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Visual search strategies in a shared zone in pedestrians with and without intellectual disability

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ABSTRACT

People with intellectual disability (ID) may find shared zones troublesome to negotiate because of the lack of the traditional clearly defined rules and boundaries. With the built environment identified as a barrier to active travel and community access, it is vital to explore how pedestrians with ID navigate shared zones to ensure that this group is not placed in harm's way or discouraged from active travel because of the implications of shared zones. This study investigated the visual strategies of 19 adults with ID and 21 controls who wore head mounted eye trackers in a Shared Zone and at a zebra crossing (as a contrast traffic environment). In total 4750 valid fixations were analysed. Participants with ID fixated on traffic relevant objects at a rate of 68 percent of the control participants. Furthermore, the males with ID were 9(4.4–18.7) times more likely to fixate on non-traffic relevant objects compared with traffic relevant objects, much higher odds than that of females with ID 1.8(0.4–1.7). Zebra crossings appeared to act as a cue, drawing pedestrians' visual attention to the traffic environment, with both groups more likely to look at traffic relevant objects on/at the zebra crossing (66%: 34%). Future implementation of shared zones needs to be carefully considered in relation to the safety of road users with ID and their capacity to identify and assess salient environmental information.

1. Introduction

Promoting physical activity amongst the population is becoming an increasingly important policy issue not only at local, state and national decision-making levels (Department of Infrastructure & Transport, 2013; Government of Western Australia, 2011; Western Australian Planning Commission & Department of Planning & Infrastructure, 2009) but also at a global level (De Nazelle et al., 2011; Institute Of Highway Incorporated Engineers, 2002; Litman, 2013; World Health Organisation, 2009). One way policy makers are seeking to address the issue of inactivity is through the creation of urban spaces that encourage people to leave their cars and walk or cycle instead (De Nazelle et al., 2011; Giles-Corti, Foster, Shilton, & Falconer, 2010; Institute Of Highway Incorporated Engineers, 2002; Litman, 2013; Western Australian Planning Commission & Department of Planning & Infrastructure, 2009). A well-designed

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urban landscape not only encourages physical activity but can have economic, community and environmental benefits as well (De Nazelle et al., 2011; Institute Of Highway Incorporated Engineers, 2002; Roads & Maritime Services, 2016; Western Australian Planning Commission & Department of Planning & Infrastructure, 2009).

One design approach, which while not new, is becoming increasingly popular is shared zones (also referred to as shared spaces, naked streets and home zones) (Appleyard, 1978; Hamilton-Baillie, 2008; Institute Of Highway Incorporated Engineers, 2002). Shared zones are pedestrian priority areas that encourage engagement between all road users by removing traditional traffic treatments designed to segregate foot and vehicular traffic (Hamilton-Baillie, 2008; Royal Dutch Touring Club, 1977). Installations including street furniture, planter boxes and garden beds are incorporated into the area, creating an attractive and engaging civic area for the community, simultaneously reducing traffic speeds and increasing driver awareness (Institute Of Highway Incorporated Engineers, 2002; Western Australian Planning Commission & Department of Planning & Infrastructure, 2009). While the impact of shared zones is over all, likely positive give their promotion of more active forms of travel, there is some evidence that they create an increased risk of injury for each extra kilometre travelled (De Nazelle et al., 2011; Elvik, 2009; Pucher & Dijkstra, 2003).

While certain aspects of shared zones are governed by formal rules such as those relating to vehicle speed, traffic flow and movement are informally directed by social protocols (Hamilton-Baillie, 2008) relying on users rapidly identifying, prioritising, interpreting and acting on salient visual stimuli within the environment. Social cues, including eye contact from other road users, enable safe navigation. Research has documented that the built environment can act as a barrier to physical activity, community and social participation, (Foley et al., 2014; Havik, Melis-Dankers, Steyvers, & Kooijman, 2012; Havik, Steyvers, Kooijman, & Melis-Dankers, 2015) the impact of shared zones on the community access of vulnerable groups remains an open question (Childs, Thomas, Sharp, & Tyler, 2010; Havik et al., 2012, 2015). Previous research has primarily explored the effect of shared zones on the health, wellbeing and participation of adults with visual impairment (Childs et al., 2010; Imrie, 2012; Moody & Melia, 2014). There is a paucity of research exploring the effect of shared zones on other vulnerable user groups, including those with intellectual disability (ID).

