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Pedestrian age and gender in relation to crossing behavior at midblock crossings in India

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ABSTRACT

Pedestrians have unique needs to ensure their safety as they interact with others within a transportation system. Since this is especially true in third world context, it is imperative to gain a better understanding of pedestrian behaviors in developing countries. The goal is to have planners and engineers create appropriate design guidelines and inform policy decisions. Data on pedestrian characteristics and behavior metrics were gathered from midblock crossings in Bangalore, Karnataka, India. Quadratic and logistic regressions suggest that pedestrian delay and utilization of crossings increase with age, while conflicts decrease with it. Male waiting time is approximately half of female waiting time, and males are twice as likely to cause conflicts with motor vehicles. These strong patterns will hopefully aid in the understanding of pedestrian behavior in relation to motor vehicle traffic in urban areas of developing countries, encouraging safer crossings to be designed.

1. Introduction

Being some of the most vulnerable users within a transportation system, pedestrians present specific challenges to transportation design and have particular needs. Due to different pedestrian characteristics, these needs require an in-depth understanding of pedestrian behavior. Pedestrians account for 22% of fatalities on roadways around the world (World Health Organization, 2013a). This number rises to above 75% in some under-developed nations (Muhlrad, 1987). Further highlighting the importance of understanding pedestrian behavior in the third world countries is the fact that upwards of 74% of all pedestrian fatalities occur in under-developed nations (Berkley et al., 1993). This figure equates to more than 500 pedestrian fatalities every day on roadways in third world countries (World Health Organization, 2013b). These tragedies should be treated as both foreseeable and avoidable. If an understanding can be obtained of how and why these fatalities occur, progress can be made to prevent them. Pedestrians' behaviors, with characteristics such as age and gender, will provide important insights into understanding their safety. In this paper, the influence of pedestrian characteristics on behavior is studied specifically at midblock

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crossings. The study also focuses on a third world context, as these countries present the most volatile areas of interaction between pedestrians and motor vehicles. The goal of this paper is to fill a gap in the current knowledge of pedestrian behavior due to its implications for pedestrian safety. The following literature review will first examine the most pertinent behavioral factors regarded as dependent variables. It will then detail past researches on the independent variables (gender and age). These sections will examine the pertinent factors in general, and not necessarily in a third world context. Then, the specific importance of India and the developing world will be introduced.

Dependent behavioral variables chosen for this study include pedestrian delay time, utilization of available crossing treatments, and conflicts between pedestrians and motor vehicles. Pedestrian delay is an important variable to study because pedestrians frequently become impatient while waiting to cross the street (Guo et al., 2012). If a pedestrian becomes impatient and unwilling to wait for a shorter vehicle gap, then he or she is more likely to enter a risky situation while crossing the roadway. Similarly, pedestrians who do not use the available crossing infrastructure are also more likely to enter risky situations. Although the safety benefits of crosswalks and other similar pedestrian treatments have been called into question by past researches, people that are willing to disobey established rules are more likely to dispose themselves to risk during their crossing (Zegger et al., 2005). This increases the likelihood of poor safety outcomes. The final dependent variable used for this analysis is conflict between pedestrians and vehicles. This variable possesses a more direct relationship with safety outcomes, as it is an indicator of collisions (Grayson et al., 1984). Gender and age are analyzed in relation to the aforementioned dependent variables.

Past research has shown that the gender of a pedestrian is an important characteristic in determining pedestrian behaviors such as waiting time and proclivity towards risk (Hamed, 2001; Kadali and Perumal, 2012; Kingma, 1994). In particular, it has been shown that male pedestrians are more willing to violate regulations and make unsafe crossing decisions. They are also less likely to perceive risk when crossing a roadway in the presence of motor vehicles (Díaz, 2002; Holland and Hill, 2007, 2010). This relationship between males and higher rates of risky behavior has even been shown in young children aged 5–8 years old (Barton and Schwebel, 2007). Male pedestrians also tend to wait for shorter amounts of time than female pedestrians when crossing a roadway (Tiwari et al., 2007). Correspondingly, male pedestrians have significantly faster walking speeds than their female counterparts, possibly relating to their shorter waiting times (Tarawneh, 2001). As is expected, males comprise up to 80% of pedestrian fatalities (Odero et al., 1997). In addition to pedestrian behavior being strongly dependent on biological gender, as shown in past researches, it has also been found to depend on the psychological masculinity of an individual (Granié, 2009).

