Interpersonal Communication and Issues for Autonomous Vehicles

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16. Abstract

Interpersonal roadway communication is a vital component of the transportation system. Road users communicate to coordinate movement and increase roadway safety. Future autonomous vehicle research needs to account for the role of interpersonal roadway communication. This literature review synthesizes research on interpersonal interaction between drivers, bicyclists, and pedestrians while also directing attention to implications for autonomous and connected vehicle research. Articles were collected from TRID, PsycINFO, Google Scholar, and ScienceDirect using search terms relevant to driving, communication, and vulnerable road users. The synthesis documents that interpersonal communication not only takes place but is also an important and understudied aspect of safe roadway travel. The review also found that road users employ a variety of communication methods that include gestures, facial expressions, and built-in vehicular devices. Comprehension of messages is influenced by a number of factors including culture, context, and experience. These results shed light on potential issues and challenges of interpersonal communication and the introduction of autonomous vehicles to the roadway.

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Introduction

Interpersonal communication has to do with the exchange of information between people that enhances mutual understanding of a situation, indicates behavioral intent, or responds to the actions of another. Effective communication involves all parties communicating their intent in a manner that is received and understood. Alternatively, miscommunication is either a failure to communicate intent effectively (e.g. clearly visible, easily understood) or a misunderstanding of a communication attempt. Lack of communication is the failure to communicate intent or response within a meaningful timeframe. Interpersonal communication between road users is an integral aspect of using the transportation system. Whether driving, riding a bicycle, or crossing the street, safe transportation requires that everyone share the road. Communication between road users helps coordinate behaviors, regulate road use, signal intent, and encourage other drivers to behave in certain ways (Renge, 2000; Shor, 1964). These interactions can involve reminding road users of formal traffic rules when they appear to be breaking them, or using eye contact to establish mutual acknowledgement of what is occurring, such as when a pedestrian crosses the street and a driver yields to him or her. Zaidel (1992) argues that the road can be considered a social environment, where driver decision making is partly determined by the way that drivers communicate with each other. Road users consider such communication important, and when drivers fail to communicate their intent, other road users view their behavior less favorably (Ba, Zhang, Reimer, Yang, & Salvendy, 2015).

In response to the critical need for interpersonal communication, modern automobiles are equipped with technologies to facilitate communication between drivers, such as turn signals, hazard lights, and car horns. For example, drivers are required to indicate to others road users their intent to turn or change lanes through the use of a turn signal, yet research shows that turn signals are not consistently used. Sullivan, Bao, Goudy, and Konet (2015) conducted a naturalistic investigation of turn signal use at intersections and found that signals were only used 71-75% of the time. When they were used, turn signals alone were not sufficient to judge a driver's intersection behaviors because signal use was partly determined by the road type, turn direction, and state of the surrounding traffic. In recognition of the need for interpersonal communication in the driving environment, other technologies have been developed for the purpose of further extending communication options while driving, such as remote-controlled

expressive car signs that utilize mountable screens that can display short messages or express emotions to other drivers (Drivemocion, 2010).

Lack of communication and miscommunication on the road also represent safety concerns. The National Motor Vehicle Crash Causation Survey (NMVCCS) found that "false assumption of others' actions" was the critical reason for 4.5% of all crashes, of which at least a part could be likely attributed to miscommunication between road users while driving (National Highway Traffic Safety Administration, NHTSA, 2008). The safety effects of miscommunication may be even greater when vulnerable road users are considered. Of pedestrians and bicyclists, 25.5% and 27.0% of fatal crashes, respectively, were attributed to "failure to yield right of way" in 2014, with a large proportion of these crashes likely attributed to lack of communication or miscommunication (Fatality Analysis Reporting System, FARS, 2017). Despite these statistics, there is not a good way to estimate the prevalence of crashes for which communication problems are primary causal factors, and, thus, a full grasp of the safety aspects of miscommunication or the lack of communication in the transportation system is lacking.

The development of automated and connected vehicles comes with promise that driver-error-related crashes will be reduced. The NMVCCS found that about 94% of crashes were due to driver error, and advocates of automated vehicles have predicted that automated vehicles will reduce 80% of crashes (Iliaifar, 2012; NHTSA, 2008). Currently, automated vehicles do not have the same capacity to communicate with other road users as drivers. For example, automated vehicles do not have a means to signal intent beyond the use of a turn signal, they cannot indicate whether or not they intend to yield, and they cannot yet read and interpret gestures from vulnerable road users (Parkin, Clark, Clayton, Ricci, & Parkhurst, 2016). Considering how ubiquitous interpersonal interaction is within the context of driving, this is a potential safety concern worth addressing. Recently, an automated vehicle was involved in a crash when it attempted to merge into traffic, to maneuver around an obstacle on the road, as a bus was approaching from behind. (Ziegler, 2016). The autonomous vehicle's programming assumed that the bus driver would yield when the autonomous vehicle attempted to merge into traffic; yet, this assumption was incorrect and the conflict could not be resolved through interpersonal communication.

