



# Smartphones and Pedestrian Behaviour

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**KEYWORDS:** pedestrian; smartphone; pedestrian crossing; walking

**ABSTRACT:** The article deals with the behaviour of pedestrians using a smartphone. The work aims to describe the behaviour of pedestrians using a smartphone while walking and to survey the factors that lead pedestrians to this behaviour. The data gathering was performed at a marked pedestrian crossing without signals in Olomouc. The statistics in question were collected via observation and interviews. A total of 2689 pedestrians were observed and 90 people took part in a structured

interview. We observed that 15% of pedestrians use their smartphone while walking. We found out that pedestrians who are holding a smartphone in their hand walk safely across a pedestrian crossing less often, rely on others more often when they are walking in a group, and step into the road more often when cars are supposed to give way to them. Furthermore, we found that pedestrians who were walking in a group and at the same time were on the phone or had on headsets were more likely to be guided by their companions than pedestrians who were not distracted.

## 1. INTRODUCTION

Humans are a key element of any transport. In 84.1% of the traffic accidents in the Czech Republic in 2019, human factors made a contribution (Police of the Czech Republic, 2020). The only form of transport in which a person can rely mostly on himself or herself is walking, which is an integral part of everyday life. It is the most ecological and economical mode of transport and one that is beneficial for humans (Schmeidler & Maršáľková, 2015).

On the other hand, pedestrians are the most vulnerable road users. Other road users, in particular drivers, make a major contribution to ensuring pedestrian safety. An important segment of pedestrians cannot take care of their own safety. These are mainly children, the elderly, and people with disabilities. Drivers need to behave in such a way that every pedestrian can cross the road safely.

The diverse pedestrian population varies in terms of different variables such as age, sex, personality characteristics, driving, experience with non-motorized mobility, etc. All these variables ultimately affect how a pedestrian behaves in a traffic situation. In addition to the personal attributes of the person, the infrastructure, society and its norms, and the behaviour of others also contribute to a pedestrian's behaviour.

Pedestrians cross the road most safely at places where there are traffic lights. They know when they can and cannot enter the road. People are even more observant of the rules when using a light-guided crossing if the signalling includes a countdown. Where there are red traffic lights, pedestrians usually try to save time or reduce their delays. Whether they decide to break the traffic rules is affected by the spacing between cars, the traffic density, the number of lanes a pedestrian has to cross, the presence of a central island, the width of the road, the waiting time, or the weather. People wait for the green light most often in cities with heavy traffic, short distances between vehicles, and on a multi-lane road. Research in the United States has shown that 20% of pedestrians violate the rules if the red light is on for one minute, but 40% of pedestrians violate them if it is on for two minutes. Fewer people enter the road when a traffic light is

red if the green traffic light is on for at least 30 seconds to allow more pedestrians to cross (Houten, 2011).

At pedestrian crossings without signals, the factors that influence the decision to enter the road are similar. Pedestrians determine the critical gap in traffic at which they still assume a safe crossing to the other side of the road is possible. This critical gap is variable, and is influenced by the road width and traffic density. The narrower the road, the smaller the gap. When a pedestrian sees that he or she will have a clearer path a little later, he or she usually waits and does not take an unnecessary risk (Schmidt & Färber, 2009).

In the research study of Holland and Hill (2007), the researchers found several interesting factors that influence the tendency to take risks when crossing the road. The first finding is that women are more sensitive to perceptions of danger in risky situations than men are and are less likely to cross in risky situations. Holland and Hill concluded that people do not decide on the basis of the level of risk they feel, but on the basis of their subjective perception of the difficulty of managing the task.

The main predictor of risky crossing is a late entry into the road, when the driver has less time to react and at the same time the pedestrian has less time to cross the road. With increasing age, a late entry into the road is more common. A predictor of safe passage is looking ahead to the road, which helps to anticipate the situation and make more efficient use of time to cross the road. For women, safe driving is associated with active driving experience. No significant effect was observed in men (Holland & Hill, 2010).

Communication between drivers and pedestrians plays an important role in crossing the road. Factors that affect a driver's decision-making include pedestrian behaviour, a pedestrian's distance from the road, the colour of the pedestrian's clothing, the number of waiting pedestrians, vehicle speed, and traffic density (Harrel, 1993; Schroeder & Roupail, 2011; Sun et al., 2002; Sucha et al., 2017).

