**PEDESTRIAN BEHAVIOUR AT UNCONTROLLED CROSSINGS**

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**Abstract**

This investigation focuses on uncontrolled crossing locations such as where pedestrian routes cross a carriageway, and near institutional and commercial complexes, bus stops and uncontrolled junctions. It is intended to be of assistance in the analysis and geometric design of roads, pedestrian crossings, and operational features. The principles described may also apply to controlled crossings and pedestrian facilities in general.

The concept embodies the measuring and recording of ‘minimum required’ values of observation-reaction time when the pedestrian is not pressured into possibly hurried or incomplete observations due to the presence of vehicular traffic, but who otherwise completes the observations as quickly as possible. This differs from concepts of pedestrian ‘delay’ and ‘gap acceptance’ times measured under actual site conditions which may reflect hurried decisions, and the absence in sampling of pedestrians who may be deterred from crossing due to traffic or infrastructure-related concerns. Pedestrians who need to exercise more than ordinary caution when crossing include children, disabled or encumbered pedestrians, and those who exercise caution in their normal movements when crossing.

The concept includes consideration of pedestrians’ saccadic head movements, focussing, and a reaction time up to the point of starting to walk across the carriageway. The Green Cross Code is adopted as a commonly understood, repeatable, sequence of actions used to determine a minimum yet complete observation process.

The study indicates that the 85th percentile total time to fully but expeditiously observe the Green Cross Code for a two-way carriageway can take up to nearly 4 seconds for a mature adult with no disability. Implications for sightline locations and distances, intervisibility, and other categories of pedestrian are addressed briefly, together with suggestions for further investigations, such as expanding pedestrian categories, and different crossing locations and conditions.

**1. Introduction and Background**

Information about the time taken for pedestrian observation-reaction and related movements before crossing a carriageway, as well as pedestrian walking speeds, is essential in considering the safety and effectiveness of pedestrian crossings. This study, therefore, examines the actions of pedestrians preparing to cross carriageways at uncontrolled locations in urban areas, and develops initial indicative values of the actions and times involved. The impetus for the study stems from the goal of attaining safe, integrated road design which encourages walking and which embodies pedestrian performance characteristics as well as those of drivers, vehicles and the affected infrastructure. The major objectives of this part of a continuing investigation are to:

* Define the actions of pedestrians preparing to cross a carriageway;
* Conceptualise and identify the actions of pedestrians employing recognized instructions for a sequence of actions when preparing to cross a carriageway;
* Select a common, measurable procedure for describing a safe observation-reaction procedure; and,
* Determine initial, indicative, values of the observation-reaction times for a ‘baseline’ condition, which can provided a background for studies under specific conditions.

The results indicate that significant periods of time are required by pedestrians in preparing to cross a carriageway This study of the observation-reaction times of four adults with typical physical and mental abilities is intended to illustrate the key characteristics of these times, their various elements and features of the measurement process. The study establishes the main features of tasks and presents values which can provide guidance for more comprehensive work and for specific locations and usage characteristics.

**2. Motor Vehicle Drivers’ Perception-reaction Times: An Overview**

Comparisons Between Drivers’ and Pedestrians’ Tasks -- A brief review of some of the key points of drivers’ perceptions and reactions provides a background on, and introduces a working terminology for, related pedestrian characteristics. Many similarities exist in the basic mental processing and physical reactions of drivers and pedestrians. Also, considerable literature exists about drivers’ perception-reaction times (for example, ASSHTO 1994, Wright 1996).

In this paper the term ‘observation-reaction’ time, coined in earlier work (Schoon 2003) is applied to pedestrians instead of ‘perception-reaction’ time as applied to drivers. This is because the use of the term ‘perception’ is taken to apply to the process of identifying some phenomena which might suddenly appear to a driver during the driving task, requiring recognition and a reaction to accommodate it before a collision occurred. Such a phenomena could be any event such as a child suddenly running into the road to a large piece of paper blown in front of the vehicle on a night of poor visibility. The more varied and unpredictable nature of these events usually will require considerable perceptive effort and time on the part of the driver to identify the event as a basis for the next step in the avoidance process. For a pedestrian about to cross a carriageway, however, it can be argued that there will be greater predictability. This is because the pedestrian will be expecting a motor vehicle to appear and his or her reaction will be to walk or not walk – to either of which the pedestrian will be more accustomed and, in many cases, ‘perception’ time may be different to that experienced by drivers.