The transportation system is not only undergoing a technological transformation but also a social-communicative transformation. As the development and deployment of automated and connected vehicles continues, there will be a mixed fleet of autonomous, semi-autonomous, and non-automated vehicles, as well as vulnerable users (e.g., pedestrians and bicyclists) that all must safely interact with each other. Thus, it is critical to better understand the nature of how, why, and when people communicate with each other on the roadway. Such information will be useful for developing future vehicles and behavioral countermeasures that will not only prevent crashes but improve the well-being of all road users.

The purpose of this report is to synthesize the literature on interpersonal communication between drivers, bicyclists, and pedestrians with the intent of identifying issues and challenges that may face developers of autonomous and connected vehicles. This review highlights future directions for automated vehicle research within the context of interpersonal communication on the road.

Methods

The initial search for literature consisted of three steps. First, we defined the forms of interpersonal communication on the roadway to be included in the report based on previous literature (Ba, Zhang, Reimer, Yang, & Salvendy, 2015; Renge, 2000) and the research team's background. The search terms used to find research materials were related to driving (driver, vehicle, driving), communication (gestures, interpersonal communication, interaction, communication), and type of communication (turn signals, horn honking, hand gestures, eye contact). Second, articles were searched in TRID, PsycINFO, Google Scholar, and ScienceDirect. From these databases, relevant journal articles, technical reports, and conference papers were gathered. An Internet search was also conducted to find news articles and web pages pertaining to this review’s topic. While there was no year restriction on the search, most articles were published after the year 2000. Finally, manual searches of the reference lists of relevant articles were conducted to collect additional articles that appeared to be appropriate. Overall, the initial search yielded 63 items.

The articles from the initial search were reviewed by the research team. To be eligible for further review, articles needed to: 1) provide findings related to the types, meanings, and use of various forms of on-road communication, and 2) focus on person-person or vehicle-person

communication, excluding vehicle-vehicle or vehicle-infrastructure communication. This review process yielded 36 articles for inclusion.

The articles utilized a wide range of data collection techniques including focus groups, questionnaires, naturalistic driving, and driving simulation. The final articles were categorized into several topics relevant to understanding the function of interpersonal communication on the road including: the ways in which people communicate; communication with vulnerable road users; how well people understand roadway communication; and how communication influences driver behavior

Results

Types of Interpersonal Communication

There are a variety of ways that road users can communicate with each other while sharing the road. Renge (2000) divided roadway communication into three categories: formal device-based signals; informal device-based signals; and informal gesture-based signals. Renge et al. (2004) added a fourth category - formal gesture-based signals, which encompasses the arm gestures that bicyclists can use to indicate the direction they intend to turn. Formal device-based signals include the use of hazard lights, turn signals, and car horns for their intended use, while informal signals can vary widely, including the use of hand gestures, eye contact, or vehicle headlights. Even with formal device-based signals, the meaning can change depending on the context in which a signal is used as is the case with the car horn. Use of honking can generally serve five different functions: as social etiquette, giving emphasis, as an expression of displeasure, giving an order, or giving notice to something (as cited in Mesken, 2002). For example, Takada, Fukuda, and Iwamiya (2008) found that light tapping of the car horn was a means for Japanese drivers to show gratitude for right-of-way yielding. Given the wide range of uses for the car horn, it is important to keep in mind that the situational context is an important component to interpreting horn honking.