Along with gender, the pedestrian characteristic of age is a significant variable in relation to pedestrian behavior. Higher pedestrian age correlates with decreased risk perception, larger minimum gap acceptance, and longer waiting times when crossing a street (Hamed, 2001; Holland and Hill, 2007; Kadali and Perumal, 2012). Pedestrian speeds are also significantly related to pedestrian age, and the speeds of pedestrians are slower as they get older (Tarawneh, 2001). Past researchers have found that pedestrians between 21 and 30 years of age are the fastest age group (Tarawneh, 2001). There remains some ambiguity regarding the relationship between pedestrian age and actual risk and conflict. While younger pedestrians are more willing to violate regulations, older pedestrians make more unsafe decisions (Díaz, 2002; Holland and Hill, 2010; Lee and Abdel-Aty, 2005). Such unsafe decisions are primarily related to older pedestrians' difficulties in interpreting the situation. Having a clearer understanding of this relationship, especially at midblock crossings in developing countries, will greatly aid the understanding of pedestrian behavior, and therefore support the overall safety of third world transportation systems.

A specific theory that has been supported in past researches to predict pedestrian behavior is of particular interest to the current study. The Theory of Planned Behavior is a method of predicting pedestrian behavior based on the intentions of the users of the system (Díaz, 2002; Evans and Norman, 1998; Holland and Hill, 2007). The theory is a good predictor of intentions, and shows that pedestrian behavior, especially with respect to safety, can be predicted and accounted for. This supports the goal of this paper, which is to help predict pedestrian behavior based on specific characteristics, in order to improve the safety of transportation systems. Just as past researchers have shown the feasibility of predicting pedestrian behaviors through the Theory of Planned Behavior, it is hopeful that the results of this study will also aid in predicting pedestrian behaviors.

This research details the relationship between age, gender and behavior in a third world context. The various behavioral variables are performed in a third world context for two reasons. First, there are serious safety concerns in third world countries, and second, the bulk of the past researches regarding pedestrian characteristics and behavior were conducted at intersections in developed countries. This paper looks specifically at third world midblock crossings, which can prove uniquely problematic and yet still a popular crossing location in informal third world settings. In India, the transportation system is a wholly different paradigm from those typically studied in developed countries. For example, during 2013–2014, over 80% of the motor vehicles sold in India were motorized two-wheelers (Society of Indian Automobile Manufacturers, 2015). This unique composition of traffic causes pedestrians to act in unique manners, and therefore warrants examination. Understanding how pedestrian behavior differs among these distinctive pedestrian contexts can inform design decisions of midblock crossing locations.

The rest of this paper builds upon the previously discussed body of knowledge. Section 2 details data collection at midblock crossings in Bangalore, India. Section 3 presents the findings and analysis, and Sections 4 and 5 provide a discussion of results and conclusions. Based on pedestrian characteristics of age and gender, a clear picture of pedestrian behavior at midblock crossings in a third world context is presented. These insights promote greater safety throughout the transportation systems.

2. Methods

Data collection occurred at 4 separate midblock crossings in Bangalore, Karnataka, India. All crossings were located along a 1.5-kilometer stretch of Hosur Road between the Wilson Garden and Koramangala neighborhoods. The observed roadway sections ran in a northwest–southeast direction. Because counts were taken along the same stretch of roadway, motor vehicle flows and compositions are similar at all of the locations. Vehicle flow rates were consistent measuring approximately 1950 vehicles per hour per lane during the observation hours. Counts were taken on weekdays between 11:30 a.m. and 4:45 p.m. Data collection days did not include rain or unusual weather events.