In traffic, it is necessary to receive a constant stream of information about one's surroundings, as the situation may change very quickly. For pedestrians, visual and auditory perception are very important cognitive processes through which they obtain information about the surrounding events.

Another important cognitive process is attention, which focuses on the necessary stimuli, consequently increasing the likelihood of a fast and accurate response (Sternberg, 2009). An important role is also played by the working memory, which is responsible for the current processing and maintenance of information. Thanks to the working memory, we can interact and manipulate various objects simultaneously in our mind (Covan, 2010). In the context of the use of smartphones while walking, the most cognitively demanding activity is writing and reading messages, which mainly affects visual perception (Haga et al., 2015). Calling primarily employs auditory perception, but a conversation can also interfere with coding visual stimuli into the working memory (Neider et al., 2010). The least cognitively demanding activity is listening to music, which uses only sound perception (Jiang et al., 2018).

Various observational or virtual reality research studies and surveys have been conducted to investigate the link between pedestrian behaviour and the use of a smartphone. Pedestrians using smartphones have been found to behave less safely than pedestrians who are not thus distracted (Schwebel et al., 2012; Thompson et al., 2012; Byington & Schwebel, 2013; Jiang et al., 2018). Research suggests that the use of a smartphone while walking leads to a higher incidence of risky road-crossing behaviour than is the case for pedestrians who are not thus distracted. Although the research varies in several specific manifestations of this risky behaviour (such as walking speed), most studies agree that pedestrians distracted by smartphones look less before entering the road (Horberry et al., 2019; Schwebel et al., 2012; Byington & Schwebel, 2013; Thompson et al., 2012) and perceive the situation less clearly (Lamberg & Muratori, 2012; Lin & Huang, 2017; Mwakalonge et al., 2015; Haga et al., 2015; Hyman et al., 2009), which increases the risk of a traffic accident. When attitudes to the use of smartphones while walking across the road were examined, it was found that a positive attitude to the use of smartphones while walking increases the likelihood that a person will behave in this way in a real situation (Barton, Kologi, & Siron, 2016).

Similar findings on attitudes have also been obtained in self-assessment online research on the use of smartphones. Additionally, people aged 18 to 30 have been found to use smartphones when walking much more often than other age groups. This group tends to indulge in more risky activities, such as writing messages or surfing the internet, while they are walking. No significant difference was found between men and women in terms of the frequency of use of a smartphone when walking (Lennon, Trespalacios, & Matthews, 2017).

## 2. RESEARCH PROBLEM AND GOALS

The use of smartphones while walking has been a problem in recent years. Researchers have investigated the effects on pedestrian safety of using a smartphone while walking in both laboratory and real-world conditions. As mentioned in the previous section, the incidence of risky behaviour is increased in these pedestrians. Despite this topic having been investigated abroad for several years, in the Czech Republic, it is still unexplored. We have decided to transfer the potential of this recent issue to the Czech Republic. We are aware that safety is affected by two main factors – the behaviour of pedestrians and the behaviour of drivers, who are responsible for preventing an accident. Besides these, there are factors such as the environment, lifestyle, strategic and tactical choices, etc. In our research, we focused on pedestrian behaviour. We assume that mapping the current state of this modern issue in the Czech environment can be the first step to improving road safety. Understanding the behaviour of pedestrians using smartphones leads to better prediction and estimation

of traffic situations. Identifying the risks associated with using a smartphone while walking can contribute to better pedestrian education and, perhaps over time, to reducing the risky behaviour of the most vulnerable road users.

The first objective of the research is to describe the connection between the use of smartphones while walking and the behaviour of pedestrians. We are trying to find out if their behaviour is different from that of pedestrians without a smartphone. On the basis of the previous research, we assume that we will see risky behaviour more often in pedestrians with a smartphone crossing the road than in pedestrians without a smartphone.

The second goal is to map the reasons that lead pedestrians to use a smartphone. We want to find out what activities they do most often on a smartphone while walking, how often they use a smartphone while walking, and whether pedestrians consider using a smartphone while walking to be safe.

For research purposes we have created two research questions:

1. What type of behaviour occurs in pedestrians who use a smartphone when walking?
2. What is the attitude of pedestrians to the use of a smartphone while walking?

