ASSESSING PEDESTRIANS' PERCEPTIONS AND WILLINGNESS TO INTERACT WITH AUTONOMOUS VEHICLES

FINAL REPORT

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16. Abstract

Autonomous vehicles are proposed as a way to make driving safer. While much research focuses on the technological and engineering aspects of autonomous vehicles, the purpose of these studies were to 1) determine differences in pedestrians' willingness to cross the street in front of autonomous vehicles based on nationality and gender, 2) determine if affect acted as a mediator, 3) identify which emotions were mediators, 4) determine the type of indications pedestrians prefer to receive from autonomous vehicles, and 5) identify which factors predict a pedestrian's willingness to cross in front of autonomous vehicles. In five studies using 4,819 participants, the findings indicate that, in general, Indian participants are more willing to cross than Americans, and experience little difference in willingness to cross between the conditions. For Americans, females tended to be significantly less willing than males. Affect was found to be a significant mediator for Americans, specifically fear for males and fear and happiness for females. Participants indicated that they preferred the large textual signal from the autonomous vehicle that it was safe to cross, and the variables of anger, fear, happiness, surprise, familiarity, fun factor, and wariness of new technology were significant predictors in the statistical model.

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EXECUTIVE SUMMARY

Autonomous vehicles have been increasing in development, and they are proposed as a way to make driving safer and improve travel efficiency. However, a missing gap in the literature has been on the views of pedestrian's willingness to interact with autonomous vehicles. The purpose of these series of studies were to: 1) determine differences in willingness to cross the street of pedestrian's in front of autonomous vehicles based on nationality and gender, 2) determine if affect acted as a mediator, 3) identify which emotions were mediators, 4) determine the type of indications pedestrians prefer to receive from autonomous vehicles, and 5) identify which factors predict a pedestrian's willingness to cross in front of autonomous vehicles. In five studies, 4,819 participants were recruited to conduct these studies.

In study 1, the research examined pedestrian's willingness to cross the street in front of a human operated vehicle or an autonomous vehicle and made comparisons across nationalities (Americans and Indians) and participant gender. The findings indicate that, in general, the Indian participants had a higher willingness to cross than American participants, and for Indians, there were no significant differences between the human operated and driverless conditions. Americans tended to be less willing to cross in front of driverless vehicles, especially American female participants.

In studies 2 and 3, the research investigated if affect or emotions were serving as mediators in the relationship between the two conditions and willingness to cross. In study 2 a general affect scale was used and found emotions to be a significant mediator between the two types of driving conditions and willingness to cross for females but not for male participants. Study 3 extended this research through the usage of the six universal facial expressions developed by Ekman and Friesen (1971). This unique methodology allowed for the researchers to examine if one or more of the six emotions were acting as mediators. The findings from study 3 indicated that fear and happiness were mediating emotions for females, and in study 3, fear was found to be an emotional mediator for male participants.

Study 4 examined if certain types of indications from the autonomous vehicle to the pedestrian could increase their willingness to cross. The type of indication (color or textual) and size of the indication (small or large) were manipulated. The results found that

pedestrians were significantly more willing to cross when presented with the large, textual display over all others.

Study 5 was conducted to create and validate a statistical model which could identify the factors that predict a pedestrian's willingness to cross rating. Stage 1 was used to develop the regression equation and an independent stage 2 was conducted to examine for model fit of the equation. The findings indicate that anger, fear, happiness, surprise, familiarity, fun factor, and wariness of new technology were significant predictors of a pedestrian's willingness to cross in front of a driverless vehicle.

DESCRIPTION OF PROBLEM

Automated vehicles promise to improve traffic safety and provide travel efficiencies. One safety issue is the vehicle-pedestrian accident which accounts for thousands of deaths each year. In a report from the National Highway Transportation Safety Administration (NHTSA) (2018), 5,987 pedestrians were reported killed in traffic accidents in 2016 representing an increase of 9% from the previous year. Further, there were an additional 185,775 nonfatal pedestrian injuries that same year (CDC, 2016). Automated vehicles may help reduce this number once integrated within society. However, many challenges remain to be solved. Additional studies have been conducted to address issues from the vehicle, driver, and passenger points of view. Fewer studies have been completed to address issues from the pedestrian viewpoint. It is vital to understand that routine interactions between pedestrians and automobiles will change dramatically exposing a knowledge gap in the understanding of a pedestrian's willingness to interact with this new technology.

Problem Statement

Recently, the automobile industry has experienced a proliferation of efforts to enhance autonomous vehicle capabilities and set an eventual goal to remove human operators when viable. However, this new goal has created a lack in the research assessing the association between autonomous vehicles and their interaction with pedestrians. It is important to realize that routine interactions between pedestrians and automobiles will change dramatically. The pedestrian crossing the street can no longer receive a visual or auditory cue from the driver signaling recognition of their presence and intentions to cross. Therefore, it is important to recognize the need for enhanced safety features encompassing a unique interaction. First and foremost, these features should be designed to enhance safety

for both the pedestrian and any passengers traveling inside of the autonomous vehicle. Furthermore, they should augment consumers' and shareholders' confidence towards investing in these products. While much research has focused on the technological developments of autonomous vehicles, a gap exists in researching how they will integrate with other road users, such as pedestrians.

Review of Existing Literature

Self-driving vehicles promise to provide a range of benefits from reducing vehicle accidents (Bansal, Kockelman, & Singh, 2016; Bonnefon, Shariff & Rahwan, 2015; Jain, Koppula, Soh, Raghavan, Singh, & Saxena, 2016) to reducing traffic congestion (Habibovic et al., 2018; Stern et al., 2018). Within this area, there are two broad lines of research: vehicle-centric and pedestrian-centric. Researchers have studied vehicle-centric aspects including technological advancement (e.g., Fang, Vázquez, & López, 2017), public acceptance (e.g., Merat, Madigan, & Nordhoff, 2017), consumer trust (e.g., Deb, Rahman, Strawderman, & Garrison, 2018), and safety benefits (e.g., Bonnefon, Shariff & Rahwan, 2015). However, studies on pedestrian-centric aspects are somewhat less in number. We contribute to this literature in the current study by expanding on pedestrian-centric characteristics by investigating the interactions between pedestrians and autonomous vehicles (AVs). Automation in vehicles can take several forms from assistive devices to fully driverless vehicles, and NHTSA (2017) describes six standardized "levels of automation: 1) no automation, 2) driver assistance, 3) partial automation, 4) conditional automation, 5) high automation, and 6) full automation." Each of these automation levels has safety and social implications. The shift from manual driving to automated driving involves a transformation

of the human-machine relationship which encompasses the interactions between pedestrians and vehicles.

Vehicle-Centric

Vehicle automation is a common and familiar form of technology. For instance, many vehicles come standard with cruise control allowing the operator to set the desired speed. Progressively, automobile makers are integrating automated assistance devices into new vehicles including "automatic emergency braking, forward-collision warning, blind-spot warning, rear cross-traffic warning, rear automatic emergency braking, lane departure warning, lane-keeping assist, lane-centering assist, and adaptive cruise control" (Consumer Reports, 2018, n. p.). The current technological high end of commercially available vehicles employ partial automation technology at automation Level 2 (NHTSA, 2017). Examples include Tesla's Autopilot (Tesla, 2018), Cadillac's Super Cruise (General Motors, 2018), Nissan's ProPilot Assist (Nissan, 2018), and Mercedes-Benz Distronic Plus (Mercedes-Benz, 2018).

The enabling technologies for AVs involve a myriad of sensors, robust data files, and sophisticated software algorithms. A challenge for designers is understanding a pedestrian's intentions and predicting their actions. Wagner and Koopman (2015) addressed this problem suggesting the study of pedestrian behaviors coupled with simulators will assist researchers to obtain an improved understanding of how the vehicle will react in both normal and abnormal situations. Zaki and Sayed (2016) studied the possibility of an automated vehicle to detect distracted pedestrians based on pedestrian gait. Alhajyaseen and Irvo-Asano (2017), documented how human vehicle operators and pedestrians act based on predictions and attempted to develop a pedestrian prediction model based on speed changes in areas in close

proximity to signalized crosswalks. Similarly, Fang, Vázquez, and López (2017), researched the possibility of modeling a pedestrian's intentions based on their pose. Ismail, Sayed, Saunier, and Lim (2009) studied pedestrian-vehicle conflicts with video data to determine correlating links.

The challenge of developing object detection, including the ability to detect pedestrians, is one of the major lines of vehicle-centric research (Chen, Kundu, Zhu, Berneshawi, M, Fidler, & Urtuasan, 2015; Girshick, Donahue, Darrell, & Malik, 2013; He, Zhang, Ren, & Sun, 2016; Hu, Paisitkriangkrai, Shen, van den Hengel, & Porikli, 2016; Kniaz & Redorenko, 2017; Wu, Li, & Zhu, 2016; Xiang, Choi, Lin, & Savarese, 2015). If there is a common theme it is this: detecting and predicting pedestrian intentions is challenging given the countless random possibilities of pedestrian-AV interactions.

Pedestrian-Centric

The introduction of new technology can bring the unintended consequence of conflict between old and new. Vehicles and pedestrians have no doubt experienced conflicts from the introduction of the first automobile. Once expectations are mutually understood, foundations of trust are built, and conflicts can be reduced. Sometimes the expectations are codified through rules and regulations, while at other times through convention. As new technology expands driving capabilities, there is an obligation to understand a pedestrian's expectations and understanding of how to operate in a new paradigm. Gaps in knowledge of how to design AVs for pedestrian safety, from a pedestrian point of view indicate a need for additional research (Deb, Rahman, Strawderman, & Garrison, 2018).