People with intellectual disability (ID) may find shared zones troublesome to negotiate given the lack of the traditional clearly defined rules and boundaries (Bodde & Seo, 2009; Foley et al., 2014). Identifying, prioritising and correctly assigning meaning to potentially ambiguous social interactions is crucial in safely navigating a shared zone. This process is dependent upon sound visual perceptual and cognitive functioning (Jonassen, 2000; Tabibi & Pfeffer, 2003), processes dependent on the receiving and processing of visual stimuli by the brain. Scanning the environment extracts visual information, received by the retina as saccades, with minimal interpretation by the brain (Falkmer, Dahlman, Dukic, Bjällmark, & Larsson, 2008; Yarbus, 1967). Fixation on external stimuli, leads to transmission and processing of visual information by appropriate areas of the brain (Falkmer et al., 2008; Yarbus, 1967). Identification of the stimulus enables an individual to reference past experiences, informing their current course of action (Falkmer et al., 2008; Yarbus, 1967). Impairment at any level of this cognitive process may lead to an inaccurate or delayed response, and in the context of a traffic environment including within a shared zone, lead to catastrophic consequences.

Cognitive processing has the most significant influence on an individual's visual attention (Einhäuser, Rutishauser, & Koch, 2008). Foveal vision can directed to an area based on external factors, including the eyes and gaze of others (Gilchrist, Heywood, & Findlay, 2003; Hamilton, 2016; Itier & Batty, 2009; Joosten et al., 2016; Ordqvist et al., 2013). While persons with ID attend to and respond to visual stimuli in the same way as their typically developing peers, the length of time spent processing this information is longer (Danielsson, 2006). This delay in processing speed may limit the ability of a person with ID to process the amount of critical visual information in complex traffic environments, such as shared zones, in order to maintain personal safety. It is therefore vital to explore how individuals with and without intellectual disability identify, interpret and respond to visual and social stimuli within the complex social environment of a shared zone, by studying the visual search strategies.

Most policies outlining the design of shared zones include provisions for those with mobility and visual impairment (Institute Of Highway Incorporated Engineers, 2002; Roads & Maritime Services, 2016), however the same consideration is often not provided for those with ID. While it is difficult to cater for the needs of all users, it is reasonable to expect that some consideration should be made for traffic users with ID, given persons with ID make up around 2.9% of the Australian general population (Australian Bureau of Statistics, 2014), and 10% of the population aged 75 years and older (Australian Bureau of Statistics, 2014). Of all people with ID, 82% live in the community, that is not in hospitals or aged care facilities, and 115, 600 of the Australians with ID are living independently, alone or in group homes (Australian Bureau of Statistics, 2014). Furthermore, inactivity, obesity and obesity-related chronic illness are major concerns for this population (Rimmer & Yamaki, 2006). Obesity (BMI > 30) and extreme obesity (BMI > 40) is more prevalent in people with ID, with some research reporting a rate twice that of the general population (Bodde & Seo, 2009; Rimmer & Yamaki, 2006). With the built environment identified as a barrier to active travel and community access, it is vital to explore how pedestrians with ID navigate shared zones to understand the implications of shared zones and ultimately their impact on the safety of persons with ID. One of several essential aspects for informing decision making in this environment is the visual search strategy that the road user uses. The visual strategy provides the conduit through which information is processed in the visual and cognitive systems, and hence is critical to effective and safe navigation of the shared space

This study utilised eye tracking technology to assess the visual strategies of individuals with and without ID. The primary objectives of the current study were to explore how individuals with and without ID visually scan the environment in a shared zone and in a traditional marked crossing (zebra crossing) We hypothesized that the participants with ID would look at traffic relevant objects and make eye contact less than the control group.

2. Methods

2.1. Participants

Participants were recruited via convenience sampling, radio advertising, and via government and non-government disability services. Participants were included in the ID group if they had a self or carer reported diagnosed intellectual disability, including Down syndrome genetic conditions, etc., were over 18 years old and were independently mobile, that is not using a wheel chair or any other walking or mobility aid. Formal testing of level of impairment was not deemed ethically appropriate as this study was a field trial and all participants had received a formal diagnosis of ID ([American Psychiatric Association, 2013](#)). The control group was recruited to represent the typical group of pedestrians that used the shared zone based on multiple observations of the population frequenting the shared zone. Participants were included in the control group if they were 18 years or older, proficient in written and verbal English, free of physical and/ or intellectual disability and independently mobile. For further information about the control group, see [Cowan et al. \(2018\)](#).