A driver’s perception-reaction time is defined as the time taken for a driver in a moving vehicle to first see an object or situation and then, through a mental and physical process which requires a finite amount of time, to react and take physical avoiding action – or not take such action (Olson 1989). A summary description of the major sequential features of drivers’ perception-reaction times on this basis is as follows:

1. Detection. Perception - response time begins when some object or condition of concern enters the driver's field of vision. The first step concludes when the driver develops conscious awareness that ‘something’ is present.
2. Identification. In this step sufficient information is acquired about the subject or conditions to be able to reach a decision as to what action, if any, is required. Identification need not be complete in detail.
3. Decision. At this point the operator must decide what action is appropriate. Assuming some action is decided upon, the choice comes down to change in speed and/or direction, or not to change.
4. Response. In this step commands are issued by the motor centre of the brain to the appropriate muscle groups to carry out the required action.

Perception-response time typically ends when the driver begins to turn the steering wheel or activate the brake pedal. Certain situations, such as inadequate visibility and poor road surfaces may require more complex manoeuvres and take longer to complete.

Within the above times it has been found that a driver requires time to shift the direction of vision and also to focus on the particular object or situation. Values for vision shift/focus time in a driving context, (Greenshields 1936) are a “vision shift” time of 0.15 s to 0.33 s and a “fixation” (focus) time of 0.1 s to 0.3 s.

Perception-reaction times are employed in geometric design of highways as a key element in estimating the total stopping distance, and for start-up times prior to crossing or joining traffic at an intersections. The stopping distance is used to guide the analysis required for design of speed controls, horizontal curve radii, and vertical curve length, as well as providing a basis for design under other, specific, conditions. Selected values associated with the perception reaction times described in official guidelines are:

* UK design practice (Ashcroft 1966, Salter and Hounsell 1996)

Perception-reaction time for geometric design: 2.0 s

* USA design policy (AASHTO 2000)

Perception-reaction time (alerted driver) Mean value 0.64 s

Perception-reaction time (non-alerted driver): Mean value 1.64 s

Perception-reaction time (non-alerted driver): Maximum value 3.5+ s

Perception-reaction time for geometric design purposes: 2.5 s

Start-up time crossing a major road -- geometric design: 2 s

**3. Pedestrians’ Crossing Behaviour Under Vehicular Traffic Conditions**

Head Movement and Delay -- Observations and analyses of adult and child pedestrians crossing carriageways have been made under varying traffic conditions in a number of studies. For example, at four uncontrolled crossing sites the number and percentage of head movements at various stages of the approach and crossing were made, together with observations of the related delays, method of crossing, and compliance with Green Cross Code actions (Grayson 1975). Conclusions and comments related to these results are as follows:

* Head movements: The range of 1.18 to 2.88 head movements for the children did not reach the three head movements which would be expected from the Green Cross Code (Driving Standards Agency, 1999) procedure. However, many of the pedestrians had made head movements as they approached the location on the kerb from which they crossed. Although in most locations the children made more head movements than the adults, for the heavy traffic situation at one of the sampled locations the adults were recorded as making 3.05 head movements, compared with the childrens’ 2.64.
* Delay time: Delay times for the children ranging from 3.7 s to 7.8 s appear to be considerably greater than those for the adults, again with the exception of the heavy traffic situation, where the delay time for adults was 9.5 s compared to the childrens’ 7.8 s.
* Green Cross Code compliance: Between 19% and 73% stopped at the kerb, and between 5% and 56% looked both ways. Yet only between 0% and 5% observed the Code in its entirety.

In another study, for different types of crossings predictive equations were developed which linked vehicle volumes to pedestrian delays (Goldschmidt 1977). It showed that using certain equations, for a volume of 500 vehicles per hour at random kerbside points the mean pedestrian delay was 2.4 s and the proportion of pedestrians delayed was approximately 40%.

Regarding age-related differences in crossing behaviour, these were examined at three roads in busy shopping areas (Wilson and Grayson 1980). The road segments comprised segments 50-100 m in length, no controlled pedestrian crossings in the vicinity, shops on both sides of the road and free-flowing traffic in the range of 600-1200 vehicles per hour. For a combination of male and female pedestrians, including those alone and accompanied, the results showed the following results:

* Mean delay at kerb varied between 1.6 s and 3.0 s;
* Mean number of head movements before crossing varied between 2.4 and 3;and,
* Mean number of head movements during crossing varied between 3.2 and 3.9.

In all cases the lower value of the above ranges applied to unaccompanied males and the higher values applied to accompanied females. The study also recorded pedestrian walking speeds for single pedestrians crossing directly without delay in the road varied from 1.10 m/s for 60+ year old females to 1.37 m/s for unaccompanied males aged 15 – 19.

The values determined in the above studies were for pedestrians’ delay times under various actual traffic and locational characteristics. From the nature of the studies the values include those for pedestrians who may adopt unsafe (perhaps due to feeling pressured in crossing to avoid excessive delay) as well as safe crossing procedures, and exclude potential pedestrians such as those with a disability or encumbrance who may be deterred by the traffic and physical conditions at the crossing. The findings provide a background to the minimum observation-reaction times which pedestrians require when following recommended Green Cross Code procedures before crossing a carriageway, and which are the subject of the remainder of this paper.