Turn signal use also depends on situational context. Faw (2013) conducted two observational studies of turn signal use rates. The first study was conducted at 22 intersections over the course of 4 months and the second at two intersections over 28 months. Turn signal use rates were measured under a variety of conditions (e.g., region, traffic volume, direction of turn). Faw (2013) found that turn signal use rates were higher in moderate traffic (92%) and lower in

light traffic (88.7%) and heavy traffic (78.9%). Drivers also signaled left turns (89.2%) more often than right turns (85.1%). The study also found that drivers signaled 7% less often when closely following another driver, although when drivers were following a vehicle that had a signal on, they activated their signal 6% more often. Sullivan et al. (2015) obtained similar results after analysis of extensive naturalistic driving data for 108 drivers. These researchers found that drivers were 1.4 times more likely to use their turn signal when turning left as compared to right, which they suggested could be due to greater perceived risk with left turns. They also found that people were about 5 times more likely to use their turn signal on major and minor surface roads compared to local roads, which tend to have less traffic. In addition, the study found that turn signal use at an intersection was 1.5 times more likely if drivers were behind a lead vehicle at the intersection. Thus, there is good evidence that signal use varies by a number of factors and Sullivan et al. (2015) concluded that signal use alone may not be a reliable indicator of a persons' intended action. In other words, a lack of signal use does not necessarily mean that the driver does not intend to make a turn.

Unlike formal device-based signals, informal signals do not have any official standard, meaning and are developed through observational learning (Renge, 2000). Hand gestures are a common category of informal communication. For example, drivers may use hand gestures to encourage other road users to go or to halt (Šucha, 2014), while pedestrians may also use hand gestures to encourage other drivers to yield and to show gratitude for yielding behavior (Crowley-Koch, Van Houten, & Lim, 2011; Šucha, 2014; Zhuang & Wu, 2014). Because different gestures can be used to convey the same message, research has been conducted to discover what kinds of gestures communicate behavioral intent more effectively (Crowley-Koch, Van Houten, & Lim, 2011; Zhuang & Wu, 2014). Turnbaugh and Turnbaugh (1987) suggested that road users use hand signals as an internalized form of reciprocal acknowledgement or as a physical expression of “monitoring” one another. Eye contact, though subtle, is another powerful form of informal communication. Eye contact is processed as a social cue; that is, a demonstrative signal that communicates who is being addressed, as well as that the ensuing action or information will be meaningful (Böckler, van der Wel, & Welsh, 2014). Šucha (2014) confirmed that pedestrians and drivers both make use of eye contact to communicate and this can be used by pedestrians to encourage other drivers to yield (Guéguen, Meineri, & Eyssartier, 2015). Informal device-based signals are another potential mode of communication. For

example, some drivers use headlights to communicate with other road users (Šucha, 2014). Renge (2000) outlined several examples of headlight flashing for communication with other road users including: blinking of headlights to yield one's way, blinking of headlights to another car that is cutting in, and blinking of headlights for thanks. Formal device-based signals, formal gesture-based signals, informal device-based signals, and informal gesture-based signals are four broad categories that can be used to classify the diverse range of methods that road users can use to communicate. Being able to detect and classify the use of signals to communicate is the first step in developing a deeper understanding of interpersonal roadway communication. However, as with other modes of interpersonal communication, the context in which the signaling takes place often dictates the communication message. Depending on the context, the flashing of one's headlights can have different meanings, such as indicating there are police or obstacles ahead, urging a driver to speed up, signaling that it is okay to merge, and a number of other messages. Therefore, the context of messaging plays a critical role in effective interpersonal communication of the roadway.

Communication with Vulnerable Road Users

Vulnerable road users also have methods they use to communicate their presence and behavioral intent to drivers. Most vulnerable road users do not have device-based means of communicating intent to drivers and so informal means of communication are often employed. Research cataloguing the use and effects of communication from vulnerable road users has focused on pedestrian street crossing and bicyclist-vehicle interaction.

A common area for pedestrian safety is crossing a road when there is traffic present and there is no signalized crossing. Research shows that drivers are unlikely to yield to pedestrians (see e.g. Bertulis & Dulaski, 2014; Emerson, Bourquin, Sauerburger, & Barlow, 2015; Foster, Monsere, & Carlos, 2014; Ibrahim, Kidwai, & Karim, 2005; Stapleton, Kirsch, Gates, & Savolainen, 2017). For example, a study in Malaysia observed pedestrian-driver interactions at a marked crosswalk utilizing cameras focused on the intersection (Ibrahim, Kidwai, & Karim, 2005). Video analysis showed drivers of automobiles yielded to pedestrians in only 1.5% of attempted crossings. The study also found that motorcycle users never yielded to pedestrians. Another study conducted in Boston found that at unsignalized, marked crosswalks on roads with 40 mph speed limits the average driver yielding rate was only 15% (Bertulis & Dulaski, 2014).