Trust in automation. Pedestrians are some of the most vulnerable roadway users (Lundgren et al., 2017), so understanding a pedestrian's approach to interacting vehicles is an

important starting point. One aspect to consider is trust in the automation as it correlates with perceptions of safety. Technology predictability or the state where technology behaves in accordance with expectations, is a prime component of trust (Deutsch, 1959; Winter, Keebler, Rice, Mehta, & Baugh, 2018b). The perception of the reliability of the technology is also an important factor (Geels-Blair, Rice, & Schwark, 2013; Parasuraman & Riley, 1997; Rice, 2009; Rice & Geels, 2010, Rice, Winter, Deaton, & Cremer, 2016). Hengstler, Enkel, and Duelli (2016) noted trust in technology can be increased through the visibility of the technology suggesting trust will increase as pedestrians become more familiar with AVs. Additionally, trust in technology is related to and trust in the company producing the technology (Hengstler, Enke, & Duelli, 2016). Knowledge regarding trust may be important as technology increases, and more AVs are on the roads.

Expectations and perceptions. In order for pedestrians and AVs to interact safely, pedestrian expectations and perception of AVs must be investigated and understood. When it comes to risk, Hulse, Xie, and Galea (2018) found pedestrians felt a confrontation with an AV was less risky than a similar confrontation with a human-driven vehicle. However, the authors noted that further research is needed to identify the reasons behind the pedestrian's perception (Hulse, Xie, & Galea, 2018). In a series of studies, Andersson, Habibovic, Klingegård, Englund, and Malmsten-Lundgren, (2017) and Habibovic et al. (2018) started their research with the proposition that pedestrians can not rely on nonverbal cues with automated vehicles. Therefore, external cues in the form of an external display might meet a pedestrian's communication needs.

The Automated Vehicle Interaction Prototype (AVIP) was designed as an external display for the AV to communicate intent. Results suggest the interface increases perceived

safety and contributes to a better pedestrian-AV interaction. Pedestrians are more likely to feel stress and lack of safety when confronted with an AV. Researchers suggest that AV designers need to ensure the vehicle does not send the wrong signals unintentionally. (Habibovic et al., 2018) But instead, have the vehicle show its intentions rather than tell the pedestrian what they can do as it could create a false impression of safety (Andersson, Habibovic, Klingegård, Englund, & Malmsten-Lundgren, 2017). Lagstrom and Lundgren (2015) also conducted a study regarding external communications. They found pedestrians prefer to know when a vehicle is operating in autonomous mode. Pedestrians become more responsive to messages once they have been trained on the external communication messaging modes indicating autonomous driving mode, yielding, resting, or about to start (Lagstrom & Lundgren, 2015). Vissers, van der Kint, van der Schagen, and Hagenzieker (2017) observed these same themes in their study and noted pedestrians appreciated messages and signals from AVs on the vehicle's intentions.

Lundgren et al. (2017) studied pedestrian-human driver interactions and pedestrian-AV interactions when crossing a road. They found that all participants attempted eye contact with a vehicle operator or occupant regardless of the operating mode. Willingness to cross the road decreased if there was no driver present or if the individual in the driver seat was preoccupied, such as reading a newspaper or on the phone. Reports of an unpleasant experience correlated with no previous experience with AVs (Lundgren et al., 2017). Because expectations between road users form the basis for actions, Sucha, Dostal, and Risser (2017) researched communication between pedestrian and drivers at marked pedestrian crossing point without a traffic signal. They discovered searching for eye contact

was the predominant signal. The findings of Suchs, Dostal, and Risser (2017) appear to agree with those of Ren, Jiang, and Wang (2016) who found eye contact affects driver behavior.

Palmeiro et al. (2018) studied pedestrian crossing calculations when confronted with an AV or human-driven vehicle at non-intersection locations. They specifically wanted to discover how pedestrians acted based on their observation of the vehicle and what they observed in the vehicle. Various types of signs were used to alert the pedestrian to the AV, though this was noted as a limitation because participants could not always read the signs. While not always clear, signs, as well as eye contact, influenced the participant's calculation of whether to cross the road. Thus, more research in better displays will improve pedestrian-AV interaction (Palmiero et al., 2018). Previous behaviors shown to increase the number of human drivers who stop for pedestrians such as smiling (Gueguen, Eyssartier, & Meineri, 2016) and staring (Guegen, Meineri, & Eyssartier, 2015) will not work for an AV though the behavior could be integrated into the vehicle's object detection algorithms.

Sometimes pedestrians are distracted from paying attention to traffic posing random safety risks. Two studies specifically targeted use of a cell phone as a possible distraction (Neider, McCarley, Crowell, Kaczmarski, & Kramer, 2010; Stavronos, Byington, and Schwebel, 2011). Neider, McCarley, Crowell, Kaczmarski, and Kramer (2010) used a simulator experiment to examine pedestrian distractions at unsigned intersections while Stavronos, Byington, and Schwebel (2011) studied distracted pedestrians in a field setting and documented pedestrian risk behavior at crosswalks among college students. In a more current study, Barin et al. (2018) investigated how to reduce pedestrian distractions at crosswalks. They painted a warning message on the ground and observed reactions. The

message did initially decrease distractions although the effect was not sustained prompting the authors to call for additional studies (Barin et al., 2018).

Human factors and ergonomic aspects. Issues arising from the interactions between humans and technology are central to the human factors and ergonomics fields of research (Cuevas, Velazquez, & Dattel, 2018). Designs should consider human limitations and capabilities to improve functionality, reduce human error, and ensure system safety (Stone, Chaparro, Keebler, Chaparro, & Mcconnell, 2018). These issues are not necessarily evident in vehicle-centric studies and are necessary to understand the needs of pedestrians. While not as prominent as other types of studies, researchers are studying audio and infrastructure technologies to address some pedestrian human factors challenges. In audio technologies, Eyobu, Joo, and Han (2017) studied the effectiveness of audio messages to alert pedestrians based on message intervals frequencies to produce optimal effects. Towards infrastructure safety measures, Albusak, Vallejo, Castro-Schez, and Gzlez-Morcillo (2018) explored the possibility of embedded road lighting systems to provide vehicle and pedestrian alerts. This study introduced the modeling behind designing the system providing a baseline for future research.

In researching the effectiveness of visual pedestrian-centric technologies, Fridman et al. (2017) conducted a study regarding perceptions of effective pedestrian displays on vehicles. They developed 29 test designs for participant review. They learned some of the test designs were not intuitive to all participants and were confusing suggesting research into common signals is warranted. Additionally, the results highlighted questions of how untrained pedestrians would interpret messages. Fridman et al. (2017) differ from other researchers finding evidence to suggest pedestrians take most of their cues from vehicles

movement rather than driver interactions, though their research was conducted via survey methods rather than field observation. Fridman et al. (2017) caution that risk may increase without a mutual understanding of the external displays. Thus, future research in this area is needed.

Gender Differences

There has been a long tradition of research that investigated the role of gender and its influence on various factors such as decision-making and risky behavior (Byrnes, Miller, & Schafer, 1999; Croson & Gneezy, 2009; Eckel & Grossman, 2008; Meyers-Levy, 1989). Decision-making theories have explained how humans make decisions and the cognitive processes humans must go through in order to make certain decisions (Gigerenzer & Gaissmaier, 2011). Evidence shows systematic differences between genders (Eckel & Grossman, 2008), therefore, the cognitive processes in which decisions are made can possibly vary based on gender. For example, Reiter (2013) investigated differences between males and females regarding decision making where a variety of choices were accessible and found that males were less selective and made decisions more quickly while females spent more time making a decision and preferred to review all options available before making a final decision. Furthermore, evaluations into decisions made under stress show that males are eager to take risks and are focused on rewarding outcomes regardless of consequences as opposed to females (Wong, Zane, Saw, & Chan, 2013). Another significate finding was that males demonstrated impulsive thinking and displayed sensation-seeking behavior more often than females (Wong et al., 2013).

Evidence of risk taking between genders illustrates that males tend to participate more frequently than females in risky behaviors (Eckel & Grossman, 2008). Additionally, evidence

suggests that the perception of risk varies based on gender; with experimental studies suggesting that gender differences are apparent in drug use, global issues, and financial matters. For example, Spigner, Hawkins, and Loren (1993) evaluated gender differences in drug abuse and reported that males participated more in drug use overall (e.g., alcohol, heroin, smoking) and believed that substance use was less risky compared to females. In addition, studies that evaluated gender differences during the Gulf War in 1990 suggested that women reported fear during the war and felt that the country would improve if the people did not concern themselves with other countries (Eichenberg & Read, 2016). Moreover, evidence suggests that females perceive a greater risk from their environment than males who are in the same environment (Huddy, Feldman, & Cassese, 2009). For instance, after the September 11th tragedy in the United States, females were more threatened by terrorism than men but were less likely to support violent and forceful retaliation (Huddy, Feldman, Taber, & Lahav, 2005). These results are consistent with past literature on gender differences with males tending to take on a dangerous situation as a challenge and can perhaps lead to higher risk tolerance (Croson & Gneezy, 2009). More broadly, gender differences have also been evaluated in economics. Prior research indicated that men partake in gambling more than females (Wong et al., 2013). Another study discovered impulsive coping and risk-taking were at the epicenter of gender differences. The authors highlight that males had higher risk taking which in turn, created lower levels of impulsive coping than females, with research suggesting that individuals who take a great deal of risks and have reduced impulsive coping have more of a possibility participate in gambling (Wong et al., 2013).

Differences between males and females have also been found in areas of general trust, driving and pedestrian behavior, and acceptance of new technology. Feingold (1994) conducted four meta-analyses to investigate personality differences between genders. The study was guided using valid personality records which illustrated that females accounted for higher scales of trust (Feingold, 1994). Gender differences in trust was also evaluated using an investment game (Buchan, Croson, & Solnick, 2008). The results indicated that females were more trusting towards associates who displayed a high level of trust to them individually. A more recent study (Haselhuhn, Kennedy, Kray, Van Zant, & Schweitzer, 2015) examined the connection between gender and trust levels and how trust changes after transgressions. They found that females were more trusting following a transgression than males. In addition, females were likelier to regain trust in individuals after repeated offenses (Haselhuhn et al., 2015). Although, the literature on gender differences is well established, evidence of gender differences in trust is divided and mixed. For example, Irwin, Edwards, and Tamburello (2015) argue women are less trusting than men in social dilemmas and less trusting of strangers. These results were similar to those of Kuwabara (2005) that investigated the role of trust and fear between genders. The author found that males were more trusting than females in trust games and noted that as female's fear increased, trust decreased. With various articles displaying conflicting ideas about which gender exhibits more trust and trustworthiness, there is a need for growing literature in these areas to help researchers understand how gender may influence trust and behavior.