**4. Pedestrians’ Observation- Reaction Times**

Observation-Reaction Time Element in Crossing -- As with drivers’ perception-reaction times, and as illustrated by the pedestrian crossing studies described above, pedestrians when preparing for crossing a carriageway also require a specific amount of time to observe and react to traffic conditions and to take appropriate action – i.e. to start to walk across the carriageway or not. This section addresses the matter of what could be called the notions of ‘time required’ vs the ‘time accepted’.

The exact nature of pedestrians’ and drivers’ perceptive and cognitive processes is complex and beyond the scope of this paper. A ‘comfort time’ of 3 s is suggested as a base setting for pedestrians at signal controlled crossings in the UK (Department for Transport 2005). A pedestrian ‘start-up’ time of 3 s for design purposes is documented in the Highway Capacity Manual (Transportation Research Board 2000) based on extensive studies (Knoblauch et al. 1996) for pedestrians at signalised pedestrian crossings. Other studies found that males at signalised intersections required up to 2.77 s for the perception-reaction time before crossing (Fugger et al. 2001). However, the conditions for observations at signalised locations are somewhat different than for uncontrolled crossings. Regarding gap acceptance at unsignalised locations an assumed time of 2.0 s to allow pedestrians to perceive and react to gaps in vehicle flow before crossing is mentioned (Hunt and Abduljabar 1993). In a pilot study the 85th percentile total observation-reaction times of 3.54 s and 5.12 s for a mature male and a mature female subject, respectively, were recorded (Schoon 2001) and in further studies of pedestrians in wheelchairs, the corresponding 85th percentile times were 4.2 s and 6 s – the difference appearing to be due to the additional time required for the wheelchair users to cross the footway before entering the carriageway (Schoon and Hounsell 2005, 2006).

Pedestrians’ Observational Tasks -- Some important characteristics of a pedestrian’s observations may be summarised as follows:

* The observation angles of up to 180 degrees along a straight road or nearly 270 degrees at a junction that a pedestrian must make require a considerable time to scan. By comparison, the typical driver’s scanning angle is up to approximately 48 degrees (Mourant and Rockwell 1972).
* During the observation stage the angular distance will require extensive head and some shoulder movement -- a movement which some pedestrians, particularly those with physical disabilities, those encumbered, and particularly those in wheelchairs, may find difficult or, in more extreme cases, impossible.
* In most cases, a pedestrian must be aware of the possibility of vehicles approaching from at least two opposite directions simultaneously. Because a pedestrian can only focus in one direction at a time, he or she has a significant ‘blind area’ for some time during the crossing process, even if visually scanning to each side during the crossing process.
* Additional time will be required for pedestrians with pushchairs, people in wheelchairs and others who cannot locate themselves, and therefore their viewpoint, just behind the kerb on the footway. In these cases effective reaction time must include moving their body position some distance across the footway to the kerb, while their pushchair or forward part of the wheelchair precedes their body position into the carriageway.

The above points imply that, compared with drivers, the observational tasks of pedestrians have greater complexity of body movement than drivers in turning the head (and usually the torso) and focussing several times during the total observational procedure. In addition, pedestrians with helpers or those accompanied with small children often require considerably more time than others.

The four stage observation-reaction process for pedestrians (similar to a driver’s detection, identification, decision and response) culminates in the pedestrian’s start of the first step into the carriageway. If as a result of the initial observational procedure a vehicle is approaching which does not permit an acceptable gap to enable the pedestrian to cross, the pedestrian must repeat the entire detection-identification-decision-response process before physically starting to walk.

Analysis of Pedestrian Crossing Actions -- As a guide for examining the necessary pedestrian actions when about to cross a road it is useful to refer to the Green Cross Code as a means of identifying the specific actions recommended for pedestrians, for example the instructions “Children learn by example, so parents and carers should always use the code in full when out with their children” (Driving Standards Agency 1999). Establishment of such a procedure also enables a common set of actions to be identified which can be repeated in further investigations. The code enables the actions to be broken down into finite parts so that the time taken to conduct each one can be identified and analysed. Furthermore, it provides a common basis for a procedure for a pedestrian to begin a safe crossing of a carriageway, even though, under heavy vehicular traffic conditions, the opportunities to cross may be limited.

