reduction of bicycle thefts in the parking facilities that were included in the experiment caused an increase of crime in bicycle facilities on other locations.

Furthermore, earlier experiments with crime prevention techniques have shown that besides displacement also, diffusion can be an effect of the intervention. Diffusion can be seen as the reverse of displacement and occurs 'when reductions of crime (or other improvements) are achieved in areas that are close to crime prevention interventions, even though those areas were not actually targeted by the intervention itself' (Guerette and Bowers 2009, p. 1334). Diffusion effects have been found in several crime prevention studies in the past (Bowers and Johnson 2003; Weisburd and Green 1995; Weisburd et al. 2006). Therefore, when interpreting the results of this study, it is important to keep these limitations in mind.

Conclusion

This study had the aim to examine whether nudging could be useful as a crime prevention strategy. To figure out whether the nudging approach could have an impact, an experiment was carried out where nudges were used to reduce bicycle theft at public parking facilities in a university neighborhood. Based on the results, it can be concluded that the nudges led to a significant improvement in cyclists' locking behavior. The first intervention caused a large and significant improvement at the treatment sites. The second intervention led to a further, but

smaller and non-significant, improvement. Meanwhile, the locking practices at the control sites remained the same during the whole experiment. This means that a combination of both nudges had an effect on the behavior of cyclists. These conclusions confirm the results of the study of Sidebottom et al. (2009) where the attachment of stickers with a similar message caused a significant improvement of cyclists' locking practices. Based on these findings, it can be concluded that nudging can be a rather cheap and easy way to improve secure behavior. However, as pointed out in the discussion, it is important to keep in mind the limitations of increased awareness on behavior and an excessive focus on victims of crime.

Appendix

See Table 5 and Fig. 6.

Table 5 Overview of maximum bicycle parking spots and conditions for each bicycle parking facility

	Maximum bicycle parking spots	Condition
Parking facility 1	86	Control site
Parking facility 2	101	Treatment site
Parking facility 3	164	Treatment site
Parking facility 4	144	Control Site
Parking facility 5	129	Treatment site
Parking facility 6	108	Control site

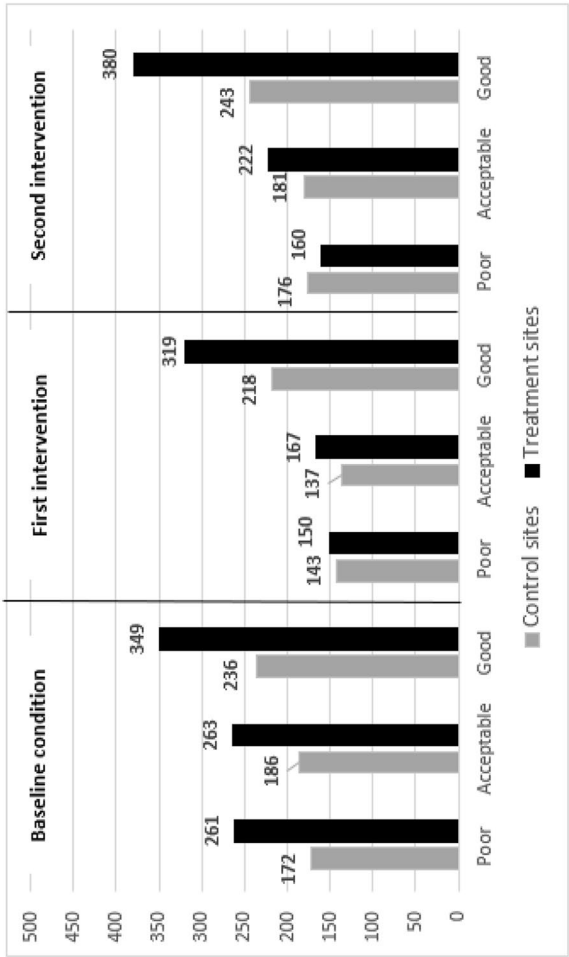

Fig. 6 Overview of the locking practices (in raw figures) at control and treatment sites at baseline condition, after the first intervention and after the second intervention ($n = 3963$)

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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