Gender differences are also prominent in driving and pedestrian behaviors. According to the NHTSA (2016) more men die from motor vehicle crashes annually than women. In addition, the NHTSA (2016) also reported the number of male deaths in vehicle crashes in

2016 were twice the amount of female deaths. Gender differences in behavior, particularly driving are associated with a number of factors. Prior research has indicated that females show less sensation seeking behavior and risk tolerance than males, and it is said that these factors mediate the gender differences seen in reckless driving (Clarke, Ward, & Truman, 2005; Nyberg & Gregersen, 2007). Deery (1999) examined the cognitive and perceptual processes underlying driving behavior and found that males participated in risky driving behavior such as operating impaired, not using a seat belt, and speeding. These results are also consistent with Laapotti and Keskinen (1998) in which the study found that males were more likely to drive in bad weather and displayed overconfidence more than females. Furthermore, a study that evaluated how lifestyle factors correlate with injuries and crashes among young adults found that males drive more intoxicated and with more passengers in the vehicle (Begg, Langley, & Williams, 1999). Research in road safety has addressed the association between driver gender and risk of a crash found that females are safer drivers than males (Åkerstedt & Kecklund, 2001; Regev, Rolison, & Moutari, 2018). However, it has been suggested that although females tend to drive more safely, the risk of injury during a crash may be higher (Regev et al., 2018; Santamariña-Rubio, Pérez, Olabarria, & Novoa, 2014).

Pedestrians are a vulnerable part of road usability. Over 270,000 pedestrians die in road traffic crashes yearly (NHTSA, 2018). In the U.S, 5,987 pedestrians were killed in 2016. The death toll of the pedestrians killed annually shows the importance of pedestrian safety overall. Studies in Canada have illustrated that female pedestrians are less likely to be killed in road accidents than male pedestrians (Government of Canada, 2018). In addition, an examination of 21,751 road injury cases revealed that 70.2% were males and 29.8% were

females (Leaf & Preusser 1999). Bergeron et al. (1998) investigated the influence of individual personality traits on whether pedestrians will follow road rules and found that males were more likely to violate road signs. Furthermore, another study explored differences between male and females in pedestrian crossing behaviors and suggested that both genders fluctuate in how they visually search while preparing to cross and while crossing (Tom & Granié, 2011). The authors highlighted that males tend to focus on vehicles whereas women tend to focus on the traffic signals and other pedestrians.

Additionally, gender differences were detected in how males and females interpret the traffic environment with differences on safety and crossing decisions (Tom & Granie, 2011). Another study found that males independently were more likely to cross with a 'Don't Walk' sign more often than females (Rosenbloom, 2009). Past research has illustrated that pedestrians are susceptible to road injuries and approximately 60% of pedestrians do not believe that drivers will safely acknowledge to road signs and operations (Karsch et al., 2012). Thus, it is imperative to understand how gender could influence driver and pedestrian's decision-making and behavior. Deb at al. (2017) analyzed pedestrian receptiveness toward fully autonomous vehicles and found that males and younger people were more receptive. A more recent study indicated gender differences were significant in the acceptance of autonomous vehicles and the risk associated with automation with males displaying greater acceptance and perceiving less risk (Hulse et al., 2018).

Kyriakidis, Happee, and de Winter (2015) established that males deemed automated vehicles more important than females. The authors also suggested that females were less willing to purchase an automated vehicle than males (Kyriakidis, Happee, and de Winter, 2015). Venkatesh and Morris (2000) explored how genders differ in technology acceptance

and found that males considered 'perceived usefulness' as a main decision to utilized technology. In contrast, females were influenced by 'perceived ease of use' and subjective norms (Venkatesh & Morris, 2000). With increasing use of technology and automation it is vital to understand the factors that can possibly contribute to human behavior and decisions to ensure the safe and effective collaboration of human-machine interactions.

Nationality

Nationality, with strong underlying cultural constructs, can be an important variant and may play a role in a pedestrian's willingness to interact with automated vehicles. Helmreich's (2000) defines culture as "the shared norms, values and practices associated with a nation, organization, or profession" (p. 134). Nationality may be a factor in how people make decisions and by considering individual's cultural background can aid in the understanding of how life experiences can shape thought. Trust, for example, is often influenced by cultural background (Hofstede, 1984). Prior studies have also suggested that individuals who are extroverts are more trustworthy than individuals who are introverts (Gaines et al., 1997; Rice et al., 2014; Shikishima, Hiraishi, & Ando, 2007).

As targets for research, many studies have investigated the U.S and India as they represent divergent cultures. More specifically, research has evaluated the differences between those from individualistic cultures versus collectivist cultures (Ragbir, Winter, Rice, & Baugh, 2018; Rice et al., 2014; Winter et al., 2015). Individualistic cultures such as the U.S display an emphasis on the individual self and immediate family over entire groups (Hofstede, 1980, 1984). Whereas, those from collectivist cultures such as India focus on in-group relationships and demonstrate a close bond to groups rather than the individual self (Markus & Kitayama, 1991). More importantly, individuals from early childhood are taught

to trust without hesitation and consider other's interest over their own (Rice et al., 2014). Previous studies have demonstrated the differences between U.S and Indian perceptions and behaviors. One dimension that shows differences between these two cultures is uncertainty avoidance, and this can be described as the threshold in which society feels endangered by ambiguous situations and in turn, attempts to avoid them (Zhang & Zhou, 2014). Research shows that those from Indian cultures are more willing to take risksduring uncertain events than individuals from the U.S (Rice et al., 2014). Furthermore, one study found that participants from the U.S trusted the human pilot more than participants from India (Rice et al., 2014). An expansion of this study which investigated the perceptions of varying cockpit setups and investigating differences in culture between India and U.S. individuals suggested that individuals from the U.S had more extreme views for configurations that did not involve two pilots in the cockpit than participants from India.

A more recent study indicated that participants from the U.S were against fully autonomous commercial flight except in ideal weather conditions (i.e., sunny, no rain, no wind). In contrast, participants from India were positive in most conditions (Ragbir et al., 2018). Since industries in transportation are consumer-centric and employed worldwide, it is important to consider consumer perceptions of new technologies and all the factors that can influence willingness to develop a multi-national understanding.

Affect

Affect or emotions are an integral part of how humans process information and can influence an individual's decision to cross in front of an automated vehicle. The impact of affect has been studied on cognitive processes such as decision making and judgments. Previous research suggests that affect can serve as information such as when decision-makers

are first presented with a decision, most individuals ask themselves, "How do I feel about this?" (Schwarz & Clore, 1983). Damasio (2002) proposes that the feelings about a particular choice are based on past experiences that are relevant to the option. Researchers expand on this idea and suggest that an individual's mood also influences decisions (Peters, Vastfjall, Garling, & Stovic, 2006). Similarly, several studies have suggested that affect can impact decisions even more so than cognitive processes (Johnson-Laird & Oatley, 1992; Lazarus, 1991; Schwarz, 1990; Simon, 1967; Tooby & Cosmides, 1990), especially when decisions are made rapidly (Frijda, 1986; Levenson, 1994; Oatley & Johnson-Laird, 1996). One study examined the effects of emotions on the behavior of traders and decision makers in economic markets (Au, Chan, Wang, & Vertinsky, 2003). The results indicated that traders who were in a good mood had poor trading performance (e.g., losing money) while participants who were in an impartial or bad mood made profit. The authors noted that this is because individuals in a positive mood made less accurate decisions than individuals who were in an impartial or bad mood. In addition, they also highlighted that individuals who were in a bad mood made more precise decisions and were more old-fashioned in their trading choices (Au, Chan, Wang, and Vertinsky, 2003). Another study evaluated the role of various emotions (i.e., anger and disgust) and risk taking. Fessler, Pillsworth, and Flamson (2004) discovered that anger was a main factor that directed higher risk taking in men as compared to women. Disgust however, led to less risk taking in women than men (Fessler, Pillsworth, & Flamson, 2004). Another examination found participants who were in a good mood viewed difficulty as an opportunity and were less risky than individuals who were in a bad mood (Mittal & Ross, 1998). Prior studies have suggested that emotional responses are the result of affective processes other than from cognitive processes (Zajonc, 1998).

Alhakami and Slovic (1994) investigated the affect heuristic and found that affect is the faster and most recurrent way to see an individual's response (i.e., whether good, bad, or unconsciously). The authors highlight that heuristics are said to offer the ideal solution to any impossible task by providing mental shortcuts although, these shortcuts may not provide the correct response (Alhakami & Slovic, 1994). Understanding human preferences during uncertain outcomes is a key component to the overview of higher levels of automation in the transportation industry. Public perception or specifically, how people feel about a particular situation can have beneficial or detrimental effects on increasing use of new technology.

The Six Universal Emotions

Ekman and Friesen (1971) pioneered the development of the six universal emotions after discovering adults and children could identify emotions portrayed as facial expressions (as shown in Figure 1) independent of culture (Ekman, Friesen, & Hagar, 1978).

Figure 1. Six universal emotions based on Ekman and Friesen (1971). From left to right the images represent anger, disgust, fear, happiness, sadness, and surprise.

Other studies have used the six-universal emotion faces to identify mediating emotions (Rice & Winter, 2015b; Winter, Keebler, Rice, Mehta, & Baugh, 2018a; Winter, Keebler, Rice, Mehta, & Baugh, 2018b; Winter, Rice, Tamilsevan, & Tokarski, 2015).