One way in which pedestrians can improve driver yielding is through communication with drivers at points of roadway crossing, such as crosswalks. Pedestrians can communicate with drivers by using their arms, making eye contact, and smiling; drivers can respond by using hand gestures, flashing their lights, or making eye contact (Šucha, 2014). The importance of interpersonal communication in driver yielding to pedestrians has been documented. Lehsing, Benz, and Bengler (2016) conducted a study in which a driving simulator was linked to a computer that allowed the experimenter to control the actions of a pedestrian (called an avatar in the study) that was visible to the study participant as they drove the simulator. The experimenter controlled the pace and walking direction of the pedestrian (e.g., turning to face the driver) in response to the participant driver's actions, thereby allowing for a form of interpersonal communication to take place. In other conditions, the pedestrian was simply programmed to move along a sidewalk and occasionally cross the street (called a bot in the study). The study measured driving behavior around the two different types of pedestrians. The researchers found that drivers drove more cautiously in the presence of the bot-pedestrian walking on the sidewalk when compared to the avatar-pedestrian, and at marked crosswalks drivers slowed significantly more for the avatar-pedestrian. The researchers suggested that drivers were more cautious around the bot-pedestrian because drivers lacked interpersonal communication with the bot and therefore did not have information about what the bot might do. On the other hand, participants noticed that avatar-pedestrians displayed safety-oriented behavior that was related to the participant's driving behaviors and this communication allowed participants to better predict the avatar-pedestrian's behavior both while walking on the sidewalk and crossing at marked locations. These results demonstrate the value of interpersonal communication between drivers and pedestrians.

Research conducted on the effects of signals that pedestrians use to communicate with drivers sheds further light on the nature of this interaction. Studies show that gestures are a common means of informal communication that improves driver-yielding behavior for pedestrians (Crowley-Koch, Van Houten, & Lim, 2011; Zhuang & Wu, 2014). Zhuang and Wu (2014) conducted a study measuring the difference in yielding rates among several gestures and concluded that visibility and clarity of the gesture were the most important aspects of an effective gesture and that many gestures were misinterpreted. Only one gesture, a left-arm, bent elbow with the palm facing the oncoming driver, was found to significantly increase yielding

(12.9%). In a similar study, Crowley-Koch, Van Houten, and Lim (2011) found that a raised arm "halt" gesture increased driver yielding at crosswalks by 29% compared to a no-gesture condition. They reasoned that this was because the raised arm was an assertive gesture, and that pedestrian assertiveness played a role in the likelihood of driver yielding. Additionally, these researchers suggested that the raised arm gesture could be more easily transitioned to a "thank you" wave which could encourage future yielding behavior.

There is some evidence that an expression of gratitude might increase driver yielding. Nasar (2003) conducted a naturalistic study in which drivers passing through two intersections had to choose whether to yield to pedestrians who were confederates for the study. If the driver yielded to the confederate at the first crossing, then they held up a written sign indicating gratitude and smiled at the driver. If the driver did not yield, at the next crosswalk another confederate presented a sign indicating disapproval and a plea to yield in the future. This treatment was conducted over the course of 3 weeks, and for each of the first 2 weeks there was an 8% and a 7% increase, respectively, in yielding at the second crosswalk, with a 5% average increase in yielding at the first crosswalk by the third week. While a modest increase, the results suggest that "thank you" hand waves or other gestures of gratitude might increase yielding behavior of drivers over the long-term.

Other forms of communication that pedestrians can employ to indicate intent to cross the road and have the driver yield include direct gaze and facial expression. Direct gaze can function as both an emotional and social cue, and therefore can be used by pedestrians to get the attention of drivers and communicate their intentions (Böckler, van der Wel, & Welsh, 2014). In another study utilizing confederate pedestrians at crosswalks, researchers found that when pedestrians stared directly at approaching drivers, drivers yielded 12.6% more often as compared to conditions when they did not stare, and the effect was greater when the confederate was female (Guéguen, Meineri, & Eyssartier, 2015). These same researchers (Guéguen, Eyssartier, & Meineri, 2016) investigated the effect of a pedestrian's smile on yielding behavior, again using confederates as pedestrians. They found that smiling increased yielding behaviors at marked crosswalks by 12.8% as compared to a neutral expression, but drivers stopped 13.5% more often when the confederate was female. Further, male drivers stopped 20.6% more often for female confederates. Finally, smiling was also found to increase yielding behavior by 11.2% at

unmarked crosswalks. These studies show the importance of nonverbal social communication for pedestrians and the influence of gender in pedestrian yielding behavior.