## 3. METHODS

### 3.1 Data collection process

The data collection took place in October and November 2018 at a pedestrian crossing in Olomouc through observation and interviews. It is a busy crossing in the city centre. It is close to tram stops and parking and sports facilities. The crossing is marked, does not feature signals, is near an intersection, and leads over two lanes. The crossing is located on level ground without bends, so that both pedestrians and drivers have a good enough view.

During the observation, we noticed which category pedestrians belonged to (they were not using a smartphone – they were holding a smartphone in their hand – they were calling/had on headphones) and the presence of risky behaviours. If no indicators of risky behaviour were observed, we considered this behaviour to be a safe crossing. The observation of pedestrian behaviour took place during working days with good weather, as fewer pedestrians move outside when it is raining, and even fewer use smartphones. The observations were made in the morning from 7 a.m. to 8 a.m., at lunchtime from 12 noon to 1 p.m., and in the afternoon from 4 p.m. to 5 p.m. At each time point, observation took place twice, so we collected data for six hours by observation. There was an observer on the pavement on each side of the crossing, watching the behaviour of the pedestrians coming towards him. Before the data collection, two pilot studies were conducted to set objective criteria according to which the observers monitored indicators and ranked people in prepared categories. The observers were trained to understand each behaviour consistently and to eliminate bias in the results of their subjective interpretation. Each observer had a few trials to clarify vagueness and then started to record. After each pedestrian had passed the observer, he recorded their behaviour in the appropriate field of the record sheet. The observers tried to act as naturally as possible so that the behaviour of the pedestrians was not affected by the presence of the researcher.

Data collection through a structured interview took place four times in total. Interviews with pedestrians were conducted between 7 a.m. and 8 a.m., 12 noon and 1 p.m., 2 p.m. and 3 p.m., and 4 p.m. and 5 p.m. The researcher stood near the crossing where the observation took place. The same researcher standing near the pedestrian crossing recorded on a prepared sheet the behaviour of a pedestrian approaching

him in the same way as in the observation. The interviewers had the same training as the observers in recording the behaviour. The interviewer then addressed the pedestrian and clarified the purpose of the interview, and the pedestrian decided whether he or she wanted to answer the prepared questions:

1. How often do you use a smartphone while walking?
2. What leads you to use it while walking? What do you most often do on it?
3. Does it limit you while walking?
4. Do you think it is safe to use your smartphone while walking? Why yes? / Why not?

### 3.2 Sample population

#### 3.2.1 Observation

During the data collection, we observed a total of 2689 pedestrians. Of the total number, 2279 pedestrians did not use a smartphone when crossing, 195 pedestrians were holding a smartphone in their hand, and 215 pedestrians were making telephone calls or had headphones on.

#### 3.2.2. Interview

We managed to get 90 respondents for the interviews. The data obtained from the interviews was not compared with the data from the observation in order to avoid duplication and mistakes during the recording. In none of the cases was it necessary to exclude all the answers. We had to exclude one respondent when verifying the frequency of use hypotheses, as his answer to the first question was missing. Twelve people said they did not use a smartphone at all while walking, so they could not answer questions about activities and restrictions. We could therefore only receive answers to the first and fourth questions from these respondents. There were 42 women and 48 men in our research group. The interviews were conducted in different age categories, with the most numerous groups being pedestrians aged 19 to 26, who make up 42% of the respondents. See Table 1 below for more information on the age range between the sexes.

Group	Count	Mean	SD	Min. (Age)	Max. (Age)
Women	42	29.0	14.8	11	74
Men	48	27.5	13.9	9	80
All	90	28.2	14.3	9	80

**Table 1. Descriptive characteristics of the groups of men and women in terms of age**

The respondents were pedestrians from all three observed categories; they did not use a smartphone when crossing, they had a smartphone in their hand while crossing, and they were on the phone or wearing headphones while crossing. See Table 2 below for age range information.

Category	Count	Mean	SD	Min. (Age)	Max. (Age)
Not using smartphone	61	30.5	15.6	9	80
Using smartphone	11	29.3	12.7	16	60
Calling/wearing headphones	18	19.8	3.0	14	27

**Table 2. Descriptive statistics in terms of behaviour category**

### 3.3 Data Analysis

We recorded the data that we obtained in Excel. We analysed the data using Statistica 13. In two cases, we used the Mann-

Whitney U-test (the difference in frequency between the sexes and the age categories). We used Pearson's chi-square test to verify the other hypotheses. We tested all hypotheses at the significance level  $\alpha$  0.05.