This approach using a specified set of actions such as those in the Green Cross Code is adopted here in contrast to the values related to pedestrians’ gap acceptance – as typified in the studies mentioned earlier. This distinction enables initial attempts at defining a ‘minimum required’ observation-reaction time to be made. Excerpts from the Green Cross Code describing this procedure are listed below, with the original section reference numbers included, as follows:

**Section 7. The Green Cross Code.** The advice given below on crossing the road is for all pedestrians.

1. **First find a safe place to cross**….. where there is a crossing nearby, use it. ……Move to a space where drivers can see you clearly.
2. **Stop just before you get to the kerb**, where you can see if anything is coming.... Keep back from the edge of the road but make sure you can still see approaching traffic. ***Note: See also the comments below about pedestrians with pushchairs and in wheelchairs.***
3. **Look all around and listen.** Traffic could come from any direction. Listen as well, because you can sometimes hear traffic before you see it***. Note: This action was formerly known as the ‘Kerb Drill’ and consisted of instructions to “look right, look left, look right again, and if clear begin to cross” – thereby providing a specific number of actions to be undertaken. These actions are used here in order to provide an identifiable, broadly acceptable, repeatable procedure which may be followed (in possibly modified form) in future investigations for comparison and data recording purposes.***
4. **If traffic is coming, let it pass.** Look all around again and listen. Do not cross until there is a safe gap in the traffic and you are certain that there is plenty of time.
5. **When it is safe, go straight across the road -- do not run.** Keep looking and listen for traffic while you cross, in case there is any traffic you did not see, or in case traffic appears suddenly.

**Section 8, at a junction**. When crossing the road look out for traffic turning into the road, especially from behind you.

In the above procedure items (a) and (b) are considered here to precede the start of the observational process, while item (c) incorporates the observation-reaction element during the process of looking (detection, identification, and decision) immediately before the response, or reaction (d), i.e. action taken or not taken to start to cross.

A key element is the phrase in Subsection (e), which states ‘…When it is safe….’’. It is assumed here that this means that a collision with a vehicle will not occur or that a vehicle will not come close enough to cause the pedestrian undue concern or intimidation.

The Code’s actions may be compressed by some pedestrians because they do not stop for each action but may conduct them while walking or even while beginning to cross. This, however, is probably difficult or time consuming for anyone with an encumbrance, a helper or a person with some impediment. Even for a perfectly able pedestrian, this action could lead to an erroneous assessment of approaching vehicles’ speeds – especially if lighting conditions are inadequate. However, in the absence of other recognised and generally accepted pedestrian codes, and in order to clearly specify and delineate the steps involved, the Green Gross Code procedure was adopted for use here. This decision was made also recognising that the Code may have some deficiencies in its content and structure – beyond the scope of this paper to address).

Observation-Reaction Time -- Immediately following the end of a typical Item (e), above, to ‘look all around and listen’ i.e., ‘look right, look left, look right again’), the final elements of the pedestrian’s observation-reaction process, *and associated time to undertake it*, take place, i.e:

Detection, identification and decision:

* decide to walk, after estimating that any approaching vehicle can be avoided by a safe margin if it does not slow down;
* look back to the ahead position; and,
* focus.

Response:

* react by starting to cross the carriageway by initiating a leaning forward movement of the body in order to take the first step. For someone pushing a pushchair, or in a wheelchair, the first action is to initiate a forward movement to cross part of the footway if the starting point is at the top of a ramp.

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**5. Definitions and Sequence of Pedestrian Actions – ‘Minimum Required’ Time Case**

The sequence of minimum required pedestrian actions described here, as an example, refers to a pedestrian crossing an essentially straight road with no vehicular traffic. For this case, intended to provide an initial exploration of the subject only, the total angle of observation is approximately 180 degrees in a predominantly horizontal arc (i.e. 90 degrees each side of a ‘look ahead’ position directly across the road). The case of a pedestrian crossing at a junction or more complex locations will be similar in principle but the head movements may include much larger angles. In order to identify and describe the variables and components of the observation-reaction times, some new terms are introduced below.

Observation-Reaction Times: Three Concepts -- Three forms of observation-reaction time (the directions of looking based upon UK’s drive-on-left rule) may be identified as:

* **Total observation-reaction time (TOR)**. The total time, when standing at the kerb, from beginning to look to the right (right saccade) then looking left and right again, then looking ahead across the carriageway and finally reacting by starting to step from the kerb onto the carriageway;
* **Penultimate observation-reaction time (POR)**. The ending point of the last look left is the latest time when the pedestrian is able to focus on a vehicle approaching from the left. The speed and extent of this loss of focus will depend upon the speed of the individual’s head turning movement ( left saccade) and upon the extent of the pedestrian’s peripheral vision and mental processing abilities. From there to the ‘start to walk’ point including the last look right (second right saccade), and then across the carriageway, is what is here called the ‘penultimate observation-reaction’ (POR) time; and,
* **Last observation reaction time (LOR)**. Starting at the end of the last look to the right 9second saccade) and then through the look ahead across the road in the direction of walking to the ‘start’ to cross point is what is here called the last perception-reaction (LOR) time. The final observation and reaction process and time should involve observation of the vehicle closest to the pedestrian which therefore would be the first to be involved in a potential collision. Under right-hand drive rules of the road this would mean vehicles approaching from a pedestrian’s right. For left-hand drive rules the process would be similar but the initial look would be to the pedestrian’s left.