Informed consent was obtained from all participants prior to commencement of the eye-tracking trial; guardian consent was also obtained where appropriate. At recruitment, the persons were asked whether they wanted to come by themselves to participate or with a guardian, i.e., a parent/carer/support work/friend, etc. When a parent was present they were asked to provide informed consent on behalf of the participant with ID should they deem it relevant. Other guardians, e.g., formal carers/support workers were asked the same question and if deemed necessary were asked to provide informed consent by the parents prior to the trial if necessary. The informed consent form in easy English was developed with experts in ID and approved by the Ethics Committee. Hence, informed consent was obtained from all participants prior to commencement of the eye-tracking trial and guardian consent was obtained where appropriate. Participants were also asked to provide continuous consent throughout the trial and were able to cease the trial at any point. All data were de-identified for confidentiality. The study and its procedures were approved by Curtin University Human Research Ethics Committee in Western Australia (HR-56/2014) and also conformed to the Declaration of Helsinki ([World Medical Association, 2008](#)).

2.2. Apparatus

In order to record participants' eye movements two head-mounted eye trackers from different providers were utilised, an Arrington View Point™ eye tracker and a SensoMotoric Instruments™ (SMI) eye tracking glasses. The use of two eye-trackers allowed the participant to make a choice based on comfort which enhanced the quality of calibration, and data generation. As the calibration procedures were quicker but equally precise with the SMI eye tracking glasses it was often preferred over the other eye tracker by the participants with ID. The Arrington unit was connected to a Dell Latitude laptop to record and store participant eye movement data. The SMI unit was connected to a Samsung Galaxy mobile telephone that recorded and stored the eye movement data. Both units were binocular, head mounted and set to operate at 60 Hz. The Arrington and SMI both recorded the eye movements of the participants and generated accumulated measurements of each participant's fixations and fixation durations. These measures were then classified in regards to *area* and *object*, and *traffic relevance* and *eye contact*. All data were identically analysed with the same matrix, minimizing systematic errors, in accordance with a previous study ([Cowan et al., 2018](#)) (Appendix 1).

2.3. Procedures

A feasibility study of three available shared zones in Perth, Western Australia was conducted in order to identify which area would best meet the needs of this study. The shared zone selected as most appropriate was dual direction and clearly marked as a reduced speed (10 km/h, the speed limit set by the Australian Department of Transport for shared zones in Australia ([Department of Transport, 2011](#))) and pedestrian right of way. The adjacent shopping centre also provided a secluded area suitable for the calibration of the Arrington eye tracking unit. Finally, a zebra crossing was located within a short walking distance from the shared zone, providing a control test site for the study, refer to [Figure 1](#). All trials were conducted during office hours on the weekday that was convenient for the participant and all followed the same study protocol.

2.3.1. Calibration

Prior to the commencement of the trial participants were met in a quiet area and given a written and verbal explanation of the study, their roles and responsibilities and the opportunity to ask questions to enhance their understanding prior to giving consent. Once consent was obtained calibration could commence. The calibration procedure for the two eye trackers was different and is outlined individually below.

2.3.1.1. Arrington. The eye tracker was fitted onto the head of the participant. If the participant wore glasses, the eye tracker was placed over these, in some cases participants were encouraged to wear their own sunglasses to reduce squinting when in the sunlight. The infrared light and eye cameras were then manually adjusted. Participants were asked to wear a hat or cap to block some of the sunlight that may interfere with the unit's ability to record eye movements. In some instances the participant declined to wear the hat/ cap. While this did not stop the trial from continuing, it may have contributed to some invalid data sets. The participants were then instructed to sit three meters from an empty wall, which served as the calibration background for the 16 point calibration procedure. Parallax correction was then conducted at least 5 different distances from the wall; allowing the unit to adjust for a