Willingness to Cross

A pedestrian's willingness to cross a street in the proximity of moving vehicles is based on a combination of experience and expectations. Research shows pedestrians use vehicle clues (i.e., distance, speed, and crossing location) and driver clues (i.e., eye contact and waiving) in their calculations. The introduction of automated vehicles may require pedestrians to change how they make crossing calculations (Habibovic et al., 2018). One step in understanding the new pedestrian paradigm is understanding perceptions, receptivity to automated vehicles, and factors involved in automated vehicle related crossing decisions. Deb et al. (2017) sought to create an instrument to assess these areas. The study found a optimistic association between perceived safety, willingness to interact with an automated vehicle, and willingness to cross the road with automated vehicles (Deb et al., 2017).

Palmeiro, van der Kint, Vissers, Farah, de Winter, and Hagenzieker (2018) studied pedestrian crossing decisions when interacting with automated vehicles versus traditional vehicles at areas away from crosswalks. If crossing decisions are predicated on situational awareness through understanding of what the vehicle is doing, then it is important to know if there is a difference between the vehicle types and if there is a mismatch when the vehicle is automated without the pedestrian's knowledge. There was no expectation the vehicle would stop, rather the participant was to judge when to cross based on their assessment of cues from the vehicle. For their automated vehicle with external displays (hood & door sign; roof sign) the participants found the roof sign to be the clearest. As the participants used speed and distance as cues to cross, that the vehicle was automated or traditional made no significant difference in their decision to cross. However, in post event interviews, participants felt more unsafe and doubtful of their decisions with the automated vehicle versus the traditional

vehicle. The majority of participants were apprehensive to cross without driver eye contact. They recommended further study on vehicle to pedestrian communication mechanisms.

Malmsten-Lundgren et al. (2017) researched whether pedestrians will require new ways of communication with automated vehicles when crossing. Their experiment was based on a mid-street crossing without a crosswalk. Willingness to cross was a direct result of perceived safety. All participants stated they would cross with eye contact. This willingness dropped dramatically when the apparent driver was reading a newspaper or when there was no visible driver. Willingness to cross was based on calculations of both vehicle and driver cues. Results indicated unfamiliarity with automated vehicles was unpleasant. Interestingly, most participants said they would expect some form of acknowledgment from the individual in the driver's seat even if the vehicle was fully autonomous. Eye contact with driver made crossing more calmed than without and made the pedestrian feel safest. Results suggest communication needs will change with automated vehicles. Further, an interface showing the vehicle's intentions could benefit a pedestrian's situational awareness and have a positive influence on perceived safety.

Habibovic et al. (2018) conducted two experiments in part to measure a pedestrian's perceived safety when crossing a street in the proximity of automated vehicles. In their experiments, (un)willingness to cross and perceived safety were linked. Pedestrians "felt significantly less safe" (Habibovic et al., 2018, p. 1) interacting with automated vehicles and indicated the experience could induce stress. An external display on the automated vehicle improves a pedestrian's perceived safety, reduces stress, and provides information required to make the willingness to cross decision. Further, the external device should indicate the state of the vehicle rather than give directions to the pedestrian to prevent incorrect

expectations (Andersson, Habibovic, Klingegard, Englund, & Malmsten-Lundgren, 2017; Habibovic et al., 2018). Deb, Rahman, Strawderman, and Garrison (2018) conducted a state-of-the-industry literature review and created a possible roadmap for continuing research. They determined three major gaps existed. First, a pedestrian behavior instrument is needed. Second, a pedestrian simulator is needed. And third, more research regarding pedestrian inputs to automated vehicle design needs to be explored. They also concluded pedestrian acceptance of automated vehicles requires research on risks to pedestrians to ensure successful vehicle integration.

Signaling: Color versus Text

The way in which human's process information is a complex and creative system. Information processing begins with input from sensory organs (e.g., eyes, ears) and then attention filters decide how important the signal is and which cognitive processes it should be made available to (Craik & Lockhart, 1972). Following the attention filter, information travels to working memory and if significant, long-term memory (Craik & Lockhart, 1972). These processes continue automatically or if an individual decides to focus more attention on a particular object or situation. The role of automatic cognitive processes is well documented and builds on many theories. Münsterberg (1892) investigated inhibiting effects in common daily routines such as opening a door or taking a watch out of a pocket and found that a given association can function automatically. When reviewing automatic processes of text and color, Stroop (1935) discovered a strange phenomenon with naming words rather than color (i.e., Stroop Effect). The difficulty stems from the words themselves, that can make it harder to say or understand the color. This problem is a result of disturbance between the various stimuli (color and words) the brain receives (Stroop, 1935). Speed of processing theory and

selective attention theory (MacLeod, 1991), are two accepting theories that could possibly

explain the Stroop Effect. The speed of processing theory explains that because words are

automatically understood faster than colors, it could be difficult to read colors (Salthouse,

1996). While the selective attention theory explains that naming colors requires more

consideration and attention than reading words, and thus a disturbance occurs (Lavie, Hirst,

de Fockert, & Viding, 2004).

In terms of determining which form of information pedestrians would respond faster

is a good implication for future studies. However, it is imperative to note that humans read

words automatically and may take longer to process color information. Research on the

perception of various colors found that the color red controls or can cause various behavioral

responses depending on the species (Hill & Barton, 2005). Moreover, red cars are a common

color car worldwide and were thought to be attention-grabbing (Solomon & King, 1997).

However, more current studies have suggested that risk perception in addition to reaction

timer to possible road dangers were not different for red cars or any other colors (Hill &

Barton, 2005). Color also has different implications are cultural background as well. In

Spain, for example, the learned behavior of the color red can be considered with danger

(Maldonado-Bascon, Lafuente-Arroyo, Gil-Jimenez, Gomez-Moreno, & Lopez-Ferreras,

2007), pain (Martini, Perez-Marcos, & Sanchez-Vives, 2013), and aggressiveness (Hill &

Barton, 2005).

APPROACH AND METHODOLOGY

Much of the focus on driverless vehicles research has been on the technological and

engineering perspective. What is less commonly seen in the literature is a comprehensive

analysis of pedestrian willingness to cross intersections when driverless cars approach and

stop at the intersection. To date, few studies have examined these issues as a breakdown of type of driver, nationality, and gender. Furthermore, the current study contributes to the field by investigating how different emotions can mediate the relationship between type of driver and willingness to cross an intersection. In a series of four studies, we presented participants with various hypothetical scenarios and asked them to rate their willingness to cross an intersection. We also tested nationality and gender differences, as well as potential emotional mediators. In the first study, we hypothesized:

> Ha1: Pedestrian willingness to cross the intersection would differ as a function of the type of driver at the stop sign; that is, participants would be more willing to cross if the driver was a human compared to if the car was driverless (autopilot).
>
> Ha2: Pedestrian willingness to cross the intersection would differ as a function of participant gender; that is, male participants would be more willing to cross compared to their female counterparts.
>
> Ha3: Pedestrian willingness to cross the intersection would differ as a function of participant nationality; that is, Indians would be more willing to cross compared to their American counterparts.
>
> Ha4: There would be significant interactions in the data; however, this was a non-directional hypothesis.

Study 1 – Methods

Participants

Seven hundred and ninety-one (289 females) individuals participated in the study. The mean age was 34.67 (SD = 12.10) years. The participants were recruited from the United States and India thru a convenience sample using the platform of Amazon's ® Mechanical Turk ® (MTurk). MTurk provides an online platform which hosts participants who are willing to complete human intelligence tasks for small amounts of monetary compensation. MTurk has been shown to provide data as reliable as traditional laboratory settings

(Buhrmester, Kwang, & Gosling, 2011; Germine et al., 2012; Rice, Winter, Doherty & Milner, 2016).

Materials, Stimuli, and Procedure

Participants began by completing a digital consent form and then read the instructions of the study. Following this, participants were presented with one or two possible hypothetical scenarios. In one scenario, participants were given the following information, "*Imagine you are approaching a 4-way intersection with no traffic lights or crosswalk indicator signaling you to proceed. You are standing at a right angle to an autonomous vehicle (i.e. DRIVERLESS) with no human driver. The vehicle has stopped at the "STOP" sign. You and the vehicle both need to cross.*" They were also presented with an image (see Figure 2), showing a top-down view of the intersection. In a second, control condition, participants were told that the driver of the vehicle was a licensed human driver.

You are standing where the blue circle appears and walking in the direction of the arrow.
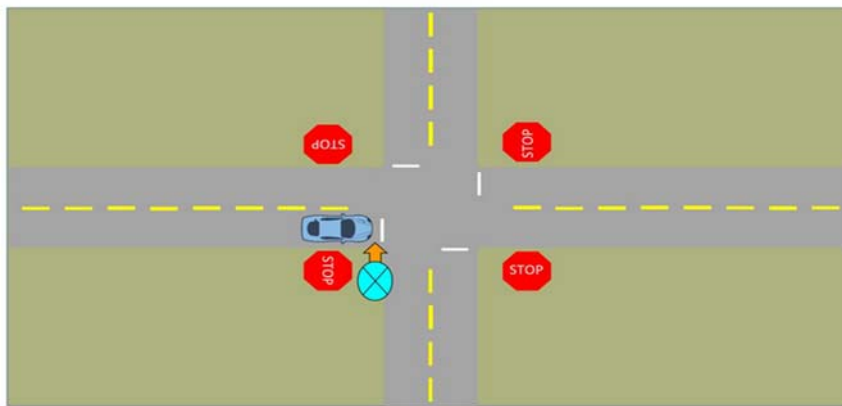

Figure 2. Image of the intersection presented to participants.

Following this, participants completed a willingness to cross the street scale (see Appendix A). They responded to seven statements on a scale from Strongly Disagree (-2) to Strongly Agree (+2) with a zero neutral option. Next, participants answered basic

demographics questions, including questions about their age, gender, ethnicity and nationality. Finally, participants were debriefed, compensated, and dismissed.

Design

The research followed an experimental factorial design, and all participants were randomly assigned to one of the two conditions. Additional factors of gender and nationality were tested post hoc.

Ethics

All ethical standards were followed in completing these studies. The research university's institutional review board approved all studies before data collection, and all researchers completed associated human subject's training programs.

