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Inter-personal Judgements for Pedestrians at Night: Exploring Information Perceived at Different Distances

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Abstract. Lighting in residential roads is designed to meet primarily the visual needs of pedestrians rather than those of motorists. These needs include enhancement of their safety and perceived safety. One aspect of safety is the ability to make judgements about the intent of other pedestrians, whether or not they present a threat. A current basis of guidance is that lighting should enable facial recognition at a minimum distance of 4m, suggested to be the minimum distance at which an alert subject would be able to take evasive or defensive action if threatened. The literature however does not conclusively support this assumption, and there are clear variations in comfortable interpersonal distances with light level and with the procedure used to measure the desired inter-personal distance. This article reports a study carried out to explore the visual information extracted about other pedestrians at a range of interpersonal distances (15, 35, 66 and 135 m). An open task was used in which test participants were instructed to report all the information they could about a target pedestrian, and these were photographs of unknown people printed at different sizes to represent different inter-personal distances. The results appear to fall into three categories according to the relationship between frequency of identification and inter-personal distance. These data provide some clue as to what features of other pedestrians might be important and whether these features are distinguishable at different distances.

Keywords: road lighting, reassurance, interpersonal judgements, comfortable inter-personal distance

1 Introduction

Street lighting is provided to meet the needs of road users such as motorists, cyclists, and pedestrians. Pedestrians are regarded as one of the most vulnerable user groups of roads in residential areas [1] and thus road lighting should enhance their safety and perceived safety at night-time.

One element of safety is making judgements about the intent of other pedestrians (i.e. whether or not they present a threat): these are inter-personal judgements. Past studies have been carried out to investigate how lighting affects facial recognition and thus how parameters such as the spectral power distribution (SPD) of lighting might be optimised. The results of six known studies are mixed [2], [3], with three suggesting that SPD does affect facial recognition, and thus that facial recognition can be gained at a further distance when using lamps of better optimised SPD, while others reported there is no effect. One limitation of these studies is that they have not addressed the inter-personal distance at which it might be desirable to make judgements about other pedestrians. It is possible that at near distances any effect of SPD is not significant because the face is of a large size. At further distances, where the face is smaller, then an improvement due to SPD may be of benefit.

Caminada and van Bommel [4], [5] proposed a foundation for the requirements of lighting in residential areas which has informed subsequent lighting guidance. They identified visual needs including facial recognition, obstacle detection, visual orientation, pleasantness and comfort, and hence the lighting criteria to meet these needs. For facial recognition they suggested a requirement to recognise the face of an approaching pedestrian at a distance of 4 m. This was rounded from the minimum public distance from proposed by Hall [6], a distance of 3.7 m (12 feet) suggested to be the minimum distance at which an alert subject would be able to take evasive or defensive action if threatened.

Hall [6] introduced a series of desirable distances for personal space according to social needs by integrating visual, auditory, olfactory and other perceptual parameters. There were four zones including an intimate distance (less than 0.5 m) at which the presence of the other person is unmistakable, personal distance (from 0.5 to 1.2 m) which forms a protective sphere, social distance (from 1.2 to 3.7 m) as a limit of domination, and public distance (3.7 m or more). For defining the public distance, it appears that Hall considered visual and auditory factors to matter. Visual definition of public distance includes: the ability to see the entire central face on the fovea, thus giving detailed vision, and Hall suggested this is possible at 3.7 m (12 feet); ability to see the faces of two people on the macular region; and the whole of a seated person in a 60° field of view. Other cues to judgements of safety include body language and action [7], [8] which might include posture and gait and these may present larger visual targets.

While Caminada and van Bommel suggest that facial recognition is needed at inter-personal distances of at least 4 m in order to permit ability to evade threat, Townsend [9] suggests that once inter-personal distance is reduced below 15 m, the space in which we have time to react to avoid trouble, or simply an undesirable situation, becomes reduced beyond comfortable levels. Further evidence has therefore been sought to confirm the minimum distance at which it might be comfortable to make decisions regarding the intent of other pedestrians.