Bicyclists also need to communicate with drivers to use the road safely. Since bicyclists interact with drivers at crosswalks and on the road, it is important that bicyclists not only make drivers aware of their presence but also communicate behavioral intent, such as turning. Studies show that gaze cues can make drivers more aware of bicyclists and their intentions because drivers tend to fixate on a bicyclist's face before directing their attention to gestures or other nonverbal signals (Walker, 2005; Walker & Brosnan, 2007). Walker (2005) conducted a laboratory experiment in which drivers had to react to bicyclists at intersections by judging their intentions and reacting appropriately. In some cases, bicyclists gave no signal indicating their intent, in other cases they gazed at the driver or used arm signals. When bicyclists used clear arm signals, drivers were far less likely to stop unnecessarily, indicating that they properly understood the bicyclist's intent. Walker (2005), however, found a potential problem with signaling: clear arm signals were the best perceived and understood but also required the most cognitive processing which slowed down reaction times and led to more collisions. Thus, there was a tradeoff between the complexity of the mode of communication and the reaction time required to respond appropriately. This finding does not mean that giving clear communication of intent is counterproductive, because it does improve yielding rates and enhances shared understanding of intended behaviors, but it does mean this communication strategy should be started well in advance of the intended behavior.

Comprehension of Interpersonal Message

Given the variety of ways in which road users attempt to communicate with each other, comprehension is a critical component to this interpersonal communication. Archer (1997) demonstrated through video recordings of gestures from around the world that nonverbal communication varies widely between cultures and even identical gestures can have different meanings in different cultures. Factor, Mahalel, and Yair (2007) presented a "social accident" model to study the effects of social and cultural factors on crashes. They argued that different social groups have different cultural characteristics which can change the way that driving situations are interpreted. Renge et al. (2004) conducted a cross-cultural study in Germany, Finland, and Japan to examine differences in comprehension for formal and informal

communication signals. Participants were presented with 22 videotaped scenes of road users employing different forms of communication and had to determine the correct meaning behind the signal use, rate their confidence in their response, and rate the presented signals on different scales of friendliness/aggression and necessity. As compared to Finnish and German drivers, Japanese drivers identified the correct meanings of formal signals less often and had lower confidence scores for their answers. Judgements of informal signals revealed several cross-cultural differences in comprehension. For example, in one scenario a motorcyclist was forced to stop when they were abruptly cut off by a driver of an automobile. The motorcyclist then protested by raising his middle finger. The German and Finnish drivers generally understood this signal as a message to “obey the traffic regulations” and as a sign of aggression. Japanese drivers, on the other hand, did not understand the gesture, with the majority interpreting the hand gesture as “thank you.” Many Japanese drivers also did not understand signals involving hazard lights and bicyclists’ turn signals. Finnish drivers were the most confident in their comprehension of communication, followed by German and then Japanese drivers. Differences in the comprehension of interpersonal messages can also occur within a country. For example, studies have shown that that "horn honking" conveys different meanings in different places in the US (see e.g., McGarva and Steiner, 2000; Novaco, 1991).

Currently and for the foreseeable future, roadway transportation can be considered a social environment, where behaviors are influenced by road users, formal traffic rules, and social norms. Therefore, both the immediate situation and past experiences factor into how roadway users may interpret interpersonal communication. Renge (2000) found that as compared to experienced drivers, novice drivers (less than <2000 km driving experience) were 30% less accurate and had significantly lower confidence scores for determining the meaning behind other drivers’ formal signal use. Differences in comprehension between novice and experienced drivers were greatest for informal signals, such as flashing headlights. These findings suggest that comprehension of communication signals depend in part on driving experience.

The comprehension of interpersonal communications can also be influenced by the ways in which communication signals are used. For example, Takada, Fukuda, and Iwamiya (2008) conducted a survey among 140 Japanese drivers and pedestrians on comprehension of horn use. The study found that horn signal comprehension varied depending on the temporal patterns of the signal (e.g., a single long honk vs. multiple short honks). Further, the study found even

within a specific horn use pattern, there was general disagreement about the meaning of that signal. Additionally, pedestrians found car horns more startling and annoying than drivers and were less likely to understand the meaning behind the horn use, interpreting the horn use as primarily for gaining attention or to inform of danger even if the intended meaning was something different such as expressing gratitude or venting anger. The authors concluded that horns were not an effective means for interpersonal communication because they do not convey clear messages.

Discussion

The purpose of this review was to synthesize the literature on roadway interpersonal communication with an underlying goal of better understanding the potential issues and challenges that may need to be addressed for the successful implementation of autonomous vehicles on public roadways. The review clearly documents that interpersonal communication not only takes places but also is an important and understudied aspect of safe roadway travel.