Within the confines of the study area, Hosur Road consists of two lanes in each direction. The east side of the road consists of residential neighborhoods, while the west side of the road primarily consists of schools, shops, and medical facilities. There are few traffic control devices along the stretch of observed roadway, and vehicles typically move unimpeded through the corridor. The lack of controlled crossing locations leads to many pedestrians crossing Hosur Road at midblock locations. The observed crossings are within close proximity to bus stations, which attract large numbers of pedestrians. The crossings have painted crosswalks, but limited traffic control and signage. Each crossing was observed twice for 30 min for a total of 4 h of observations. Observations were only made when the traffic was freely flowing. When traffic flow became impeded due to congestion, observations were stopped until traffic resumed at a free flow.

Data were gathered through manual observations and recorded in a field journal. Reliability between different observations locations was ensured by having the same individual make all studied observations. Only single pedestrians were noted, as groups of pedestrians can have altered behavior patterns. If pedestrians approached the crossing in a group, they were not counted. For these reasons, the findings of this work can only be generalizable to individual pedestrians and not groups. Due to the number of factors being recorded, only one pedestrian was observed at a time. If there was more than one pedestrian crossing at a time, only the first one arriving at the roadway was recorded. Observations were made from a point close enough to the roadway that pedestrian characteristics could be observed. However, the individual being observed was not aware of the observation process so as not to disrupt crossing behaviors. If a pedestrian was observed to have an accompanying item, such as a stroller or a bicycle, they were not counted. A number of observations were recorded for each pedestrian: gender, age, waiting time, vehicle conflicts, and the utilization of crossing infrastructure. Pedestrian observations began when a pedestrian approached the roadway with the intent to cross. Waiting time counts began as soon as the pedestrian arrived at the curb, and ended once the pedestrian initiated roadway crossing. Age and gender were both recorded while the pedestrian was waiting. The utilization of crossing infrastructure was defined as whether or not a pedestrian crossed completely within the painted crosswalk and utilized the provided break in the median barrier. If a pedestrian started crossing within a crossing treatment, but left the treatment before completing their crossing, they were counted as not having fully used the treatment. As a safety study, pedestrian injuries or fatalities would have been the most valuable dependent variable to study. Since they are relatively rare, and reliable data does not exist, a proxy measure of conflicts is recorded. A vehicular conflict is defined as an interaction between a pedestrian and a vehicle, which would result in a collision if one party did not change speed or direction (Lord, 1996). This has been shown to be a good substitute for more direct measures of pedestrian safety (Turner et al., 2006).

Gender recordings of pedestrians were clear with few examples of ambiguity. Age recordings were based on estimations from the pedestrians' facial characteristics, which has been shown to be an accurate measure (Burt and Perrett, 1995; Pittenger and Shaw, 1975; Rhodes, 2009; Sörqvist and Eriksson, 2007). Accurate and precise estimates were especially marked for individuals aged between 20 and 60 years old (Burt and Perrett, 1995). The majority of pedestrians were within this accurate and precise age range. Estimations of the average age of an unknown person based on facial characteristics have deviations of 2.39 and 2.83 years (Rhodes, 2009; Sörqvist and Eriksson, 2007). The 5-year increments in which age estimations were made in this study were therefore warranted by the past researches. Inter-rater reliability issues were avoided by having one single data collector throughout the process. Both spatial and surface cues were used to make age estimations. Facial texture was the primary surface characteristic used. Wrinkles and other lines on a person's face indicate advanced age. Lines will accumulate with time, and more natural accumulation typically indicates older age. Spatial distributions of the primary facial features, such as noses and eyes were also used to derive age estimations. The observer was close enough to note these surface and configurational characteristics and make an age estimation based on observation of the pedestrians.