2 Studies of Inter-Personal Distance

Gibson [10] used the hypothetical example of an ancestor genus homo in order to illustrate the relationship between inter-personal distance and comfort:

For example, one conceivable object to which he must have been sensitive was a sabre-toothed tiger or some beast of equal ferocity. His conduct must have been rather nicely adjusted to distance when he encountered one in open country, varying as the retinal image varied in a precise way. To the tiger at a mile he could react by going about his business. To the tiger at 400 yards he should have reacted by going in another direction. To the tiger at 10 yards he must have reacted (if he was one of our ancestors) by running like the wind. His behaviour was graded in relation to a variation of his retinal images. [Gibson, 1950, p. 197].

Clearly, distance affects perceived safety. Judgements of desirable interpersonal distance are made in order to maintain a certain level of reassurance, the difference between an approaching tiger and an approaching person being the relative distances for the different levels of perceived safety.

One criterion may be ability to perceive details about other people, as was used by Hall. In 1877, the German architect Maertens [11] introduced the human scale into urban design. He suggested that the nasal bone is a critical feature for the perception of the individual and considered the one minute of visual angle as the smallest size of detail discernible. From this he proposed critical distances including 12 m, at which people can be distinguished, 35 m at which the face becomes featureless, and at a distance of 135 m body gesture can be discerned.

One question to ask is whether Hall's work, which did not specifically address vision at low light levels, is indeed a suitable basis for road lighting – is the minimum distance of 4 m still relevant to the situation of pedestrians walking at night under street lighting? Adam and Zukerman [12] examined inter-personal distance at low and high light levels using a stop-distance procedure. In the stop-distance procedure the test participant and/or the experimenter walk towards one another and the test participant stops walking (or otherwise indicates) at the point where the presence of the other person becomes uncomfortable. The stop-distance procedure is regarded as an attractive technique for measuring personal space since it places the subjects in a real situation [13]. It may however provide an underestimate if carried out in a laboratory where test participants are not subject to the same types of fear as they might in real streets. Adam and Zukerman used two light levels, 1.5 lx and 600 lx. The mean comfortable distance was greater (1.17 m) under low illuminance than under high illuminance (0.53 m), indicating a preference for greater separation from unknown people at night-time than at daytime.

Fujiyama et al [14] also used a stop-distance procedure to investigate comfortable distance. Under five illuminances, ranging from 0.67 lx to 627 lx, ten stationary participants were asked to say "stop" when an unfamiliar person walking towards them felt uncomfortable. The results are reported only graphically and without error bars or similar to indicate variance. Mean comfort distances lie in the region of 4.0 to 5.2 m, with a slight trend to decrease at higher light level. Fujiyama et al report only a few sample statistical analyses. Comfort distances at 0.67, 2.8 and 5.5 lx are significantly longer ($p<0.05$) than that at 627 lx, but they did not find a significant difference between comfort distances at 12.3 and 627 lx.

Figure 1 shows the results from Adam and Zukerman and from Fujiyama et al. While the results from Fujiyama et al suggest comfortable inter-personal distances similar to that proposed by Caminada and van Bommel, for both low and high illuminances, the results from Adam and Zukerman suggest much shorter comfortable distances. Both studies were carried out in interior spaces. One difference is the size of the laboratory: Adam and Zukerman used a small room of dimensions 5.18 m x 6.1 m while Fujiyama et al used the Pedestrian Accessibility and Movement Environment Laboratory (PAMELA) which is much larger (80 m^2). Thus there may be a range bias: Adam and Zukerman used a small room which resulted in a small estimate of comfort distance.