<h1 align="center">Study 1 – Results</h1>

Prior to analysis, principal components factor analysis was performed and produced a single factor solution (eigenvalue = 5.71, 81.32% of the variance explained). Cronbach's Alpha scores were 0.95 and 0.94 for the Driverless and Human Driver conditions, respectively. This indicated high internal consistency for the scale. Guttmann's Split Half scores were 0.94 for both conditions, indicating high reliability. Thus, the scores for each scale were averaged in the following analyses. These data can be found in Figure 3.
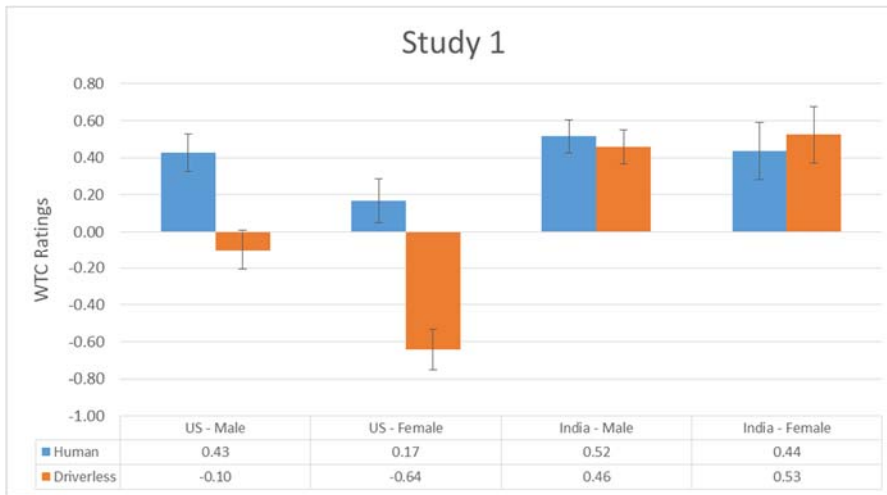
Figure 3. Data from Study 1 as a function of Type of Driver, Gender and Nationality. Standard error bars are present.

A three-way analysis of variance was used to analyze the effects of Type of Driver, Gender and Nationality as the factors. There was a main effect of Type of Driver, $F(1, 783) = 15.38$, $p < .001$, *partial eta squared* $= .02$, a main effect of Gender, $F(1, 783) = 6.00$, $p = .015$, *partial eta squared* $= .01$, and a main effect of Nationality, $F(1, 783) = 38.89$, $p < .001$, *partial eta squared* $= .05$. These main effects were qualified by significant interactions between Gender and Nationality, $F(1, 783) = 5.62$, $p = .018$, *partial eta squared* $= .01$, and between Type of Driver and Nationality, $F(1, 783) = 16.75$, $p < .001$, *partial eta squared* $= .02$. No other significant effects were found in the data. As Figure 1 reveals, Indians did not differ much as a function of Type of Driver or Gender, while Americans differed dramatically as a function of Type of Driver and Gender. Specifically, Americans in general were much less willing to cross in front of a driverless car, and American females generated the lowest WTC ratings.

Study 1 – Discussion

The findings from Study 1 are straightforward. As predicted, WTC was affected by the type of driver, gender of the participant, and nationality of the participant. However, the interactions in the data present an interesting, and somewhat unexpected, story. In general, Indians were more WTC compared to their American counterparts, and were in fact not affected by the type of driver or gender. Only American males reported similar WTC ratings compared to all Indians. American females, on the other hand, produced lower WTC ratings across the board, and were particularly unwilling to cross in front of a driverless vehicle.

Study 2 – Introduction

In study 2, we sought to replicate the findings from the first study with a new sample set, and we wanted to examine a possible mediator, emotions, that could explain the relationship between type of driver and WTC. In other words, are people less WTC in front of driverless vehicles for emotional reasons? It was hypothesized that affect would be a significant mediator of that relationship.

Study 2 – Methods

Participants

Three hundred and ninety-six (184 females) individuals completed the study. The mean age was 36.62 (SD = 12.66) years. As in Study 1, Amazon's ® Mechanical Turk ® (MTurk) was the platform used to recruit participants, and the study used a convenience sample.

Materials, Stimuli, and Procedure

The second study was the same as Study 1 with two exceptions: 1) an affect scale (see Appendix B) (Rice & Winter, 2015a) was added to the data collection to capture participants' emotional responses to the hypothetical scenarios, and 2) only data from Americans was

collected. The reason for this was that Type of Driver did not appear to affect Indian WTC, so there was no point in examining potential mediators in their case.

Design

An experimental factorial design was employed using Type of Driver and Gender as factors. An additional correlation design was used to examine a causal mediation model.

<div align="center">

Study 2 – Results

</div>

Inferential Statistics

A two-way analysis of variance using Type of Driver and Gender as factors revealed a main effect of Type of Driver, $F(1, 394) = 35.94$, $p < .001$, *partial eta squared* = .08, and a main effect of Gender, $F(1, 394) = 15.36$, $p < .001$, *partial eta squared* = .04. There was not a significant interaction between the factors, $F(1, 394) = 2.69$, $p = .10$, *partial eta squared* = .01. These data are presented in Figure 4.
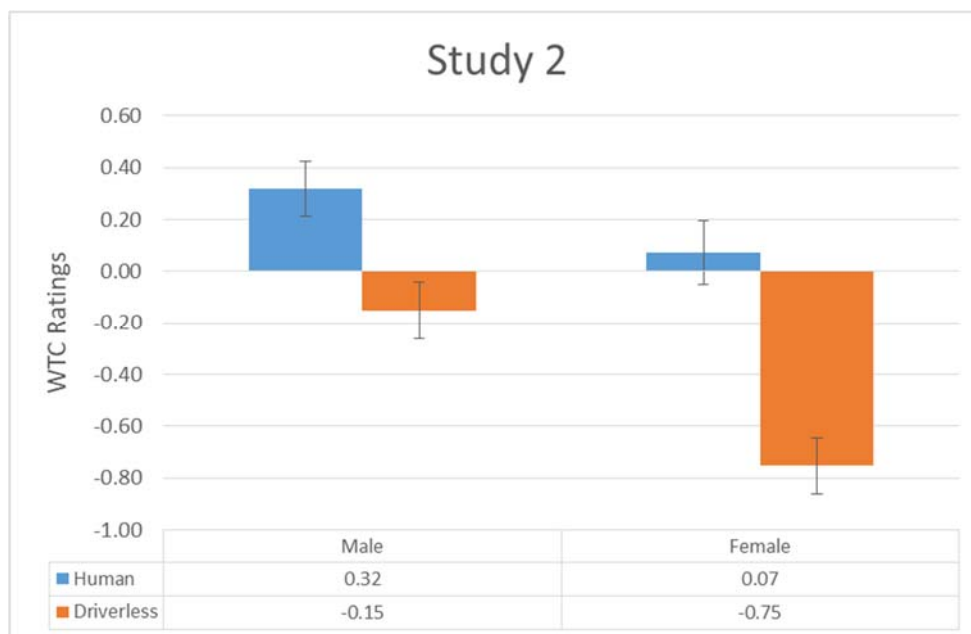

Figure 4. Data from Study 2 as a function of Type of Driver, and Gender. Standard error bars are present.

Mediation Analyses

A causal mediation model was tested to examine if affect was a mediator in the relationship between Type of Driver and WTC. For both females and males, the standardized regression coefficient between Type of Driver and WTC, and the relationship between affect and WTC were found to be statistically significant. From 10,000 bootstrapped samples (Hayes, 2013), a 95% confidence interval ranging from -.13 to .27 was obtained for males. The data found that an indirect effect was not significant and there was no mediation on the relationship between Type of Driver and WTC. A 95% confidence interval ranging from .01 to .46 was obtained for females and indicates that an indirect effect was significant. Therefore, mediation was identified on the relationship between Type of Driver and WTC.

Study 2 – Discussion

The data from the second study supported the prediction that Type of Driver and Gender would have significant effects on participants' WTC ratings. Specifically, both females and males were less WTC in front of a driverless vehicle compared to one with a human driver.

In addition, mediation was found to be significant for females; that is, the relationship between Type of Driver and WTC ratings was at least partially explained by the presence of emotional factors. These participants typically lowered their WTC scores because they felt more negative about crossing in front of driverless vehicles compared to vehicles driven by human drivers. There was no mediation effect for male participants.

Study 3 – Introduction

In Study 2, general affect was shown to be a significant mediator in the relationship between Type of Driver and WTC. The purpose of Study 3 was to determine if a specific

emotion could be identified as the mediator. The six universal faces were first researched by Ekman and Friesen (1971). In this study, participants rated how strongly they felt like the facial expressions depicted based on the hypothetical scenario (see Figure 1). This methodology has been used successfully in prior research (e.g., Rice & Winter, 2015b). We hypothesized that at least one of the emotions would mediate this relationship.

Study 3 – Methods

Participants

Four hundred and eight (203 females) individuals participated in the study. The average age was 37.86 (SD = 11.76) years. As in Studies 1 and 2, Amazon's ® Mechanical Turk ® (MTurk) was used to recruit participants from the United States using a convenience sample.

Materials, Stimuli, and Procedure

The third study was duplicate to Study 2 with one exception: instead of a general affect scale, specific emotions were used to provide potential mediators (see Figure 1).