The first step of age estimation is to categorize pedestrians into their respective gender grouping. Next, facial textures such as wrinkles, creases, and other lines were recorded. A ranking of facial textures was given to each pedestrian, with few lines receiving a low ranking and more lines receiving a high ranking. Finally, the facial configuration was noted. Again, a ranking was given based on facial configuration. From these factors, an age estimation to the closest 5-year interval was created.

After data were gathered, results were analyzed using t-tests, quadratic regressions, and logistic regressions. The dependent variables of the use of crossing infrastructure and conflicts were easily turned into dichotomous variables, allowing for a robust logistic regression analysis. The continuous dependent variable of waiting time was analyzed using t-tests and quadratic regressions. The analytical software IBM SPSS statistics was used in the analyses.

3. Results

3.1. *Descriptive statistics*

There were 195 pedestrians observed and recorded at midblock crossing locations within the 4-hour observation period (Table 1). Each crossing location had between 10 and 35 pedestrians crossing in their respective 30-minute time frames. This resulted in an average of 24.4 pedestrian crossings per 30-minute viewing period. There were 118 male pedestrians (60.5%) and 77 female pedestrians (39.5%) that were observed crossing the road. The average age estimation was 34.3 years of age and the average waiting time was 24.7 s. Approximately 45.1% of pedestrians used the crosswalks and 25.6% of pedestrians caused a conflict with a motor vehicle (Table 1).

The waiting time follows an exponential decay curve as expected (Fig. 1). The estimated ages follow a normal curve as expected (Fig. 2). In order to perform the desired analysis, the pedestrian sample was separated and organized by the characteristics of gender and age to analyze specific crossing behaviors. This was done for the relationship of each independent variable with the unique dependent variables. These individual relationships are important, serving as the focus of this study. Future work should incorporate a comprehensive model that integrates both independent variables so that the interrelationship between gender and age, in terms of crossing behavior, can be better understood.

3.2. *Gender*

Crossing behaviors were first analyzed in relation to gender. The average waiting time of female pedestrians is 34.4 s, which is 88.0% longer than the average waiting time of male pedestrian of 18.3 s (Table 2). Based on a 0.067 significance of the Levene's Test, the two waiting time samples can be assumed to have statistically equal variances. Using independent samples *t*-tests, the male and female samples are statistically different from one another in terms of waiting time (Table 2). In terms of using available crossing treatments, only 39.8% of males and 53.2% of females used the available crosswalks. This shows that females are over one-third more likely to properly use crossing infrastructure than males. However, based on logistic regression results, this relationship was not found to be significant (Table 3). The most striking finding related to gender is the difference between males and females in terms of conflict with motor vehicles while crossing. While only 14.3% of females caused a conflict with a motor vehicle, 33.1% of males caused a conflict. This is a 131.5% increase in the probability of causing a conflict, which is statistically significant at the 99% confidence level and a strong trend which indicates vital safety behavior differences between the two genders (Table 3).

Table 1 – Descriptive statistics of observed pedestrians.

Total pedestrians	195
Male	118
Female	77
Average age estimation (year)	34.3
Average waiting time (s)	24.7
Utilization of crosswalks	45.1%
Causing a conflict	25.6%

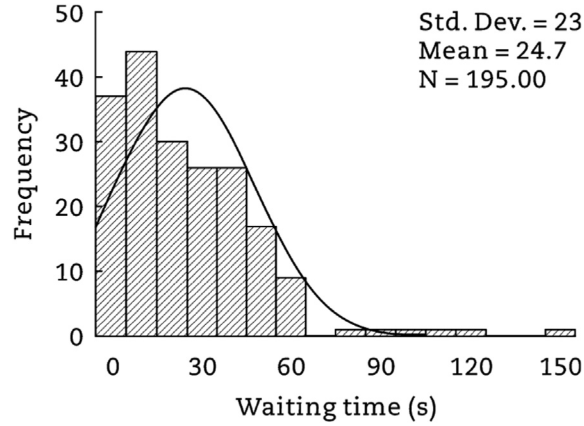

Fig. 1 – Frequency of observed waiting time.