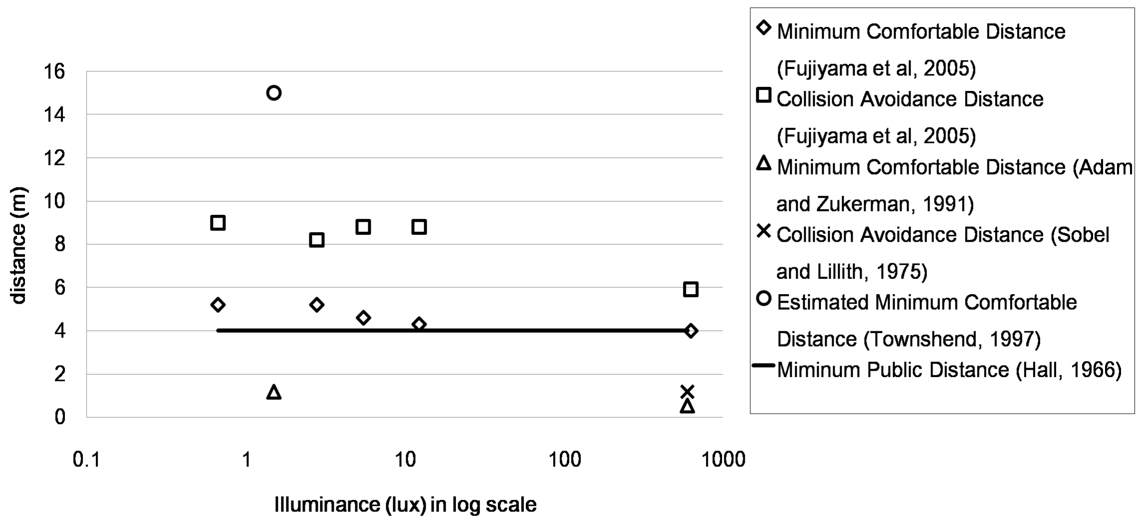

Figure 1 Minimum interpersonal distances reported in past studies.

Townshend [9] determined his estimate of a minimum comfort distance of 15 m using a field study in which he asked members of the public about their attitudes to being in a city centre, and this was done after dark. One task was to estimate the distance at which they would be comfortable about an approaching person or group of people. The average comfort distance under this dim lighting was 15 m.

Table 1 summarises past studies of desirable inter-personal distances for comfort. The available data are limited and thus further evidence was sought from investigation of collision avoidance when walking. Collision in this context means avoiding contact with another person rather than a stationary object. This avoidance may be for reasons of accident avoidance and for comfort.

Table 1. Past studies of inter-personal distances required for comfort between pedestrians.

Study	Method	Suggested Comfort Distances Dim lighting	 Bright lighting
Comfort distance			
Adam and Zukerman, 1991	Stop-distance	1.17 m (1.5 lx)	0.53 m (600 lx)
Fujiyama et al, 2005	Stop-distance	5.2 m at 0.67 lx (p<0.05)* 5.2 m at 2.8 lx (p<0.01) 4.6 m at 5.5 lx (p<0.05) 4.3 m at 12.3 lx (n.s.)	4.0 m (627 lx)
Townshend, 1997	Field interview	15.0 m	-
Maertens, 1877	Theoretical calculation based on ability to see detail.	-	12 m: distinguish people 35 m: face featureless 135 m: discern body gesture
Collision avoidance distance			
Fujiyama et al, 2005	collision avoidance response distance	9.0 m at 0.67 lx (n.s.) 8.3 m at 2.8 lx (p<0.05) 8.8 m at 5.5 lx (n.s.) 8.8 m at 12.3 lx (p<0.05)	5.9 m (627 lx)
Sobel and Lillith, 1975	Observation of public behaviour	-	1.18 m

Note: * difference between comfort distances at dim light level and 627 lx in Fujiyama et al. Note: n.s. = not significant.

Sobel and Lillith [15] carried out a field survey in which they watched the movements of unaware members of the public in a shopping street. Colleagues would walk toward approaching members of the public without changing their direction, whilst observers noted the distance at which members of the public took collision avoiding action. The average avoidance distance was 1.18 m. Fujiyama et al [14] measured collision avoidance distances between pairs of pedestrians in a laboratory. Test participants were used in pairs, simultaneously walking towards one another, and the distances between the two points at which participants started avoidance manoeuvres were recorded. Mean collision avoidance distances were in the region of 8.0 to 9.0 m for the four lower illuminances (0.67, 2.8, 5.5 and 12.3 lx), reducing to 6.0 m for the higher illuminance (627 lx). Statistical analysis of differences suggests a mixed pattern and may suffer from the small sample size. Again, there are no reported variance data for these results.

Caminada and van Bommel suggested a minimum inter-personal distance of 4 m following the work of Hall. While the experiment reported by Fujiyama et al also suggested minimum comfort distances of 4.0 m to 5.2 m, they used a very small sample size and the results are incompletely reported. Adam and Zukerman suggest a smaller comfort distance (1.2 m at their low light level) but this may be a range bias caused by the small size of their test room. Townshend suggested a longer distance (15 m) than Fujiyama et al. This may be because Townshend was asking about perceived comfort distance whereas Fujiyama et al employed a more objective test procedure. Data from collision avoidance studies also do not provide consistent evidence. It is not possible to propose from the literature a minimum comfort distance at which inter-personal judgements are desirable.