In the data analysis, we worked with three main categories of pedestrians: they are not using a smartphone; they are making a phone call/have on headphones; they are holding a smartphone in their hand. In the analysis, we distinguish whether the pedestrian crossed alone or in a group of at least two people.

In Table 3 below, the individual categories of pedestrian behaviour that we worked with in the analysis can be seen.

Behaviour	Acronym
Safe crossing	SC
The pedestrian enters the crossing without looking both ways, but the road is clear and he or she pays attention to the surrounding events	WRE
The pedestrian enters the crossing without looking both ways, but the road is clear and he or she pays attention to his or her smartphone	WRS
The pedestrian enters the crossing without looking both ways, the car slows down or stops, and the pedestrian begins to pay attention to the surrounding events	WSE
Before the crossing, the pedestrian looks both ways, enters the crossing, and the car slows down or stops	LS
Before the crossing, the pedestrian looks both ways, the road is clear, and he or she pays attention to his or her smartphone	LRS
Before the crossing, the pedestrian looks both ways, the road is clear, and he or she pays attention to something else	LRE
The pedestrian walks in a group and lets himself or herself be led by other people	GP
The pedestrian walks in a group and he or she pays attention to the surrounding events	GE

**Table 3. Categories of observed pedestrian behaviour**

## 4. RESULTS

In this section, we describe what operations we performed during the data processing and then present their descriptive statistics. We will present the results in two parts, which we divided according to the method used for the data collection. Within each part, we describe the results of the data collection and the results of the statistical analysis.

### 4.1 Observation

Out of the total number of 2689 pedestrians, 85% did not use a smartphone while crossing, 7% were holding a smartphone in their hand, and 8% were making calls or had on headphones.

In Table 4 below, the absolute and relative frequencies of the observed pedestrian behaviours are shown. In each category the dominant behaviour is that before the crossing, the pedestrian looks both ways, the road is clear, and he or she pays attention to his or her smartphone. We named this behaviour as a safe crossing.

By analysing the data, we found out that in certain situations, pedestrian behaviour varies across categories. Detailed results are shown in Table 5. An important finding is that pedestrians holding a smartphone in their hand while walking cross the road safely less often than pedestrians without a smartphone or pedestrians who are calling/have on headphones. In Table 5 it can be seen that we did not find

Category	Does not use the smartphone		Holds smartphone in hand		Makes calls or has on headphones		Total
	Absolute	Relative (%)	Absolute	Relative (%)	Absolute	Relative (%)	
SC	953	42	75	39	132	62	1160
GE	763	33	28	14	9	4	800
LS	244	11	30	15	38	18	312
GP	153	7	16	8	13	6	182
LRE	81	4	5	3	7	3	93
WRE	74	3	4	2	13	6	91
WSE	11	<0.5	0	0	3	1	14
WRS	-	-	5	3	0	0	5
LRS	-	.	32	16	0	0	32
Total	2279	85	195	7	215	8	2689

**Table 4. Absolute and relative frequency of individual behaviours in pedestrians according to categories**

a difference between the individual categories of pedestrians in terms of whether they look both ways before entering the road. We have found out that pedestrians in each category force car drivers to give way equally often. We did not find any statistical difference between the individual categories of pedestrians (Table 5). Another finding is that pedestrians who are holding a smartphone in their hand while crossing pay attention to the traffic less often than pedestrians without a smartphone or pedestrians who are calling/have on headphones. By examining the behaviour of pedestrians walking in groups, we found out that those pedestrians who are not using a smartphone are least reliant on others when walking.

#### 4.2 Interviews

In the group of 90 respondents, six types of behaviour were observed: SC (73%), GE (16%), LRS (6%), LRE (3%), GP (1%), and WRS (1%).

For the first question concerning the frequency of use, we categorized the answers using a five-point Likert scale (not at all – rarely – sometimes – often – all the time). Respondents who never use a smartphone while walking are included in the “not at all” category. We classify respondents as “rarely” if they use one at most several times a month. Respondents who use a smartphone several times a week are classified as “sometimes”. In the category “often” we include people who use their smartphones every day while walking. The last category includes respondents who use a smartphone almost every time they walk. One respondent’s answer to this question is excluded from the data analysis, as his answer was incorrect.

12 respondents belong to the category “not at all”, 20 to the category “rarely”. 13 respondents answered that they “sometimes” use smartphones while walking, and 19 respondents answered “often”. 25 respondents use a smartphone “all the time” while walking.