The TOR, POR and the LOR times for a pedestrian crossing a straight two-way carriageway and looking first to the right (right saccade) can be shown conceptually in a time – observational angle relationship in Figure 1. This shows the pedestrian’s angle of head and eye movement from the ‘ahead’ position, with saccades to left and back, related to the time taken for the movements during the observations. In this diagram, the focussing time at the end of each head movement is shown as a horizontal line – i.e. there is no head movement during these times. The time periods for the POR and the LOR times are also labelled.Relationships between the saccade and fixation are described in the context of drivers’ perception of hazards (Velichkovsky et al. 2003). During the observation stage a pedestrian’s angular movement will require extensive head and some shoulder movement and may for some pedestrians, be difficult or impossible - especially for people in wheelchairs or encumbered.

9

Start to walk

0

Stand at kerb

8

Focus ahead

6

Focus right

5

Look right

4

Focus left

3

Look

left

1 Look right

2

Focus right

7

Look ahead

Look

right

Time

Time

Look

 left

**Last o-r time (LOR)**

**No further focus on vehicles approaching from right or left**

**Penultimate o-r time (POR). No further focus on vehicles approaching from the left or right**

Initial observations to right and left

**Total observation-reaction time (TOR)**

Summary of Pedestrians’ actions when following the Green Cross Code in preparing to cross a two-way carriageway.

The diagram above illustrates the following (numbered items correspond with those in the pictograph) sequence of actions from the initial standing at the kerb:

1. First look to the right (right saccade), approximately 90 degrees;
2. Focus to the right (starts at completion of look to the right);
3. First look to the left (left saccade) approximately 180 degrees (starts at completion of focusing right).
4. Focus to the left (starts at completion of look to the left);
5. Second look to the right (right saccade), approximately 180 degrees (starts at completion of focus to the left). From the start of this action the pedestrian is ‘blind’ to vehicles approaching from the left;
6. Focus to the right (starts at completion of second look to the right);
7. Look to the ‘ahead’ position (left saccade), i.e., looking straight across the carriageway. From the start of this action the pedestrian is ‘blind’ to vehicles approaching from the left and the right;
8. Focus to the ‘ahead’ position (starts at completion of looking ahead); and,
9. Start to walk ahead (directly across the carriageway) -- (starts at completion of focusing ahead and represents the reaction stage of the process.

Basis for Sequence of Actions

The sequence of actions is based upon the requirements of the Green Cross Code (formerly the ‘kerb drill’) to stand at the kerb, look right, look left, look right again. If nothing is coming walk straight across the road’.

**Figure 1 Pedestrian head movement and observation-reaction time scale: concept diagram**

For pedestrians with a pushchair or in or a wheelchair, although the concepts will be similar, the analysis must include the fact that the pedestrian’s viewpoint will be back from the kerb, thus altering the locations of sightlines, and also requiring a greater distance to walk across the footway in order to start crossing the carriageway. For some disabled people, the time taken for angular head movements may be greater and more difficult, thus requiring more time. Various other kinds of assistance devices such as frames, canes, and presence of a helper will also require consideration.

The dashed lines in Figure 1 indicate the possible action of most pedestrians in that when turning to look in a certain direction they start to focus on approaching vehicles during the head movement and complete the focussing, observation, etc. while the head is stationary. If no vehicle is approaching from the direction of looking, the head is then immediately turned (in the minimum time case) in the opposite direction. The exact points at which the focussing begins and ends must be a matter for future investigation, and are beyond the scope of this work. Therefore, it is assumed that the combination of head and eye movements in the directions of approaching vehicles amounts to a total of approximately 90 degrees from the look ahead position. It is assumed that the head movement is being initiated as a result of the observation-reaction process of the preceding observation direction. This implies that the pedestrian’s attention is now aimed at a possible vehicle approaching from the new direction – i.e., that the pedestrian no longer is focussing on and fully aware of a vehicle approaching from the preceding direction.

The relationship of the pedestrian’s observation time to the actions of walking across a carriageway, plus a safety margin, are shown conceptually in Figure 2. The total time for a pedestrian to cross is therefore the sum of each of these elements. The relationship of the por and lor to the total process is also shown.