One result that does appear to be consistent is that estimates of comfort distance under dim lighting tend to be longer than estimates of comfort distance found under bright lighting. Furthermore there is a clear effect of methodology, and the greater the amount of perception in the task then the greater the estimated minimum comfort distance.

The aim of this work is to investigate how lighting can be optimised to enhance inter-personal judgements. Before doing so, there is a need to identify what visual features are used to guide such judgements, and at what distances we might desire to make them. This article presents a pilot study carried out to explore inter-personal judgements.

3 Method

A test was carried out to identify what features of target pedestrians at different distances would be mentioned in an open response task. Test participants were asked to describe features of target people, these being presented at different sizes to represent different distances, and the task was carried out without time restriction.

Four target images were used (Figure 2). These were photographs of four different people on a neutral background; they were standing upright and were asked to hold particular objects. One target was female, three were male; all were aged approximately 20 years old; one male was Chinese, the other three were European. Each target person was asked to hold/wear specific items and these are described in Table 2.

Figure 2 The four target images used in trials (Target 1 to 4 from left to right).

Table 2 Specific objects worn or held by the four target people

Target	Number of objects	Objects held in hands	Objects worn
Target 1	5	book in right hand, metal bottle in left hand	scarf, hair ornament, black earphone
Target 2	2	a pair of scissors in right hand	headphone set
Target 3	6	fruit knife in right hand, beer bottle in left hand	headphone, glasses, bracelet on right wrist, watch on left wrist
Target 4	4	tripod held horizontally in both hands	shoulder bag, glasses; watch on left wrist

The aim of the experiment was to determine what features of the targets would be reported at different distances from the test participant. The four distances were 15 m, 35 m, 66 m, and 135 m, The shortest distance, 15 m, was derived from Townshend [9] who suggested that an interpersonal distance of 15 m was required for comfort at night time; according to Maertens' [11] 35 m is the distance at which human faces becomes featureless and 135 m is the maximum distance at which we are able to distinguish gender and body gesture under daylight. The 66 m distance was included to provide an intermediate point between 35 m and 135 m. Using these distances in an experiment would be impractical and therefore the targets were observed at constant distance (3.5 m) with real distance simulated by target size (Figure 3). Each of the four targets was presented at all four distances, thus giving 16 target images, and these were printed on A3 size paper.

The tests were carried out in a laboratory. During trials the laboratory was lit using indirect lighting (6500 K fluorescent), with the luminaire placed behind the test participant and aimed toward the ceiling. The wall surrounding the target images was painted white and this had a mean luminance of 1.0 cd/m^2. The luminance of the neutral surround on each image was approximately 0.5 cd/m^2.

Figure 3 Example of target people at the four different sizes representing four observation distances. At full size these were printed on A3 paper.

4 Procedure

The experiment was carried out by individual test participants, and these were seated facing the target images (Figure 4). Each trial started with 15 minutes for adaptation to the low light level. Test participants observed four images in sequence: each of the four target images was seen at one of the four target distances, and these were presented in a semi-random order, balanced so that each target image was the first to be presented for an equal number of trials. The test participants were instructed to report all the information they were able to provide about the target person on the poster. This was done without a time limit. The experimenter recorded which items were correctly reported. For example, stating (correctly) that the target wore a red jumper would be recorded as a correct response for type and colour of upper clothing, but stating (incorrectly) that the target wore black trousers when they wore yellow trousers would be recorded as a correct response for type of lower clothing but an incorrect response for colour of clothing. A practise image was presented before any trials: this was a photograph of a target person at 15 m, but was a different target to those used in trials. The practice trial was carried out to inform participants of the type of information that was sought and so that they were familiar with the response format.