The second question focuses on the activities that a pedestrian performs on a smartphone. On the basis of the answers of the respondents, we created six categories – calls, messages, internet (includes social networks, news, information retrieval, etc.), transport (includes searching for bus/train timetables and navigation), work, listening to music, other (e.g. playing games, taking photos, checking the time, learning vocabulary), and a seventh and last category, nothing, which concerns the respondents who stated that they do not use a smartphone while walking.

The most common activity when walking is writing messages (40 respondents), followed by making phone calls (33 respondents), music (23 respondents), the internet

(18 respondents), transport (12 respondents), and others (11 respondents), while the least frequent is work (four respondents). 12 respondents answered that they do not use a smartphone while walking.

The third question, in which we asked whether the respondents were restricted as a result of using a smartphone while walking, was again not answered by the respondents who stated that they do not use a smartphone while walking. The answers of the other respondents were coded into two groups – yes and no. 27 respondents answered yes and 51 no. We then compared the rationales for the answers. For those respondents whose smartphone restricts them when walking, the most common explanations were reduced attention, walking more slowly, and the need to pay more attention to what was happening around them. Respondents who replied that their smartphone did not restrict them when walking often explained that they were careful enough, and so this behaviour did not limit them. Some respondents said that although they need to be more vigilant when using a smartphone while walking and have already got into conflict situations, this behaviour does not limit them in any way.

The fourth and last question concerning the safety of using a smartphone while walking was answered by all the respondents and no answer had to be ruled out. We classified the answers into three categories needed to verify the statistical hypotheses, yes (11 answers), no (56 answers), and depending on the situation (23 answers). Respondents who considered the use of a smartphone while walking stated that it was safe if the pedestrian took care of himself or herself. Respondents who considered the use of a smartphone while walking dangerous were the most likely to report that a pedestrian paid reduced attention to this behaviour, was less alert, and was more prone to an accident. Respondents who said that safety depended on the situation most often argued that on pavements or in less frequented places, using a smartphone was safe, but it was not safe to use it at intersections and when crossing a road.

Detailed results of the statistical analysis are shown in Table 5. Analysis of the data found no difference between the sexes in terms of the frequency of use. We did not find a difference in the frequency of using a smartphone when walking between respondents under 30 and over 30. In Table 5, it can be seen that we did not find a difference in the perception of the safety of using a smartphone when walking among different categories of pedestrians. We can see that the opinion on whether a pedestrian reduces his or her use of a smartphone while walking does not differ across categories.



	Test statistic	p-value	Effect size
<b>SAFE CROSSING</b>			
holding a smartphone in one's hand – without a smartphone	$\chi^2=25.58^{***}$	< 0.001	0.13
holding a smartphone in one's hand – making calls or having headphones on	$\chi^2=12.39^{***}$	< 0.001	0.19
making calls or having headphones on – without a smartphone	$\chi^2=0.19$	0.67	0.01
<b>LOOKING BOTH WAYS BEFORE ENTERING THE ROAD</b>			
holding a smartphone in one's hand – without a smartphone	$\chi^2=0.02$	0.89	0.003
holding a smartphone in one's hand – making calls or having headphones on	$\chi^2=0.68$	0.41	0.04
making calls or having headphones on – without a smartphone	$\chi^2=1.18$	0.28	0.03
<b>CAR STOPS OR SLOWS DOWN WHEN PEDESTRIAN ENTERS THE ROAD</b>			
holding a smartphone in one's hand – without a smartphone	$\chi^2=0.12$	0.73	0.01
holding a smartphone in one's hand – making calls or having headphones on	$\chi^2=0.1$	0.75	0.02
making calls or having headphones on – without a smartphone	$\chi^2=0.71$	0.4	0.02
<b>WATCHING TRAFFIC WHILE WALKING</b>			
holding a smartphone in one's hand – without a smartphone	$\chi^2=87.12^{***}$	<0.001	0.24
holding a smartphone in one's hand – making calls or having headphones on	$\chi^2=40.57^{***}$	<0.001	0.34
making calls or having headphones on – without a smartphone	$\chi^2=1.7$	0.19	0.03
<b>BEING LED BY A GROUP WHILE CROSSING</b>			
holding a smartphone in one's hand – without a smartphone	$\chi^2=11.19^{***}$	<0.001	0.11
making calls or having headphones on – without a smartphone	$\chi^2=26.51^{***}$	<0.001	0.17
<b>INTERVIEW</b>			
There is a statistically significant difference between the sexes in terms of the frequency of using a smartphone when walking.	U=909.5	0.52	0.46
People under the age of 30 use their smartphone when walking more often than people over the age of 30.	U=678.5	0.08	0.41
Pedestrians who <b>did not use</b> a smartphone when crossing consider the use of smartphones to be less safe than other pedestrians.	$\chi^2=0.19$	0.91	0.05
Opinions on the safety of using your smartphone while walking differ between pedestrians who did not use a smartphone while crossing, pedestrians who had a smartphone in their hand while crossing, and pedestrians who were on the phone or had on headphones.	$\chi^2=1.15$	0.89	0.11
The opinion on whether a <b>pedestrian is restricted by the use of a smartphone</b> while walking differs between pedestrians who did not use a smartphone while crossing, pedestrians who had a smartphone in their hand while crossing, and pedestrians who were on the phone or had on headphones.	$\chi^2=0.48$	0.79	0.08