Study 3 – Results

Inferential Statistics

A two-way analysis of variance using Type of Driver and Gender as factors revealed a main effect of Type of Driver, $F(1, 404) = 34.85$, $p < .001$, *partial eta squared* = .08, and a main effect of Gender, $F(1, 404) = 12.18$, $p = .001$, *partial eta squared* = .03. There was not a significant interaction between the factors, $F(1, 404) = 3.58$, $p = .06$, *partial eta squared* = .01. These data are presented in Figure 5.
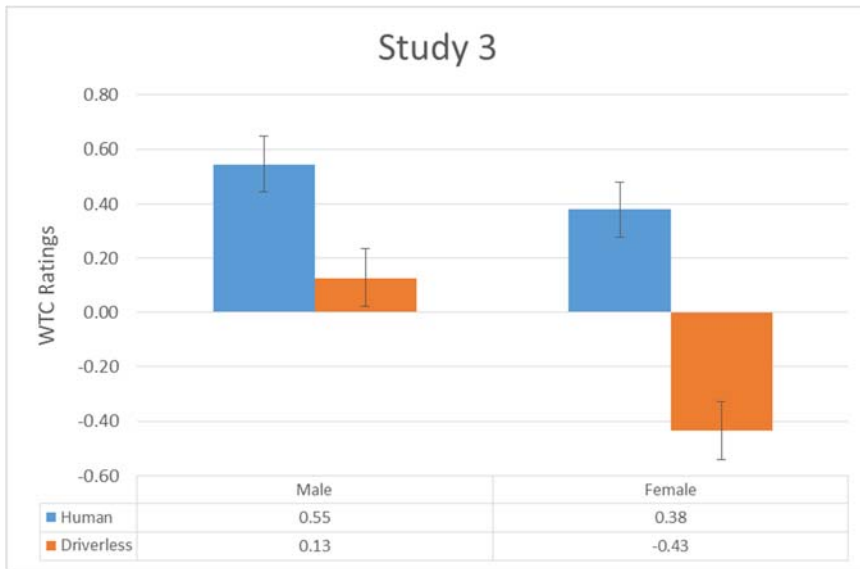
Figure 5. Data from Study 3 as a function of Type of Driver, and Gender. Standard error bars are present.

Mediation Analyses

A causal mediation model was tested to examine if one of the six emotions mediated the relationship between Type of Driver and WTC. From 10,000 bootstrapped samples (Hayes, 2013), a 95% confidence interval ranging from .06 to .35 was obtained for males in the Fear emotion. A 95% confidence interval ranging from .04 to .36 was obtained for females in the Fear emotion and ranging from .05 to .26 in the Happiness emotion, indicating that an indirect effect was significant and there was mediation on the relationship between Type of Driver and WTC.

<div align="center">

Study 3 – Discussion

</div>

The findings in Study 3 replicate the differences in willingness to cross from Studies 1 and 2, in addition to identifying affect as a mediating variable. Study 3 provides additional information as to which emotions, as expressed using the six universal facial expressions, act as mediators. Of note, while general affect did not mediate for males in Study 2, the emotion

of fear was a mediating variable for males in Study 3. The relationship between the type of vehicle and willingness to cross was mediated by fear and happiness for females in Study 3. In general, participants were more fearful of the autonomous, and at least in the case of female participants, expressed happiness toward the human operated vehicle. It is possible that participants are fearful of driverless vehicles due the lack of prior real-world interactions with them.

Study 4 – Introduction

Studies 1, 2, and 3 indicated that participants were less willing to cross in front of a driverless vehicle compared to one driven by a human driver. The purpose of the fourth study was to determine what signals from the autonomous vehicle to the pedestrian would produce the greatest willingness to cross of participants. The factorial study examined for size of the indication (small or large) and type of indication (red color, green color or textual).

Study 4 – Methods

Participants

Two thousand three hundred and eighty-eight (1,233 females) individuals participated in Study 4. The average age of participants was 37.83 (SD = 12.11) years. As in the previous studies, Amazon's ® Mechanical Turk ® (MTurk) was used to recruit participants from the United States using a convenience sample.

Materials, Stimuli, and Procedure

Participants completed the consent form, verified they were older than 18 years old, and read the instructions. After, participants were presented with a scenario and one of six images. The scenario read, "*Imagine you are approaching a 4-way intersection with no traffic lights or crosswalk indicator signaling you to proceed. You are standing at a right*

angle to a DRIVERLESS car that has just come to a complete stop. Below is a picture of the car and crosswalk." After the scenario, participants were presented with one of the six images shown in Figure 6a. A baseline condition was established using Figure 6b. Following this, participants rated their affect using the six universal facial expressions as in Study 3 and asked to complete the willingness to cross the street scale used in Studies 1-3. Next, participants answered basic demographic questions, including questions about their age, gender, ethnicity, and nationality. Finally, participants were debriefed, compensated, and dismissed.

Design

A factorial experimental design was employed using Size of Indication and Type of Indication as the between-participant factors.

Study 4 – Results

Inferential Statistics

A two-way analysis of variance using Size of Indication and Type of Indication as factors revealed a significant main effect of Size of Indication, $F(1, 2382) = 12.58$, $p < .001$, *partial eta squared* = .005, and a significant main effect of Type of Indication, $F(2, 2382) = 7.00$, $p = .001$, *partial eta squared* = .006. These main effect were qualified by a significant interaction between Size of Indication and Type of Indication, $F(2, 2382) = 18.79$, $p < .001$, *partial eta squared* = .016. Data from Study 4 are presented in Figure 7. The six conditions were compared to a baseline condition ($M = 0.00$, $SD = 1.17$, $SE = 0.06$, $n = 398$) using a *t*-Test and a Bonferroni correction which has also been collected from MTurk. As shown in Table 1, the only condition significantly different from the baseline was the large text depiction.

Figure 6a. The six conditions used in this study. Top row left to right: Small/Red, Small/Green, Small/Text. Bottom row left to right: Large/Red, Large/Green, Large/Text.

Figure 6b. A depiction of the baseline condition.

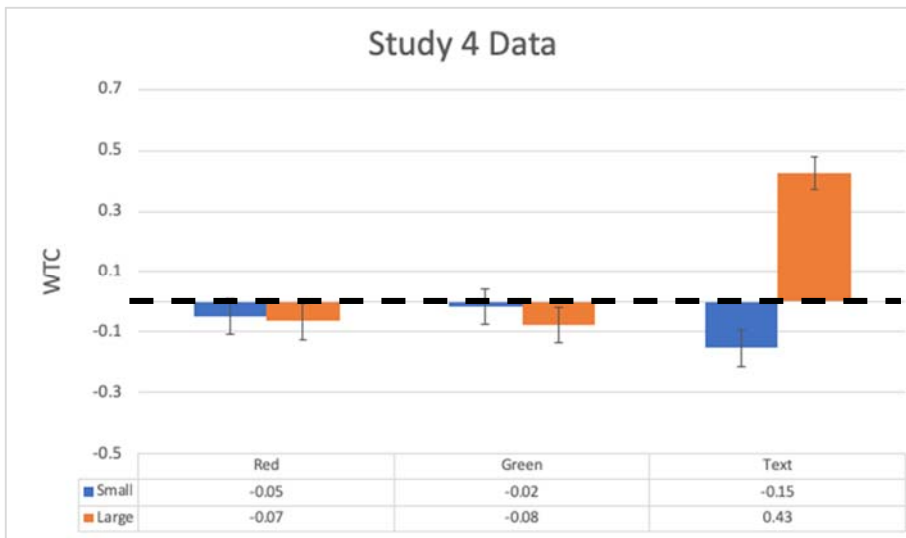|	Red	Green	Text
■ Small	-0.05	-0.02	-0.15
■ Large	-0.07	-0.08	0.43

Figure 7. Data from Study 4 as a function of Size of Indication and Type of Indication. The black dashed line indicates the baseline condition. Standard error bars are depicted.

Table 1

Comparison of the six conditions to the baseline condition using a Bonferroni correction.

Condition	n	Mean	SE	t-Value	df	p-value	Cohen's d
Small/Red	398	-.050	.058	.599	794	.549	.043
Small/Green	398	-.018	.059	.221	794	.825	.017
Small/Text	398	-.154	.060	1.84	794	.067	.127
Large/Red	398	-.065	.060	.784	794	.433	.059
Large/Green	398	-.076	.059	.920	794	.358	.068
Large/Text	398	.427	.053	-5.37	794	< .001*	.384

Note: *indicates significant when applying a Bonferroni correction.

Study 4 – Discussion

The findings from Study 4 indicate that participants were most willing to cross in front of the driverless vehicle when the size of the indication was large, and the type of the indication was textual. As seen in Figure 6, when compared to the other conditions, it is possible that this condition may have provided the most information to participants, as the colors could be somewhat ambiguous in their meaning to participants, especially when considering the consequences of stepping out in front of an automobile. In general, it appears that the more clearly the information is presented to participants, the greater their willingness to cross.

Study 5 – Introduction

The purpose of the fifth study was to attempt and identify which possible factors would be significant predictors of pedestrian's willingness to cross in front of driverless vehicles. Using the most favorable indication from Study 4, participants responded to a hypothetical scenario and rated their willingness to cross. Through the non-experimental design, a statistical model was developed to predict a person's willingness to cross in front of

a driverless vehicle. The data from this study may provide additional information about the types of persons most willing to interact with driverless vehicles.

Study 5 – Methods Stage 1

Participants

Four hundred and twenty-one participants completed the Study 5 instrument. An initial screening of the data yielded 401 usable cases (219 females) for data analysis. The main reason for an unusable case was incomplete or missing data from the respondents. The mean age of participants was 36.02 (SD = 11.18) years. As in the earlier studies, Amazon's ® Mechanical Turk ® (MTurk) was used to recruit participants from the United States.

Materials and Stimuli

After responding to the informational post on MTurk, participants were provided with a link to the instrument hosted on Google Forms. Participants first completed a digital consent form, verified they were over 18 years old, and read instruction. After, they read the following information, *"Imagine you are approaching a 4-way intersection with no traffic lights or crosswalk indicator signaling you to proceed. You need to cross the road. You are standing at a right angle to a DRIVERLESS car that has just come to a complete stop. Below is a picture of the car and crosswalk."* Participants were then shown the same Large/Text image as in Figure 6a. They were then asked to respond to each of the six universal facial expressions using Ekman and Friesen's (1971) as depicted in Figure 1. They responded on a scale of "I do not feel this way at all" (1) to "Extremely feel this way" (10). Participants then provided information on five Likert scales related to their perceptions on the complexity, familiarity, fun factor, and wariness of driverless vehicles. Each scale has five statements that ranged from strongly disagree (-2) to strongly agree (2) with a neutral option of neither

disagree nor agree (0). A copy of the five scales are located in Appendix C. Participants then reported their willingness to cross in front of the driverless vehicle, and provided demographics such as age, gender, and nationality. Lastly, participants were debriefed, compensated, and dismissed.