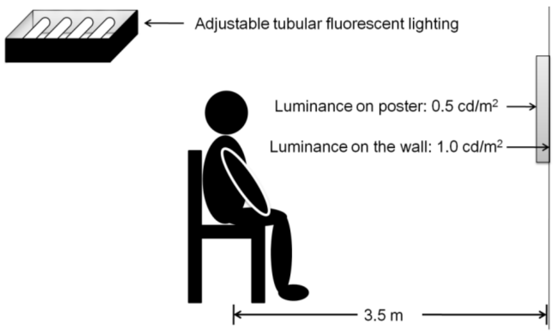

Figure 4 Schematic diagram of test procedure

Twenty test participants carried out the test. These were recruited from staff and students at the University of Sheffield and were paid a small fee for their contribution. Nine were male and 11 were female; they were drawn from European, Middle East and Asian populations; 15 were young (aged 18-34 years old) and five were in the 35-54 age group.

5 Results

Reported features were placed into 14 categories. Table 3 shows the frequency by which each feature was correctly identified during trials, summated across targets for each distance and summated across distances for each target. The data in Table 3 excludes the specific objects identified in Table 2 and which are analysed separately below because these were not consistent between Targets.

Table 3 does not suggest a significant difference between the four target people and the feature frequencies within each Target tend to follow the same trend as with the total frequency. Subsequent analyses therefore do not distinguish between the Targets.

Table 3 shows that the frequency by which features were reported decreased as distance increased. Figure 5 suggests a linear relationship with log distance. At 15 m most features (except for hair colour, facial expression and facial feature) were mentioned correctly in at least 50% of trials. Facial expression was mentioned at 15 m but not at greater distances. At 35 m only half of the features were correctly reported in more than 50% of trials, and at 66 m, only gender, hair length, type of lower clothing and build were correctly reported in more than 50% of trials. At 135 m no features were correctly reported more than 50%.

Table 3. Frequency of correctly reported features summated across targets and test distances

Feature	Frequency at each distance				Frequency for different targets				Total
	15 m	35 m	66 m	135 m	Target 1	Target 2	Target 3	Target 4	
Gender	20	19	19	9	14	18	18	17	67
Hair Length	19	19	16	4	15	13	15	15	58
Type of clothing: lower body	20	16	13	7	13	16	16	11	56
Build	19	16	15	5	15	14	13	13	55
Colour of clothing: lower body	19	15	9	6	9	15	13	12	49
Type of clothing: upper body	20	16	10	1	11	9	16	11	47
Colour of clothing: upper body	16	11	8	3	10	9	16	3	38
Age Group	19	8	5	0	8	9	9	6	32
Shoe Colour	14	8	4	1	8	9	3	7	27
Ethnic Group	11	3	4	0	5	7	5	1	18
Shoe Type	10	3	0	0	2	5	4	2	13
Hair Colour	5	5	2	0	3	6	2	1	12
Facial Expression	9	0	0	0	5	4	0	0	9
Facial Feature	0	0	0	0	0	0	0	0	0
Total	201	139	105	36	118	134	130	99	481

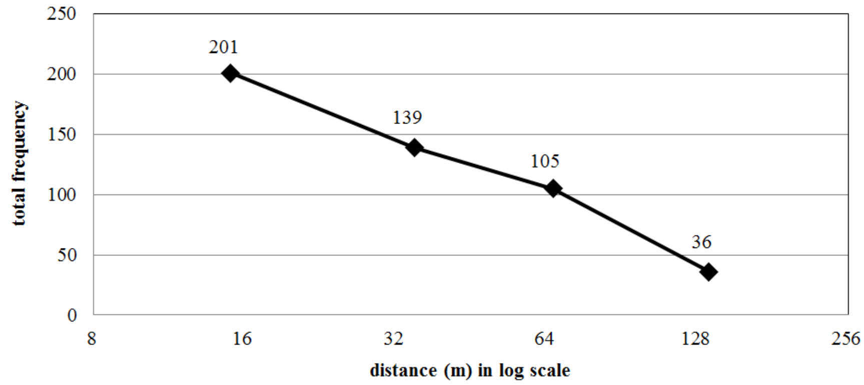

Figure 5. Frequency of correctly mentioned features at different distances, summated across the four Targets.