*Note:* The effect size for the chi-square test is  $\Phi$  (the  $\Phi$  value is always bounded between 0 and 1). A value of 0.1 is considered a small effect, 0.3 a medium effect, and 0.5 a large effect. For the Mann-Whitney U-test the effect size is AUC (the AUC score is always bounded between 0 and 1). A score of 0.5 or less suggests no discrimination, 0.7 to 0.8 is considered acceptable, 0.8 to 0.9 is considered excellent, and more than 0.9 is considered outstanding discrimination. Each hypothesis was tested at a significance level of 0.05. \*\*\* indicates  $p < 0.001$ .

**Table 5. Overview of the results of statistical data analysis**

## 5. DISCUSSION

The first goal of our work was to describe the behaviour of pedestrians who used a smartphone when crossing the road, whether they were holding it in their hand, making phone calls, or listening to music. We wanted to find out if the different categories of pedestrians behave differently. We were also interested in whether pedestrians whose attention and capacity are engaged by a smartphone display more frequent elements of risky walking than pedestrians who do not use a smartphone when crossing the road.

A total of 15% of the pedestrians who used a smartphone while crossing at the pedestrian crossing appeared in our group. By comparison, researchers in Melbourne observed 20% of pedestrians using a portable device (Horberry et al., 2019), and in Seattle almost 27% of pedestrians were observed to be using a mobile device (Thompson et al., 2012). In this survey the shares are lower than those found elsewhere. This could be because of the frequency of the transition, the time of the observation, or the country in which the research was

conducted. In any case, this is not a negligible proportion of pedestrians, and therefore we consider it important to know the differences in their behaviour in order to be able to predict and also educate road users.

### 5.1 Safe crossing

We consider using a pedestrian crossing safely to be a behaviour in which a pedestrian looks both ways before entering the road, enters when he or she has a clear path, and watches what is happening around him or her. We considered pedestrians who had crossed safely to be those in whom there was not a single manifestation of risky behaviour. In our group, we did not find a significant difference in terms of safe crossings between pedestrians who were not distracted by anything and pedestrians who were calling, or those who were using headphones. In both cases, safe passage approached 70% of the observed cases. In contrast, in the group of pedestrians holding a smartphone in their hand when walking, safe crossing occurred the least often, in about half of the cases. The

difference between the pedestrians holding smartphones and the other two categories of pedestrians proved to be statistically highly significant. On average, every second pedestrian with a smartphone in his or her hand had at least one manifestation of risky behaviour. By comparison, Thompson et al. (2012) observed at least one manifestation of risky behaviour in pedestrians using a smartphone up to four times more often than in pedestrians who were not distracted by any devices.