3.3. *Age*

Statistically significant relationships were observed between age and the observed crossing behaviors. Waiting time is at a minimum for individuals in their twenties, and then steadily increased with increasing age (Fig. 3). Waiting time ranged from a minimum of 19.0 s for pedestrians in their twenties to a maximum of 59.1 s for pedestrians in their seventies. After testing for non-linear effects in the model, a linear regression was not the optimal model for this relationship. Upon trials of different polynomial regression forms, it was found that a quadratic regression was the strongest form to model the relationship between age and waiting time. The results from this regression suggest that the relationship between age and waiting time is statistically significant at an alpha level of 0.01 (Table 4).

Older pedestrians are more likely to use the crosswalks, with the average age of utilizing at 37.2 years, and the average age of non-usage at 30.7 years (Table 5). Logistic regression results show that, as age increases, the likelihood of using available crosswalks also increases (Table 3). The relationship between age and crosswalk utilization is statistically significant at a 99% confidence level. The difference in age between pedestrians who caused conflicts with motor vehicles and those who did not cause conflict is highly similar to the difference in utilization of crosswalks.

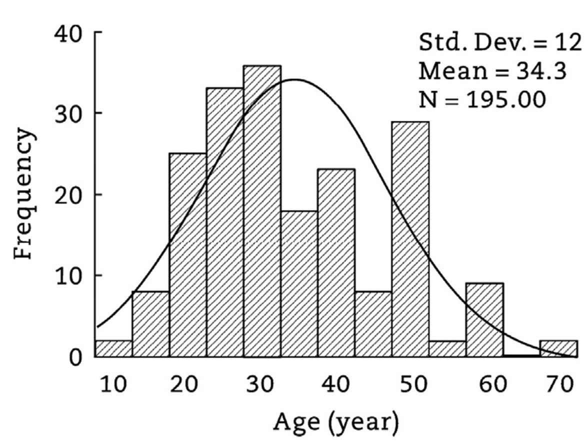

Fig. 2 – Observed ages following a normal curve.

Table 2 – Differences in pedestrian behavior by gender with statistical significance of the differences.

	Male	Female	Difference (%)	Sig.
Waiting time (s)	18.3	34.4	88.0	0.000
Utilization of crosswalks (%)	39.8	53.2	33.7	0.067
Causing a conflict (%)	33.1	14.3	131.5	0.004

Table 3 – Logistic regression between gender/age and risk/conflict (male = 0).

	B	S.E.	Sig.	exp(*B*)
Gender				
Utilization of crosswalk	0.543	0.296	0.067	0.581
Causing a conflict	−1.086	0.380	0.004	0.338
Age				
Utilization of crosswalk	0.034	0.012	0.005	0.967
Causing a conflict	−0.046	0.015	0.002	0.955

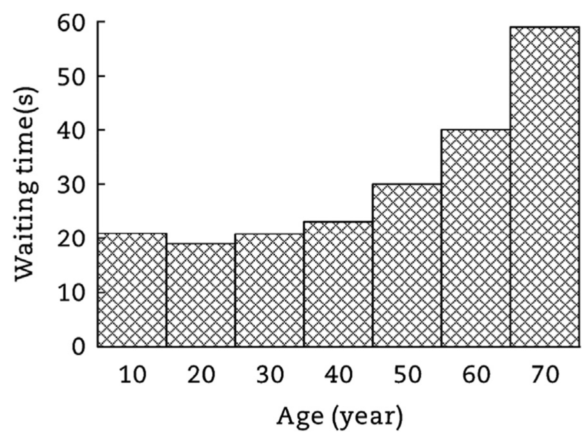

Fig. 3 – Increase in waiting time with increasing age.