Figure 6 shows the relationship between distance (log units) and frequencies by which individual features were mentioned, and these have been grouped according to the apparent trend. For three features (gender, hair length, and build) correct responses were gained at an approximately consistent level of between 75% and 100% for the nearer three distances. It was only at the longest distance, 135 m, that a large reduction was found. For six features (type and colour of clothing on upper and lower body, age group, and shoe colour) there is an approximate linear relationship between log distance and frequency of correct mention, and for all six items there is a high frequency of correct identification at the nearest distance. For three features (ethnic group, show type, and facial expression) correct mention at the nearest distance is only approximately 50%, and subsequently decreases to less than 25%. For the final two features (hair colour and facial feature) there was a poor frequency of correct mention at all distances.

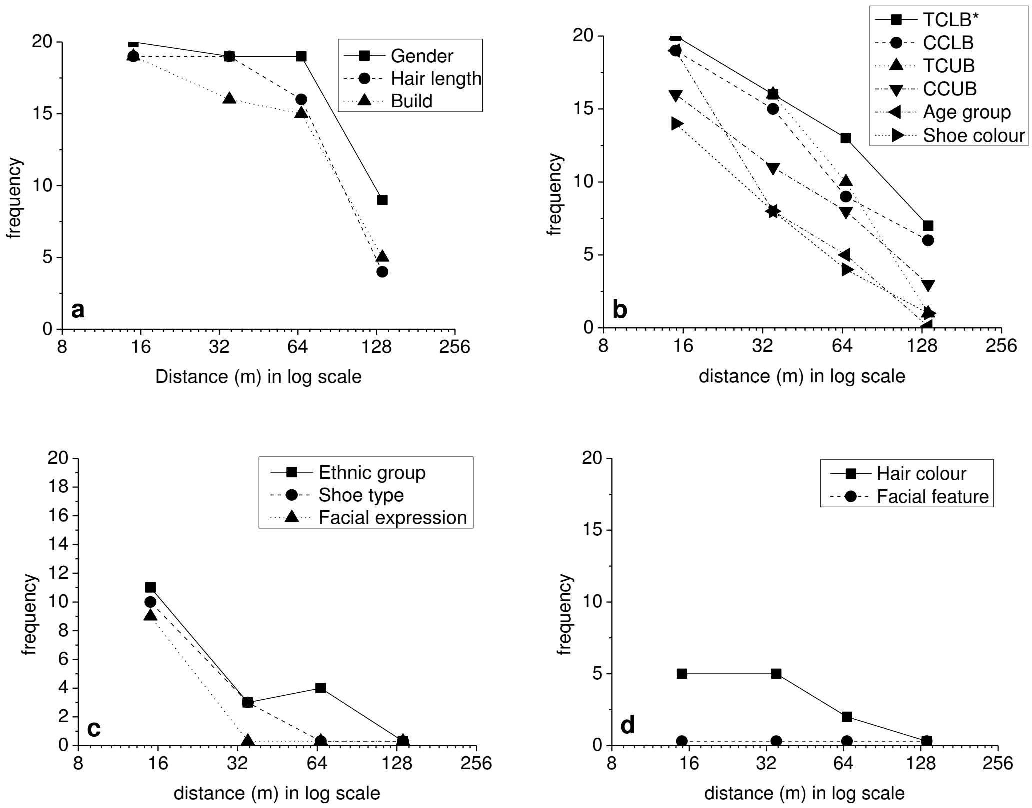

Figure 6 Four groups of frequencies of individual features at different distances. (Note in 6b: *TCLB = type of clothing: lower body; CCLB = colour of clothing: lower body; TCUB = type of clothing: upper body; CCUB = colour of clothing: upper body)

6 Individual Objects

The results of the target-specific objects are presented in Table 4. The numbers and types of objects worn and held by the four target people were not identical and are thus incomparable with other features. To enable comparison between Targets these are reported in Table 4 as the mean percentage of the total objects associated with each Target. Thus the score of 56% for Target 1 at 15 m indicates that each test participant mentioned approximately 2.5 of the five objects that were held or worn.

Table 4 Percentage of correctly reported specific objects

Target person	**1**	**2**	**3**	**4**	**Average**
Number of objects held/worn	5	3	6	4	
Number of trials per distance	5	5	5	5	
Distance	**Percentage of correctly identified individual objects, %**				
15 m	56	27	30	50	41
35 m	20	0	7	20	12
66 m	0	7	0	5	2
135 m	4	0	0	0	1
Average	20	9	9	19	

Table 4 shows that the objects were rarely reported at distances beyond 15 m. The relationship with distance follows a similar trend to that of ethnic group, show type and facial expression (Figure 6c) as is shown in Figure 7. Target 3 held a knife, an object which would likely be interpreted as threatening. Target 3 was seen by five test participants at each test distance, of whom only one participant reported the knife at 15 m and 35 m and no participants reported the knife at 66 m or 135 m.