Design

The study used a quantitative non-experimental design. Backward stepwise regression was the statistical analysis to create the regression equation and determine the significant predictors of a pedestrian's willingness to cross in front of a driverless vehicle.

<div align="center">Study 5 – Results Stage 1</div>

The purpose of stage 1 was to develop the regression equation for testing model fit in stage 2. There were 14 possible predictors used in the study: anger, disgust, fear, happiness, sadness, surprise, complexity, familiarity, value, fun factor, wariness of new technology, age, gender, and ethnicity. The outcome variable was willingness to cross. An a priori assessment determined the minimum sample size for each stage should be 194 participants, using an estimated medium effect size of .15, alpha .05, power .95, and 14 predictors.

Initial Data Analysis

The data were vetted to ensure it met the requirements of completing the regression. No values exceed the critical Mahalanobis' distance of 23.68, Cook's value of 1, nor Leverage values of .2. The Durbin-Watson statistic was reported as 2.173. Since this value is near 2, it is assumed that the data does not violate the assumption of residuals. Finally, the assumptions of normality and homoscedasticity were visually inspected through the use of residual histogram plots, P-P plots, and standardized residual vs. standardized predicted residual values. All assumptions appeared to be met.

Regression Equation Development

Backward stepwise regression was completed on the 14 possible predictors to identify which factors significantly predicted a participant's willingness to cross in front of a driverless vehicle. The data from the study identified seven significant predictors: anger, fear, happiness, surprise, familiarity, fun factor, and wariness of new technology. The resulting regression equation was:

$$Y = -.017 + .035X_1 - .08X_2 + .128X_3 - .039X_4 + .213X_5 + .266X_6 - .078X_7$$

Where Y is the predicted willingness to cross in front of a driverless vehicle and the scores from X_1, X_2, X_3, X_4, X_5, X_6, and X_7 are anger, fear, happiness, surprise, familiarity, fun factor, and wariness of new technology, respectively. The predictors suggest as anger, happiness, familiarity, and fun factor increase so does a participant's willingness to cross in front of the driverless vehicle. As fear, surprise, and wariness of new technology increase, a participant's willingness to cross decreases. This model accounted for 63.9% (63.3% adjusted) of the variance in willingness to travel to and live on Mars, and the model was significant, $F(7, 393) = 99.41$, $p < 0.001$. A summary of the regression weights in found in Table 1, and Table 2 provides a summary of the model statistics.

Table 1

Summary of Regression Weights for Variables Predicting Willingness to Cross in Front of a

Driverless Vehicle from Stage 1 (N = 401)

Variable	B	SE	t	Sig.
Constant	-.017	.133	-0.131	.896
Anger	.035	.018	1.871	.062
Fear	-.08	.019	-4.263	.001
Happiness	.128	.014	8.962	.001
Surprise	-.039	.015	-2.692	.007
Familiarity	.213	.044	4.807	.001
Fun Factor	.266	.037	7.203	.001
Wariness of New Technology	-.078	.039	-1.986	.048

Table 2

Summary Stage 1 Model (N = 401)

R^2	Adjusted R^2	df	F	Sig.
.639	.633	7, 393	99.41	.001

Study 5 – Introduction Stage 2

The rationale for stage 2 was to assess the model fit of the regression equation developed in stage 1 using an independent sample of participants. The model fit was assess using three measures: an independent samples *t*-test between the actual willingness to cross scores from stage 2 and the predicted willingness to cross scores calculated using the stage 1 equation, a bivariate correlation between the predicted and actual willingness scores, and a calculation of the Cross-validated R^2.

Study 5 – Methods Stage 2

Participants

A new sample of four hundred and fifteen participants were recruited to complete stage 2. Three hundred and eighty-five participants (192 females) were found to have provided valid and usable data in the instrument. The most common reason for an unusable case was incomplete or skipped questions. The average age of participants was 36.76 ($SD =$ 11.66) years. As in stage 1, Amazon's ® Mechanical Turk ® (MTurk) was used to recruit participants from the United States using a convenience sample.

Materials and Stimuli

Participants followed the same procedure and completed the same instrument as those participants in stage 1

Design

Stage 2 used the same design as stage 1, except the data from the study was used to assess model fit of the regression equation from stage 1.

Study 5 – Results Stage 2

The regression equation from stage 1 was examined for model fit in stage 2. Three assessments were used to determine model fit: a *t*-test of actual willingness to cross score from stage 2 with the predicted willingness to cross scores calculated using the stage 1 regression model, a bivariate correlation between actual willingness and predicted willingness scores, and a cross-validated R^2.

The first assessment of model fit was a *t*-test of actual willingness to cross scores from stage 2 and predicted willingness to cross scores. An independent samples *t*-test found no significant differences between the actual stage 2 scores ($M = 0.35$, $SD = 1.09$) and predicted stage 2 scores ($M = 0.36$, $SD = 0.82$), $t(768) = -0.187$, $p = .851$. Since there were no significant differences between the actual stage 2 scores and the predicted scores, this suggests that the original equation is a valid model to predict willingness to cross in front of a driverless vehicle.

Second, a Pearson's correlation was completed between the actual willingness scores from stage 2 and the predicted willingness scores. The data resulted in a statistically significant relationship, $r(383) = .757$, $p < .001$. This significant relationship between the actual and predicted willingness scores suggests the original regression equation is a valid model.

Lastly, the cross-validated R^2 was used to evaluate model fit. Cross-validated $R'^2 = 1 - (1 - R^2)[(n + k) / (n - k)]$, where R^2 is the overall R^2 from the stage 1 model, n is the sample size of the stage 1 sample, and k is the degrees of freedom. The Cross-validated R'^2 for this data equals .626. Due to the low difference between the overall R^2 and the Cross-validated R'^2, this further supports the validity of the model.

Study 5 - Discussion

The findings from Study 5 produced a valid statistical model which predicts a pedestrian's willingness to cross in front of a driverless vehicle. Seven variables were determined to be significant predictors: anger, fear, happiness, surprise, familiarity, fun factor, and wariness of new technology. Through the use of a two-stage process, over 800 participants were used to develop and validate the model.

FINDINGS, CONCLUSIONS, RECOMMENDATIONS

The purpose of these studies was to explore pedestrian's WTC intersections when driverless cars approach and stop at an intersection. The study focused on examining these issues as a function of type of driver, nationality, and gender. Affect data was also collected to determine how different emotions can mediate the relationship between type of driver and willingness to cross an intersection. With increased distribution of enhanced autonomous vehicle capabilities, it is important to consider the how these vehicles will interact with other road users such as pedestrians. Prior research on pedestrians showed that communication needs to change with automated vehicles because pedestrians will no longer have driver cues to ensure it is safe to cross (Malmsten-Lundgren et al., 2017). Thus, examining pedestrian perceptions on the interactions (e.g., crossing at an intersection) that will take place with fully autonomous vehicles can further aid in the development of safer driverless vehicles that pedestrians will trust and feel comfortable interacting with.

The first hypothesis predicted pedestrians would be more willing to cross if the driver was a human compared to a fully driverless vehicle. The data from the study supported this hypothesis as WTC was affected by the type of driver, gender, and nationality of the participant. One potential reason that participants may be more willing to cross in front of a human driven vehicle is the familiarity with the operation of a human driven vehicle rather than an autonomous one. Prior research has suggested that new technology can be perceived as risky (Venkatesh and Morris, 2000) and this may deter individuals from interacting or utilizing new technology (e.g., autonomous vehicles). Another possible explanation could be the lack of visual confirmation to the pedestrian from the driver. A more recent study investigated whether pedestrians will require new ways of communication with automated

vehicles when crossing the street (Malmsten-Lundgren et al., 2017). All participants stated that they would cross with eye contact from the driver, though their willingness dropped significantly when the driver was reading or when there appeared to be no driver (Malmsten-Lundgren et al., 2017). The authors highlighted that participants felt eye contact with a driver made crossing more pleasant and made them feel safe (Malmsten-Lundgren et al., 2017).

These findings are similar to other studies that have examined consumer perceptions of fully autonomous aircrafts (Hughes, Rice, Trafimow, & Clayton, 2009; Ragbir et al., 2018; Rice et al., 2014). Hughes et al. (2009) found that participants preferred the human pilot more than the auto-pilot. In addition, a further examination into consumer perceptions of fully autonomous aircrafts, human remote- controlled operated aircrafts, and human operated aircrafts found that participants did not agree with the fully automated aircraft and the remote-controlled aircraft (Rice et al., 2014). The study emphasized that participants were unwilling, untrustworthy, and uncomfortable with the fully automated aircraft and the remote-controlled operated aircraft despite there being a human controlling the remotely operated airplane (Rice et al., 2014).

The second hypothesis proposed that pedestrian willingness to cross an intersection would differ as a function of participant gender; that is, male participants would be more willing to cross compared to their female counterparts. The hypothesis was supported by the data as gender had significant effects on participants' WTC ratings. Although, both males and females were less willing to cross in front of a driverless vehicle, it appears that the hesitation females experienced was at least partially explained by the presence of emotional factors. One possible explanation could be the differences in how both genders deal with various emotions. Several studies have suggested that affect may impact decisions greater

than cognitive processes (Johnson-Laird & Oatley, 1992; Lazarus, 1991; Schwarz, 1990; Simon, 1967; Tooby & Cosmides, 1990). Fessler, Pillsworth, and Flamson (2004) evaluated the role of various emotions (i.e., anger and disgust) and risk taking. They suggested anger was the source of higher risk taking in men as compared to women. Disgust however, led to less risk taking in women than men (Fessler, Pillsworth, & Flamson, 2004). Kuwabara (2005) examined the role of trust and fear between both genders and found that males were more trusting than females in trust games; he also highlighted that as female's fear increased, trust decreased.