The average age of pedestrians that did not cause a conflict is 36.0 years, while the average age of pedestrians that cause a conflict is 29.5 years. This represents an approximately 22.0% increase in age between the two unique types of behavior. As can be seen from the negative *B* value in the logistic regression results, the likelihood of causing a conflict decreases as age increases (Table 3). This relationship is statistically significant at a 99% confidence level as well. As their age increased, pedestrians in this study become increasingly conservative in their behavior.

Table 4 – Quadratic regression results for age versus waiting time.

R^2	*F*	*b*1	*b*2	Sig.
0.068	6.993	−1.100	0.02	0.001

Table 5 – Differences in pedestrian behavior by age.

	Average age (year)
Utilizing crosswalk	37.2
Not utilizing crosswalk	30.7
Causing conflict	29.5
Not causing conflict	36.0

4. Discussion

Pedestrian behavior shows strong patterns based on the characteristics of age and gender at midblock crossings in a developing country context. This paper clarifies past ambiguities concerning the relationship between age and pedestrian behavior, and solidifies the relationship between gender and pedestrian behavior. Besides, this work examines pedestrian behavior in relation to safety at midblock crossings in a third world context, and, more specifically, in India. This was a gap in the current body of knowledge that needed to be addressed. When pedestrian behavior can be predicted, then pedestrian injuries and fatalities may be able to be predicted, as well as prevented. If midblock crossings can be planned with these behaviors in mind, a safer roadway environment for all users, and especially, pedestrians, may be realized.

Results show that males exhibit more dangerous crossing behavior than females by waiting for shorter amounts of time, using the crosswalks less, and causing more conflicts with motor vehicles. While the relationship between gender and using crossing infrastructure did not reach levels of significance, the relationship between gender and waiting time and the relationship between gender and conflicts are significant and strong. This agrees with past literature that found males were less willing to wait at crossings and more likely to disregard rules (Díaz, 2002; Hamed, 2001; Holland and Hill, 2007, 2010). However, nearly all past work examining the subject was based in a developed country context. The results from this paper contribute to the body of literature by investigating the relationship between gender and crossing behavior in a developing country context. The current results are also significant because they account for numerous crossing behaviors within the same study, which past work failed to do. Studying multiple crossing behaviors in the same study allows for consistency and uniformity within the findings, which is especially important when exploring transportation systems in developing countries.

Results also indicate that older pedestrians are more conservative in their behaviors by waiting longer, using the crosswalks more, and causing less conflicts with motor vehicles than their younger counterparts. All of these relationships reached levels of significance. This refuted some past researches that stated that older pedestrians took risks and caused conflicts at higher levels than their younger counterparts, mostly because of an inability to accurately perceive their surroundings (Granié et al., 2014; Lobjois and Cavallo, 2007; Oxley et al., 1997, 2005). Other existing studies conflictingly found that older pedestrians were more conservative in their crossing behaviors, introducing ambiguity – and a gap – in the current literature (Lobjois et al., 2013; Lobjois and Cavallo, 2009; Sun et al., 2003). Again, all of the above mentioned studies had been conducted in a developed country context. The results from this work help to fill the gap in the literature by clearing up the ambiguity and studying pedestrian behaviors in a developing country context. This is an especially important gap to fill as older pedestrians are one of the most vulnerable users in a transportation system. The current work also adds to the body of knowledge by holistically examining multiple crossing behaviors within the same study. Finally, specifically examining behavior at midblock crossing locations offers a new and an important aspect of this paper. Future work can examine the influence of vehicle speeds and vehicle compositions on the relationship between crossing behavior and age.

Knowing which users of the system exhibit the most dangerous behaviors may allow planners and designers to account for them. Understanding how long pedestrians are willing to wait and their risk tolerance at midblock crossings will lead to design considerations accounting for their safety needs. Planners and policy makers may be able to identify areas with high concentrations on certain types of users and accordingly ensure that the built environment meets their needs. Transportation simulation models can also be improved by more accurately reflecting actual user behavior. Having more accurate transportation simulation models would help immensely with the planning and design of our transportation systems.