A variety of nonverbal communication strategies are employed by drivers, pedestrians, and bicyclists ranging from the use of formal, technology-based strategies (such as turn signal use) to informal strategies (such as hand gestures or eye contact). While there is little research on the frequency with which these strategies are used, evidence seems to suggest that they are commonly employed.

The review addressed specifically the interpersonal communication strategies utilized for communication between drivers and vulnerable road users (pedestrians and bicyclists), particularly for roadway crossings. The review documented the difficulties that vulnerable road users have in getting drivers to yield for roadway crossings and the important role interpersonal communication can play in increasing the chance of getting a driver to yield. Because vulnerable road users do not have technology-based strategies, they frequently employ body language, eye contact, and smiling to communicate to drivers their intent to cross a roadway. These strategies increase driver yielding behavior some, but yielding is still low overall. Some research has investigated the use of hand gestures, and these also increase yielding behaviors moderately.

Despite the variety of ways that road users engage in interpersonal communication, there are a surprising number of factors that can influence message comprehension, such as the context in which messaging takes place. An identical message, such as flashing head lights, often is

comprehended differently for different road users because of these factors. One of these factors stems from the fact that many informal message strategies have developed out of necessity and are learned while people travel on the roadway. Thus, different areas of the US and different countries have developed different interpersonal message norms that do not necessarily mean the same things. This also explains the fact that informal interpersonal roadway message comprehension is better among experienced drivers. Another factor affecting comprehension is that for some strategies the message's meaning changes depending on the context. For example, the flashing of headlights might have one meaning if you have just merged in front of a driver and another meaning if the driver has been following behind you.

These results shed light on potential issues and challenges of interpersonal communication and the introduction of autonomous vehicles to the roadway, a topic that others have started to discuss (see e.g., Köhler et al., 2012; Parkin et al. 2016). These issues and challenges are:

- Regardless of how quickly the vehicle fleet transforms to autonomous vehicles, the issues surrounding interpersonal communication will need to be addressed. Even with a fully autonomous fleet, there will still be vulnerable road users for which the autonomous vehicles will need to safely and effectively interact. Given the importance of interpersonal communication for roadway crossing events in particular, there will need to be intelligent strategies for the vulnerable roadway user to signal intent to cross and for the vehicle to signal whether or not it will yield.
- Autonomous vehicles will need to be able to not only detect but accurately interpret the variety of strategies used by all road users. This interpretation is nontrivial given the several factors that can impact comprehension, including cultural norms and the context in which the message-strategy is used. Thus, the sensing and control system for the autonomous vehicle will have to measure and analyze information in addition to the specific message-strategy.
- Autonomous vehicle algorithms that are designed to predict the intent of other drivers will have to rely on both formal and informal communication strategies. For example, the research on turn signal use shows that when used, turn signals do a good job of signaling the intent to turn, but they are not used all of the time. Thus, a lack of turn signal use is not a sufficient predictor of whether or not a driver will turn.

- Traffic safety professionals might want to consider developing and promoting greater standardization among the various informal communication strategies, in much the same way as the arm-signal to indicate the intent to turn left or right was developed. Gestures could be standardized for pedestrian crossing, increasing the autonomous vehicle's ability to correctly comprehend a pedestrian's intent.
- Interpersonal communication is a transaction among two or more parties. As such, autonomous vehicles will likely need a set of communication strategies that can be used to both acknowledge the reception of a message and to communicate the vehicle's intended behaviors to other road users.
- Along this same line, the research showed that drivers used relative speed as a means to communicate (e.g. slowing down or speeding up to indicate intent) with vulnerable road users. In order for autonomous vehicles to more effectively communicate with road users, they may need programming to incorporate this form of communication, both in terms of signaling intent and in receiving messages from other drivers.
- An important medium for pedestrians to communicate to drivers is facial, socially-based expressions such as smiling. In human-to-human contact, smiling occurs in the context of this social interaction. It is unlikely that this type of communication will naturally occur with autonomous vehicles present because pedestrians will not have another human for which to direct social-based expressions for communication. Thus, one important medium of communication, particularly among vulnerable road users, may not be available for autonomous vehicles.
- The literature on interpersonal communication is sparse. In order to develop effective ways for autonomous vehicles to detect, receive, and properly interpret interpersonal communication on the roadway, there is a critical need to better understand how people do this effectively and also when this communication fails. Further research is needed.

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