Another possible explanation could be that females believe that crossing in front of an autonomous vehicle is risky. There is substantial evidence that suggest that males engage in riskier behaviors than females (Eckel & Grossman, 2008). According to the NHTSA (2016) more men die from vehicle crashes annually than women. In addition, the NHTSA (2016) reported the number of male deaths in vehicle crashes in 2016 were twice the amount of female deaths. Experimental studies on risk aversion have suggested that gender differences are apparent in drug use, global issues, and financial matters (Croson & Gneezy, 2009; Eichenberg & Read, 2016; Huddy, Feldman, & Cassese, 2009; Spigner, Hawkins, & Loren, 1993). In general, females are less likely to participate in substance abuse (Spigner, Hawkins, & Loren, 1993) and are less likely to retaliate violently towards global issues (Huddy, Feldman, & Cassese, 2009). Furthermore, prior research indicated that men are involved more in gambling than females (Wong et al., 2013). These findings are consistent with past research on gender differences with males tending to perceive dangerous situations as challenges when it could potentially be a threat (Croson & Gneezy, 2009). Thus, it is

imperative to consider how gender could potentially influence pedestrians WTC and even driving behaviors, so industries can help improve and develop safer roadways and vehicles.

The third hypothesis predicated pedestrian willingness to cross the intersection would differ as a function of participant nationality; in other words, Indians would be more willing to cross compared to Americans. The findings reinforced this hypothesis as WTC was affected by the nationality of the participant. However, the interactions in the data present an interesting and unexpected result. In general, Indians were more WTC compared to their American counterparts, and were not affected by the type of driver or gender. Only American males reported similar WTC ratings compared to all Indians. American females, on the other hand, produced lower WTC ratings across the board, and were particularly unwilling to cross in front of a driverless vehicle. One possible explanation for this outcome may be the differences between cultural upbringings between American and Indian individuals. The Indian culture, being mainly collectivist, are said to have certain subconscious traits to not hold extremists' views and to not to go against traditions (Wu & Jang, 2008). In addition, Indians are taught from a young age not to rebel, but rather follow a more traditional path of culture (Rice et al., 2014).

Uncertainty avoidance could potentially be another reason pedestrians may be less WTC. Prior studies demonstrate that Americans are less likely to take risks than Indians and are less likely to take risks during uncertainty (Robbins & Judge, 2009). Similarly, other studies have investigated the differences between these two nationalities and willingness to fly on a fully autonomous aircraft. Rice et al. (2014) found that Indian participants were less extreme in their views towards automated aircraft and remote-controlled aircraft as opposed to participants from America. A more recent study indicated that Indian participants were

comfortable with auto-pilot commercial flight expect when weather was showing hazardous conditions. While American participants were not comfortable with auto-pilot commercial flights, except when ideal weather conditions were present (Ragbir et al., 2018).

Furthermore, another possible reason American males reported similar WTC ratings compared to all Indians is because males are more likely to take risks. Evidence of risk perception between males and females illustrates that females are less likely to contribute in risky behaviors than males (Eckel & Grossman, 2008). Experimental studies and meta-analyses on perceived risk have found that gender differences are apparent in general trust, global issues, drug use, financial matters, driving and pedestrian behavior, and acceptance of new technology (Clarke, Ward, & Truman, 2005; Croson & Gneezy, 2009; Feingold, 1994; Haselhuhn et al., 2015; Kuwabara, 2005; Spigner, Hawkins, & Loren, 1993; Wong et al., 2013). Moreover, prior research has revealed that females are less trusting than males (Kuwabara, 2005). Another study found that females were less likely to violate road signs than males (Bergeron et al., 1998). Additionally, Rosenbloom (2009) found that females were less likely to cross with a 'Don't Walk' sign than males (Rosenbloom, 2009). Overall, it is vital to consider the many factors that can influence pedestrian's WTC and even decision-making to ensure the accurate and safe development of future vehicles, roadways, and road signs.

The fourth hypothesis predicated there would be significant interactions in the data. The results of the study supported this hypothesis in Study 1 illustrating significant interactions between Nationality and Gender, Type of Driver and Nationality, and in Study 4 between Size of Indication and Type of Indication. First, Figure 1 revealed Indians were more WTC compared to their American counterparts and were not affected by the type of

driver or gender. Only American males reported similar WTC ratings compared to all Indians in the human operated condition. However, American females exhibited lower WTC ratings for both conditions and were generally unwilling to cross in front of a driverless vehicle. One probable reason American males displayed similar ratings to Indian participants, at least in the human operated condition, could be their perception of risk associated with crossing in front of an autonomous vehicle; this also represents the known condition with which participants are familiar. Overall, evidence of risk aversion between genders is well-established and demonstrates that males are more likely to participate in riskier behaviors than females (Eckel & Grossman, 2008). Furthermore, those from Indian cultures are more likely to take risks with ambiguous outcomes (Rice et al., 2014), and perhaps exemplifies the similarities between American males and Indian individuals.

Second, the type of driver was important when it came to WTC in front of an autonomous vehicle versus a human driver, that is, in most cases participants were more WTC in front of a human-driven vehicle. Familiarity with crossing in front of a vehicle that has a human driver could potentially influence an individual's WTC. In addition, prior research shows eye contact with a driver can make pedestrians feel safer when crossing (Malmsten-Lundgren et al., 2017). While Americans were more extreme in their views of WTC in front of a driverless vehicle, Indians displayed an increased willingness in both conditions. Perhaps, with the tight knit cultural teachings to trust without hesitation (Rice et al., 2014), could be a possible reason of why they are more WTC. Moreover, a study that looked at cultural differences of comfort, trust, and willingness toward remotely controlled and completely autonomous commercial flight operations found that participants from the U.S trusted the human pilot more than participants from India (Rice et al., 2014). However, it

is an interesting finding that there was no significant difference in willingness to cross based on the type of driver or gender of the Indian participants.

Third, as it relates to sending indications from the autonomous vehicle to pedestrians, the size of indication and type of indication showed a significant interaction in the data. Participants were most willing to cross in front of the driverless vehicle when the size of the indication was large, and the type of the indication was textual. Large fonts can usually be read by most people regardless of vision problems (i.e., glasses or contacts). Humans read words automatically and may take longer to process color information (MacLeod, 1991). Figure 6 illustrates that this condition may have provided the most information to participants, as the colors could be somewhat ambiguous in their meaning to participants. Colors can represent different information depending on location and culture. For example, in Spain, the learned behavior of the color red can be considered with danger (Maldonado-Bascon, Lafuente-Arroyo, Gil-Jimenez, Gomez-Moreno, & Lopez-Ferreras, 2007), pain (Martini, Perez-Marcos, & Sanchez-Vives, 2013), and aggressiveness (Hill & Barton, 2005), while in China, red is considered good luck.

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APPENDIX

Appendix A - Willingness to Cross the Street scale.

Principal components factor analysis was performed and produced a single factor solution (eigenvalue = 5.71, 81.32% of the variance explained). Cronbach's Alpha scores were 0.95 and 0.94 for the Driverless and Human Driver conditions, respectively. This indicated high internal consistency for the scale. Guttmann's Split Half scores were 0.94 for both conditions, indicating high reliability.

Please respond how strongly you agree or disagree with the following statements.

1. I would be willing to cross the street in this situation.

　　　Strongly Disagree　　Disagree　　Neutral　　Agree　　Strongly Agree

2. I would be comfortable crossing the street in this situation.

　　　Strongly Disagree　　Disagree　　Neutral　　Agree　　Strongly Agree

3. I would have no problem crossing the street in this situation.

　　　Strongly Disagree　　Disagree　　Neutral　　Agree　　Strongly Agree

4. I would be happy to cross the street in this situation.

　　　Strongly Disagree　　Disagree　　Neutral　　Agree　　Strongly Agree

5. I would feel safe crossing the street in this situation.

　　　Strongly Disagree　　Disagree　　Neutral　　Agree　　Strongly Agree

6. I have no fear of crossing the street in this situation.

　　　Strongly Disagree　　Disagree　　Neutral　　Agree　　Strongly Agree

7. I feel confident crossing the street in this situation.

　　　Strongly Disagree　　Disagree　　Neutral　　Agree　　Strongly Agree

Appendix B. Affect Scale (Rice & Winter, 2015a)

Please respond how strongly you agree or disagree with the following statements:

1. I feel good about this.

     Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

2. I feel positive about this.

     Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

3. I feel favorable about this.

     Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

4. I feel cheerful about this.

     Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

5. I feel happy about this.

     Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

6. I feel enthusiastic about this.

     Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

7. I feel delighted about this.

     Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree

Appendix C. Five Scales from Study 5

Complexity Scale

Please respond to each of the following statement:

1. The automation that controls driverless cars is very complex.

2. I do not understand the automation that controls driverless cars.

3. It is difficult to know how the automation that controls driverless cars works.

4. I have no idea what the automation that controls driverless cars is doing.

5. It is a mystery to me how the automation that controls driverless cars operates.

Familiarity Scale

Please respond to each of the following statement:

1. I am familiar with driverless cars.

2. I have a lot of knowledge about driverless cars.

3. I have read a lot about driverless cars.

4. Driverless cars have been of interest to me for awhile.

5. I know more about driverless cars than the average person.

Value Scale

Please respond to each of the following statement:

1. A driverless car is something that would be beneficial to me.

2. Driverless cars would be something valuable for me to own.

3. I think driverless car technology is useful.

4. There would be value in using a driverless car.

5. If driverless cars were available, I think it would be beneficial to own one.

Fun Factor Scale

Please respond to each of the following statement:

1. I like the idea of driverless cars.

2. I think it would be fun to ride in a driverless car.

3. I am interested in trying out a driverless car.

4. I think it would be cool to have a driverless car.

5. I've always wanted to ride in a driverless car.

Wariness of New Technology Scale

Please respond to each of the following statement:

1. In general, I am wary of new technology.

2. New technology scares me.

3. New technology is not as safe as it should be.

4. I tend to fear new technology until it is proven to be safe.

5. New technology is likely to be dangerous.