It is an important caveat that the results of the current study only apply to midblock crossings in an Indian context and further generalizability should not be implied. Future studies are needed to explore whether the results of this work are applicable with other contexts, including developed countries and situations with varying traffic volumes and speeds. Furthermore, future work should investigate whether differences in the available pedestrian infrastructure would change the behavior of the different groups in a uniform manner. Future work may take the current results one step further and explore treatments that may prevent these risky behaviors. It would also be valuable to determine whether engineering, education, encouragement, enforcement, or a combination of these conditions can ensure the safety of the unique user groups. Finally, it is important that future work directly examines safety outcomes to understand whether risky behaviors correlate with injuries and fatalities. By understanding how transportation systems function based on the actions of all users, the community will be able to plan, design, and construct better transportation systems for all.

5. Conclusions

Pedestrians are a particularly vulnerable part of the transportation system. Special care should be taken to understand their specific needs and behaviors. The pedestrian behaviors of waiting, crosswalks utilization, and causing motor vehicle conflicts were studied at midblock crossings in Bangalore, Karnataka, India. These behaviors were analyzed in relation to the pedestrian characteristics of age and gender for individual pedestrians.

Results indicate that gender and age both have a strong and significant relationship with the observed safety-related behaviors. Males exhibited shorter waiting time, used the crosswalks less, and caused far more conflicts with motor vehicles than the females. Older adults were more conservative in their crossing behaviors than their younger counterparts by waiting longer to cross, using the crosswalks more, and causing less conflicts with motor vehicles. With this deeper understanding of pedestrian behavior at midblock crossings in an Indian context, it is hopeful that safer systems can be built in the future for the benefit of all.

Age estimation process

Faces hold many cues. Simply by looking at their face, we can interpret – with considerable accuracy – the emotions, gender, and ethnicity of a person (George and Hole, 2000). We can also estimate a person's age with a high degree of accuracy by making a simple facial observation. There are numerous cues available to help observers make estimations of age based on facial characteristics. These cues are related to both spatial and surface characteristics of the face. Spatial characteristics include head-shape and placement of features (i.e. nose, eyes, etc.). Surface characteristics include texture of the face and other two-dimensional considerations (George and Hole, 2000). These cues can be used to read both familiar and unfamiliar faces (George and Hole, 2000).

In particular, we used these aforementioned features to deduce age estimations of pedestrians in Bangalore, India. Facial texture was primarily used. Wrinkles and other lines on a person's face indicate advanced age. Lines will accumulate with time, and more natural accumulation typically indicates older age. Spatial distributions of the primary facial features such as the nose and eyes were also utilized to derive age estimations. Observers were close enough to the crossings to note these surface and configurational characteristics and make an age estimation based upon observation of the pedestrians.

The first step of age estimation was, upon observation, to categorize pedestrians into their respective gender grouping. From there, facial textures such as wrinkles, creases, and other lines were noted. A ranking of facial textures was given to each pedestrian, with few lines receiving a low ranking and many lines receiving a high ranking. Finally, facial configuration was noted. Again, a ranking was given for the appearance of facial configuration. From these factors, an age estimation to the closest 5-year interval was created. Because ages can be predicted to a particularly high degree of accuracy within the age range of 20–60, this method was justified by past research (Burt and Perrett, 1995; Pittenger and Shaw, 1975; Rhodes, 2009; Sörqvist and Eriksson, 2007). An average age estimation of an unknown person based on facial characteristics has been shown to have 2.39 years of deviation (Rhodes, 2009) and 2.83 years of deviation (Sörqvist and Eriksson, 2007). The 5-year increments in which age estimations were made were therefore warranted by this past research.

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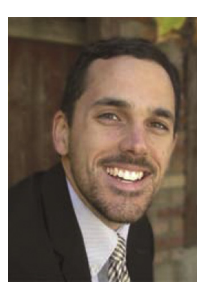

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