Boyce and Bruno [16] carried out an object identification task in which their 15 test participants were asked to identify the object held by an experimenter walking back and forth at a distance of approximately 10.5 m. This was repeated using five different objects, chosen at random from a set of ten.

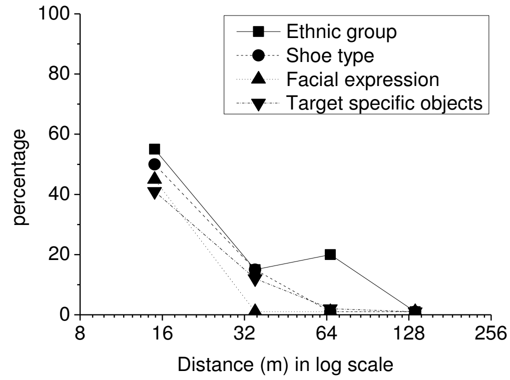

Figure 7. Percentage of correct identification of the target-specific objects at different distances presents a similar trend to that found for ethnic group, shoe type and facial expression.

At the lower light levels (2-5 lx) Boyce and Bruno found mean correct identification of approximately two of the five objects (40%), increasing to approximately 3 (60%) at the higher illuminances (22-50 lx). It is interesting that the identification rate (40%) reported by Boyce and Bruno at their low illuminance is similar to the average across targets found in the current study (41%) at a similar distance (15 m).

7 Conclusion

This study was carried out to explore how inter-personal distance affects visual information for pedestrians when making inter-personal judgement under low light levels. This was done because the literature does not offer any conclusive evidence as to the distance at which such decision is desirable, and these data would be of use in determining where lighting may be of benefit.

A test was carried out to question the inter-personal features that are observed. The 14 types of features were categorised according to the relationship between frequency and distance, in particular whether a linear or non-linear relationship. These data are limited, being an open response task with only 20 observers, but provide some clue as to what features of other pedestrians might be important (those mentioned with high frequency at near distance) and whether these features are distinguishable at different distances.

8. Further Work: Consistency

An aim of this project is to determine how lighting affects the judgements we make of the intent of other people, i.e. whether or not they are considered to be threatening, and the distances at which these judgements can be made. A fair trial requires that such judgements are consistent: if a person is considered to present a threat, they should still do so when that judgment is made at a different occasion under the same visual conditions. It has been suggested that facial expression and body posture may contribute to judgements of intent. Therefore further work is being carried out to determine whether judgements of intent based on facial expression and body posture are repeatable.

Figure 8 shows a sample of the faces used in trials, and these were drawn from the FACES database [17] at the Max Planck Institute for Human Development. FACES is a set of images of naturalistic faces of 171 younger, middle-aged and older women and men displaying each of six facial expressions: neutrality, sadness, disgust, fear, anger, and happiness.

Figure 8. Sample of facial expressions from the FACES database [17]. Pilot studies suggest the left-hand image to be threatening and the right-hand image not to be threatening.

Figure 9 shows body postures from the Bodily Expressive Action Stimulus Test (BEAST) [18], a validated set of whole body expressions termed bodily expressive action. The database comprises 254 whole body expressions from 46 actors expressing four emotions - anger, fear, happiness, and sadness.

In pilot studies we asked test participants (n=24) simply to state which people are considered to present a threat. There are 12 target people in each set with six facial expressions and four body postures. To avoid familiarity, each participant is presented with 12 faces and 12 bodies, this being one expression or posture per target. The aim is to identify which targets are consistently found to be threatening or non-threatening, both within and between subjects. If consistent judgements are found these targets will be used in further studies exploring the effects of lighting.

Figure 9. Sample of body postures from the BEAST database [18]. Pilot studies suggest the left-hand image to be threatening and the right-hand image not to be threatening.

Acknowledgement

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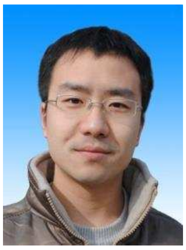

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