Observation-reaction Walking Safety margin

 ( See Fig. 1)

Look right

Time

LOR

Look left

POR

TOR

**Figure 2 Time space diagram showing relationship between approaching vehicle and pedestrian’s crossing activities**

Application of Observation-Reaction Times – In most cases the pedestrian’s observational direction of the por and lor times will depend upon the initial direction in which the pedestrian looks. This is typically to the right in the UK, because this is the direction of the most immediate threat from approaching vehicles, and to the left in countries with right hand drive. However, for safety it would be prudent assume that the POR and the LOR times could apply to the left or the right of a pedestrian’s position, although the POR will always be the longer of the two. Also these times, would ideally be added to the associated walking and safety margin times, and equated to vehicle approach times when estimating available sight distances to the left and right of the pedestrian’s crossing location. As will be seen later from the pilot study, a por time of 3 s would not be unusual and, in this time a vehicle traveling at 45 kph would travel a distance of about 40 m if the driver failed to take avoiding action. From a pedestrian’s point of view, then, the following assumptions are appropriate:

* For a two-way road, the POR and LOR times are applicable in each relevant direction; and,
* For a one-way road, or the case where a pedestrians’ refuge island is installed, the lor is theoretically applicable because vehicles should only approach from one direction, and this would be the lor time. However, it is advisable to check the physical and operational features of the crossing location carefully to ensure that a pedestrian does not become vulnerable because of some unpredictable vehicle movement.

It should be noted that, in Figure 2, no indication is shown of the pedestrian’s head movement during the walking portion of the total crossing activity. Although such movement is considered important from a safety point of view the focus here is on the actions up to the point of a pedestrian’s ‘start to cross’, as might be considered in a crossing design procedure. Full consideration of the nature, extent, and circumstances of the pedestrian’s avoidance actions after leaving the kerb is important and can be complex, and is beyond the scope of this investigation.

**6. Estimating Values of Pedestrians’ Observation-Reaction Times**

Applicable Variables -- Before describing the values of pedestrians’ observation-reaction times it is useful to outline the nature of variables. This also assists in setting the extent and nature of the times into context. The values can be related to:

1. Basic behavioural characteristics, typical of non-disabled and non-encumbered pedestrians divided into groups which could include:
* Pre-school children;
* Primary-school children;
* Secondary school children;
* Young adults;
* Mature adults;
* ‘Mature’ elderly; and,
* ‘Older’ elderly.
1. Forms of disability or encumbrance:
* Encumbered pedestrians (shopping bags, prams, young children etc.);
* Disabled ( inability to observe or walk normally);
* Accompanied disabled (pedestrians requiring a helper to accompany them);
* Wheelchair-bound pedestrians; and
* Combinations of the above.
1. Traffic conditions, in terms of volumes, speeds and composition of vehicular traffic.
2. Locations at which the pedestrian is crossing, related to the location’s physical and operational features such as those for straight roads, uncontrolled junctions, refuges islands, kerb radii etc.

5. Environmental conditions – lighting, noise, or other distractions.

Summary of Study -- As a preliminary investigation the pilot study addressed two cases in order to obtain a sense of the order of magnitude of the pedestrian movements and observation-reaction times. Of the above categories, the study selected the following baseline conditions:

* Pedestrian Categories – Mature male and female adult subjects with no known physical or mental impairments or encumbrances;
* Traffic conditions – No traffic, but the possibility of some traffic occurring – in order to establish a basic value for the pedestrian categories used. In this case, a minimum value would obtain because the head turning actions and values would be essentially similar. Also, the delay following focussing would occupy the least amount of time for this task because, since no vehicles were approaching, the next head movement could follow with a minimum of delay;
* Location – At the kerb edge of a straight portion of a two-lane, two-way carriageway, approximately 7 m wide.
* Manner of observation – Green Cross Code procedure described earlier. Pedestrian stands at kerb preparing to cross; and,
* Environmental conditions – Adequate lighting, and no excessive noise or other distractions.

Observation Method – Video observation was made of each pedestrian repeating the Green Cross Code mentioned earlier. Headgear consisting of a cycle helmet adapted to show target markings was used to identify the head movements. The video image included the entire height of each subject in order to link the head movements with the initial start of the step into the carriageway. The four subjects were identified as Male 1 and Male 2, and Female 1 and Female 2.

Analysis of Data – The video images were transferred to a television screen via a time recording and display device providing digital readouts. Head movements were identified and the elapsed times for each of the nine actions, above, noted. Computer spreadsheet analysis and statistical and graphical portrayal of the results then followed. The sample sizes for the subject were 30 observations for each of the two male subjects and 20 and 15 for female subjects 1 and 2 respectively. The statistical analysis was conducted with the intent of deriving indicative information in the knowledge that more detailed studies would be appropriate for establishing greater statistical detail and tests.