Looking both ways before entering the road is considered a predictor of crossing safely (Holland & Hill, 2010). In their research, Schwebel et al. (2012) found that undistracted pedestrians look both ways before crossing more often than pedestrians who were distracted by their smartphones. In contrast, several studies (Byington & Schwebel, 2013; Thompson et al., 2012; Horberry et al., 2019) have found out that pedestrians who actually use a smartphone while crossing look less often than undistracted pedestrians before entering the road. In our research, we compared whether one of the categories of distracted pedestrians looks less often before crossing than undistracted pedestrians and also whether pedestrians holding a smartphone in their hand look less than pedestrians who are making phone calls or have on headphones. In neither case did we find a significant difference. We assume that the differences between our research and the foreign research may be due to the size of the set of pedestrians using smartphones and differences in traffic habits between countries. The role of the attitude to the safety of using a smartphone while walking is also worth considering. 88% of the respondents do not consider it safe to use a smartphone when crossing the road. We did not find any difference between the perceived danger of using a smartphone when walking between the pedestrians who used one when walking and those who did not. An interesting finding in our research is that although safe behaviour varies between categories of pedestrians, their views on safety are the same across categories. We believe that looking carefully before entering the road can thus be a strategy to reduce the perceived potential risk.

Another factor to monitor was whether pedestrians entered the crossing when they had a clear path or entered it regardless of whether the car had to slow down or stop. Although drivers are obliged by law (361/2000 Sb.) not to endanger or restrict pedestrians, pedestrians may not enter the road if the driver is forced to make a sudden change of direction or speed. Many pedestrians rely on the crossing to have priority but neglect to consider the distance and speed of the oncoming vehicle. They do not realize that they do not have absolute priority and that such behaviour endangers themselves. When they are paying attention to a smartphone, their perception is limited and their estimate of the distance and time of the encounter may be skewed (Eysenck & Keane, 2008). We assumed that drivers would have to give way to pedestrians who are using a smartphone when crossing more often than they would have to do in the case of undistracted pedestrians. We also assumed that car drivers would have to give way to pedestrians who have a smartphone in their hand when crossing more often than to pedestrians who are making phone calls or have on headphones. The willingness of drivers to give way to a pedestrian decreases if the waiting pedestrian is engaging in another activity, such as telephoning or writing messages (Sucha et al., 2017). On this basis, we believed that pedestrians using smartphones would have to "force" their crossing more often. We did not confirm this assumption with statistical analysis, and the low value of the coefficient indicates that no relationship can be found between the use of a smartphone and crossing if the driver of the car has to give way to the pedestrian.

## 5.2 Paying attention

An important factor in safe walking is paying attention to the surrounding events. Using a smartphone while walking reduces the available information processing capacity (Lamberg & Muratori, 2012). Pedestrians who use a mobile device when walking register fewer objects than undistracted pedestrians, which reduces their ability to respond appropriately to environmental conditions (Hyman et al., 2009; Neider et al., 2010; Kuzel et al., 2008 in Mwakalonge et al., 2015). We found that pedestrians who had a smartphone in their hand when crossing failed to deal with what was happening around them more often than pedestrians who were not occupied with their phone. It was mainly behaviour in which pedestrians looked at their smartphone and were using it at that moment, or, exceptionally, engaged in something else (e.g. eating). Byington and Schwebel (2013) observed similar distracted pedestrian behaviour in their study. Pedestrians who paid attention to their smartphone display spent less time checking the traffic.

Although we found out that pedestrians holding a smartphone in their hand fail to register things around them more often than other pedestrians, we did not find a difference between pedestrians who were on the phone or had headphones and undistracted pedestrians. When one is making calls or using headphones, there is a limited supply of audio signals from the environment. Telephoning even reduces the ability to process visual information (Neider et al., 2010). Although making phone calls and listening to music are cognitively demanding activities, they draw on less available working memory capacity than direct manipulation of a smartphone. We believe that we did not find a difference between these pedestrians and undistracted pedestrians because the restriction of their visual perception is not visible to the observer with the naked eye. The observers in the present study recorded freely observable behaviour such as the direction of view or the rotation of the head. Although the observer sees that the pedestrian is looking around, he is unable to determine whether he or she perceives the stimuli around him or her. Therefore, in further research, following the example of foreign studies (e.g. Hyman et al., 2009; Neider et al., 2010), we would recommend examining whether pedestrians who are calling or use headphones only see things or actually perceive them.

When observing people walking in groups, we found that pedestrians who had a smartphone in their hand while walking did not pay attention to what was happening around them and were guided by the group more often than undistracted pedestrians were. In this case, pedestrian behaviour is the same for individuals and groups. In contrast, a pedestrian who is on the phone or has on headphones and is walking alone tries to pay attention to his or her surroundings. An interesting finding is that in most cases, this category of pedestrians did not pay attention to the surrounding events when in a group. The main factor in assessing the behaviour was the direction of view and the rotation of the pedestrian's head. Pedestrians who did not change the direction of their gaze when walking and devoted it only to other pedestrians or their smartphone display were categorized as being guided or not paying attention. We believe that the non-monitoring of traffic may be caused by reliance on others, in addition to depleted cognitive capacity. Although other members of the group watch the changing traffic environment and may react to it, a pedestrian who does not pay attention to what is happening around him or her is still at risk.