**7. Results**

Summary -- The individual and elapsed times for each of the nine elements of the total observation –reaction time for each of the subjects are summarized in Figure 3 to show the average, median, 85th percentile and also the standard deviation and values of the TOR, POR and LOR times. From this it can be seen that the range of average times for the major head movements and focusing for the four subjects were as follows:

* Range of an average head saccade 90 degrees was between 0.29 s and 0.45 s;
* Range of an average head saccade180 degrees was between 0.34 s and 0.67 s;
* Range of average focus times to either left or right was between 0.19 s and 0.36 s;
* Range of final focus ahead time before walking was between 0.16 and 0.32 s;
* Range of average TOR times was was between 1.02 s and 3.15 s;
* Range of average POR times was was between 2.42 s and 1.60 s; and,
* Range of average LOR times was between 2.42 s and 3.15 s.

In examining 85th percentile values, Figure 4 shows firstly the results of the observations for the two extreme subjects, Male 1 and Male 2, and then highlights the TOR, POR and LOR values for each of the four subjects. The range of values for the two female subjects lies within the envelope of these

values. The maximum values, exhibited by Male 1, showed that total observation-reaction of nearly 4 s. Within that period, the 85th percentile LOR time related to vehicles approaching from the pedestrian’s right means that this subject would be blind to his right for 1 s plus the time taken for walking some distance into the carriageway while simultaneously looking to the left when beginning to cross. If the sum of the LOR time and the walking time to a point in the carriageway time were approximately 3 s an approaching vehicle moving at 48 Km/h (30 mph) would travel approximately 27 m. Thus if the pedestrian’s visibility distance to the vehicle were less than this distance due, say, to some obstruction, this could result in an undesirable level of danger of collision if the driver had been inattentive -- even if the pedestrian had fully observed the Green Cross Code. Circumstance compounding this situation could include a pedestrian having less than adequate ability to turn his or

her head, or a pedestrian crossing with small children. Similarly, the 85th percentile POR time of nearly 2 s means that the the pedestrian would be essentially unable to see vehicles approaching from his left before walking into the carriageway for this period of time, and the same principles but with the relevant values would apply in terms of pedestrian/vehicle collisions.

**Last o-r time (LOR)**

**No further focus on vehicles approaching from right or left**

Initial observations to right and left

**Total observation-reaction time (TOR) time**

**Penultimate o-r time (POR). No further focus on vehicles approaching from the left or right**

8

Focus ahead

2

Focus right

1 Look right

7

Look ahead

3

Look

left

4

Focus left

5

Look right

6

Focus right

9

Start to walk

Look

 left

Time

Look

right

Time

0

Stand at kerb

**Male subject 1**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  | tor | por | lor |
| Average | 0.45 | 0.23 | 0.62 | 0.24 | 0.67 | 0.21 | 0.41 | 0.32 | 3.15 | 1.60 | 0.73 |
| Median | 0.46 | 0.21 | 0.62 | 0.24 | 0.68 | 0.20 | 0.38 | 0.33 | 3.11 | 1.59 | 0.71 |
| 85th%ile | 0.50 | 0.35 | 0.71 | 0.33 | 0.74 | 0.25 | 0.52 | 0.42 | 3.81 | 1.93 | 0.94 |
| Std. Dev | 0.06 | 0.10 | 0.09 | 0.08 | 0.07 | 0.07 | 0.08 | 0.09 | 0.64 | 0.32 | 0.18 |

**Male subject 2**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  | tor | por | lor |
| Average | 0.36 | 0.35 | 0.36 | 0.33 | 0.34 | 0.24 | 0.29 | 0.16 | 2.42 | 1.02 | 0.44 |
| Median | 0.38 | 0.35 | 0.36 | 0.33 | 0.34 | 0.24 | 0.28 | 0.15 | 2.42 | 1.01 | 0.43 |
| 85th%ile | 0.40 | 0.46 | 0.39 | 0.40 | 0.38 | 0.32 | 0.33 | 0.22 | 2.88 | 1.24 | 0.55 |
| Std. Dev | 0.05 | 0.09 | 0.03 | 0.06 | 0.04 | 0.06 | 0.03 | 0.07 | 0.44 | 0.20 | 0.10 |

**Female subject 1**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|   |   |   |   |   |   |   |   |   | tor | por | lor |
| Average | 0.40 | 0.33 | 0.52 | 0.19 | 0.53 | 0.28 | 0.38 | 0.16 | 2.78 | 1.34 | 0.54 |
| Median | 0.40 | 0.31 | 0.51 | 0.18 | 0.51 | 0.26 | 0.38 | 0.14 | 2.69 | 1.29 | 0.51 |
| 85th%ile | 0.45 | 0.41 | 0.57 | 0.25 | 0.59 | 0.38 | 0.43 | 0.29 | 3.36 | 1.68 | 0.72 |
| Std. Dev | 0.06 | 0.08 | 0.05 | 0.05 | 0.06 | 0.08 | 0.05 | 0.08 | 0.52 | 0.28 | 0.14 |

**Female subject 2**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  | tor | por | lor |
| Average | 0.42 | 0.25 | 0.61 | 0.21 | 0.62 | 0.25 | 0.41 | 0.27 | 3.05 | 1.55 | 0.68 |
| Median | 0.41 | 0.25 | 0.59 | 0.20 | 0.61 | 0.26 | 0.40 | 0.28 | 2.99 | 1.55 | 0.68 |
| 85th%ile | 0.46 | 0.35 | 0.67 | 0.31 | 0.68 | 0.33 | 0.45 | 0.30 | 3.55 | 1.75 | 0.75 |
| Std. Dev | 0.13 | 0.09 | 0.07 | 0.09 | 0.10 | 0.07 | 0.06 | 0.04 | 0.64 | 0.26 | 0.09 |

**Figure 3 Observation-reaction times for male and female subjects**

Although other factors may come into consideration in this scenario it points to the fact that the pedestrian’s perception-reaction time can be an important element in the calculation of visibility distances and that some minimum time is required to account for the observation-reaction of the pedestrian in analysis and design of pedestrians crossings –whether controlled or uncontrolled locations.



Male 2

Male 1

0.94

0.55

1.25

1.93

Female 1

Female 2

0.72

0.75

1.68

1.75

*Note: All values are times in seconds*

Penultimate observation-reaction (POR) time, sec.

Last observation-reaction (LOR) time, sec.

**FIGURE 4 85th percentile values for key characteristics: plotted results and diagrammatic summary**

Implications of Differences Between Subjects – A comparison between the subjects of this study, can be informative for several reasons. For example, it can be seen that there is a considerable difference in all of the observation times. This could be expected because each subject represents a small portion of a much wider population of pedestrians, but of essentially the same pedestrian category (mature adults). As further investigations are made a more complete picture will emerge about the range of values associated with these and other categories of pedestrian. The investigations would have to be extended to all categories of pedestrians in order to develop a satisfactory overall spectrum of pedestrians’ observation-reaction abilities.

**Summary and Areas of Potential Further Studies**

Geometric Design Implications – The results indicate that consideration of pedestrians’ observation-reaction times within the integrated road and highway design process could be beneficial. The concepts and results indicate a potential basis for describing and measuring the sequence of observations during the preparation for crossing a carriageway. The concepts of the penultimate and the last observation-reaction times (POR and LOR, respectively) indicated that the observation-reaction times could be a significant portion of the total time required by pedestrians crossing a carriageway. Therefore, they could be an important factor in the analysis and design of uncontrolled (and possibly also controlled) crossing locations and the estimation of appropriate pedestrians’ sight line locations and visibility distances. At present, except for the instances mentioned earlier for signalised crossings, no consideration is given to observation-reaction times as an element in a pedestrians’ total time required to cross a carriageway.

It should be noted that application involving visibility distances must include consideration of vehicles’ approach speeds. Evidence appears to indicate that more limited visibility may lead to lower vehicle speeds on roads and streets where residential activity and relatively low traffic volumes occur (Jones 2003).

Potential Expansion of Findings – Expansion of the results to provide more statistically reliable information would include various other pedestrian categories, types of locations including junctions, and consideration of applications. Considerations in structuring further research would include:

* Pedestrian category. Samples of each of the pedestrian categories listed earlier would be included in a full analysis. However, before specifying the categories to be included a policy decision would be required concerning categories of pedestrians to include. Ideally, all pedestrians should be included. But because little or no data is available about the quantitative observation-reaction times and crossing speeds of people who are disabled and/or encumbered in some way, the approach to doing this usually involves consideration of a possible ‘best estimate’ based upon the location and the abilities of the users.
* Crossing Location. The nature of crossings can make a considerable difference in complicating a pedestrian’s observational tasks and increase the time required to accomplish them. Crossings at or adjacent to a junction or other conditions which require a pedestrian’s observation angle of up to 270 degrees, with associated focusing requirements, are of particular concern.
* Environmental conditions. These conditions can vary from the ideal to the extremely adverse. Much investigation is needed, particularly about the various levels of lighting and weather conditions in the context of pedestrians’ abilities to see approaching vehicles.

In this study the concepts and values resulting from the study illustrate a part of the total range of values for selected pedestrian categories and locations. The results indicate that further, more detailed investigations would be valuable in the analysis and design of pedestrian facilities.

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