## 5.3 Survey

Following the example of self-assessment research (Lennon et al., 2017), we compared the frequency of use among our respondents. We compared the differences between the sexes and the differences between older and younger respondents.

We found that there is no difference between men and women in terms of how often they use their smartphones while walking. Unlike the research study by Lennon et al. (2017), we did not find a significant difference in the frequency of using a smartphone when walking between people under 30 and people over 30, although we can observe a certain trend here.

Foreign research shows that the use of a smartphone while walking affects the speed and manner of walking (Kao et al., 2015; Lin & Lin, 2016; Jiang et al., 2018). On the basis of this, we assumed that respondents would have different opinions on whether their use of a smartphone while walking affects their behaviour.

Slower walking was one of the things that the respondents considered restrictive. The respondents also considered reduced attention and limited perception to be limiting. In our group, however, we did not find a difference of opinion on restrictions between the individual categories of pedestrians. The reason may be that pedestrians do not feel the changed behaviour when using a smartphone to be restrictive. Another reason may be that they thought about the situations in which they actually use their smartphone while walking, not about the crossing we observed.

Another goal of the work was to map the reasons that lead a person to use a smartphone while walking, i.e. what activities he or she does on it most often. The most common response from the respondents was writing messages, either via SMS or various applications. This is the activity that is most cognitively demanding and in which the pedestrian is most deprived of information from the environment (Haga et al., 2015; Jiang et al., 2018). The other most common activities were making phone calls, listening to music, and surfing the internet. By comparison, in a US survey, telephoning was the most common activity, followed by listening to music, and in third place was writing messages (Liberty Mutual Insurance, 2013). The differences may be due to this being older research, as smartphones and mobile internet access have become much more accessible and widespread over the last seven years. The difference could also be caused by differences between the Czech and American populations.

We assume that the results of this research can help to improve pedestrian safety in the Czech Republic. It can be the basis for further research and subsequent education and prevention aimed at safe pedestrian behaviour in the world of modern technology. Awareness of the risks posed by using a smartphone while walking and acquiring safe behaviour in traffic could improve the safety of the most vulnerable road users.

## 6. CONCLUSION

In our research, it was found out that 15% of pedestrians use a smartphone when crossing at a pedestrian crossing – either they have it in their hand or are making a call, or they have headphones. We found out that pedestrians in the category of those who had a smartphone in their hand crossed safely less often than pedestrians without a smartphone or pedestrians who were calling or had headphones on. In terms of crossing safely, we did not find a difference between pedestrians who were on the phone or had headphones on and pedestrians for whom we did not observe a smartphone.

We compared walking behaviour among pedestrians who were not using a smartphone, were holding one in their hand, and were making phone calls or had on headphones. We did not find a difference between these categories in terms of how often they looked both ways before crossing at the pedestrian crossing. Neither did we find a statistically significant difference in which category of pedestrians cars had to give way to more often.

In our research, we found that pedestrians who have a smartphone in their hand pay attention to the traffic and what is happening around them less often than the other two categories of pedestrians. We did not notice a difference in terms of watching what was happening around them between pedestrians who were on the phone or had on headphones and pedestrians for whom we did not observe a smartphone. We observed that pedestrians who were using smartphones and walked in groups were led by others and did not follow what was happening around them more often than undistracted pedestrians.

We found that the frequency of using a smartphone while walking does not differ between men and women. We did not observe a statistically significant result in terms of the frequency of use among respondents under the age of 30 and above the age of 30, but we can at least observe a trend.

On the basis of the statements of the respondents, we found the opinion on the safety of using a smartphone while walking and the opinion on whether their smartphone restricts their walking. When comparing their behaviour and the expressed opinion, we found that the opinions do not differ across the three categories of behaviour that were observed.

An interesting finding is that the opinion on the safety of using a smartphone when walking does not differ between the various categories of pedestrians, but the perception of what is meant by crossing safely differs between these categories.

Through interviews, we found that the most common activities for pedestrians are writing messages, making phone calls, listening to music, and surfing the internet.

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