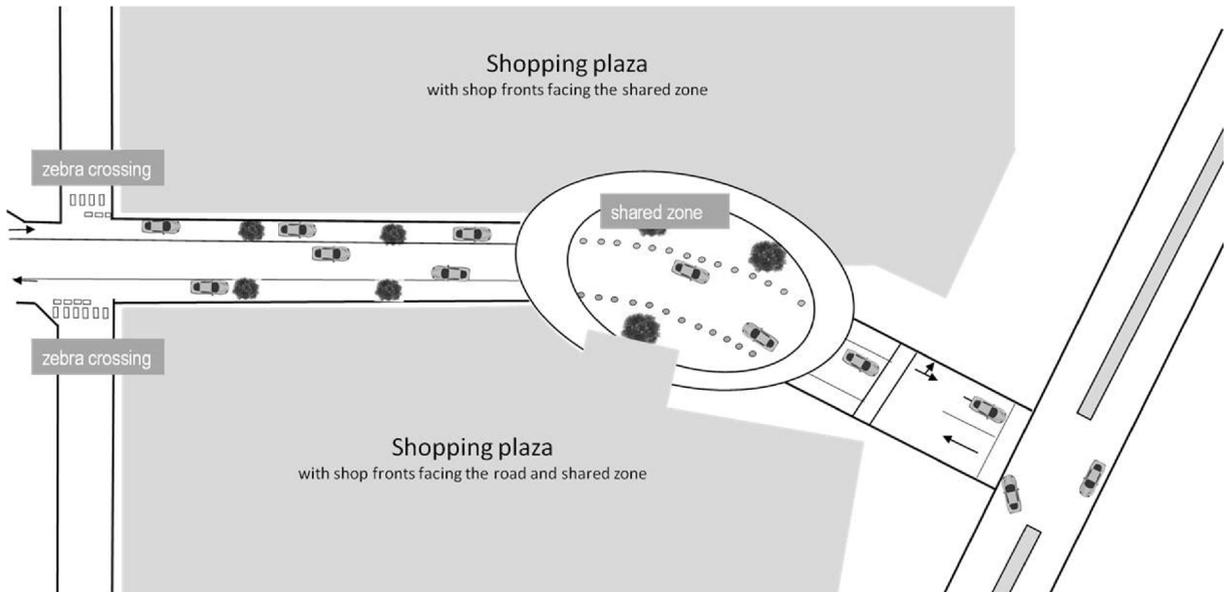


Fig. 1. Overhead view of the shared zone and zebra crossings used in this study.

binocular visual field (as opposed to a monocular visual field). The laptop was then placed in a back pack on the participant's back, supporting optimal freedom of movement, with participants subsequently accompanied to the start point of the trial.

2.3.1.2. SMI. Prior to placing the eye tracker on the participants' face the experiment leader selected either a tinted or clear lens based on environmental conditions and the participant's personal preference. The eye tracker was then fitted on the participant's face and the participant was asked to look at a specific point 1 m away (typically the tip of a pen) and a one-point calibration was conducted. Accuracy of the calibration was then checked using a three-point chart, if necessary the calibration was redone in order to improve accuracy. Once calibration was considered adequate the participant was asked to hold the recording device, or store it in a pocket and was then accompanied to the start point of the trial.

2.3.2. Trial protocol

Once at the starting point participants undertook a set of pre-determined tasks within the shared zone and at the zebra crossing, with tasks subsequently assigned as follows on completion of the previous task; 1) walk to the automatic teller machine (ATM), 2) go to the Jamaica Blue Café (or to the café with the blue sign depending on the participants reading ability), 3) go to the Post Office, (the shop with mail boxes and red sign), 4) go to the escalator, 5) go to Nando's restaurant, (the restaurant with the green sign and chicken), 6) cross the road using the zebra crossing (depending on personal jargon the zebra crossing may have been referred to as a pedestrian crossing, marked cross walk, or cross walk), 7) return across the road using the zebra crossing, 8) go to the Commonwealth Bank, (the bank/ shop with the large yellow sign) and, 9) return to the start point. These tasks were selected because they typically required a participant to shift their attention in order to attend to multidirectional traffic cues, as well as stationary and moving landmarks, and to establish eye contact with other road users in order to gain vital information required for the safe negotiation of the shared zone and zebra crossing.

The participant was shadowed at all times by the assessor (first author) to make sure that they maintained their personal safety and to give instructions to the participant according to the predetermined protocol. The assessor (first author) did not cue or interfere in the participant's action and only intervened if they deemed that the participant was making or about to make an unsafe decision. The protocol was adapted to meet the specific cognitive needs of the participant, which was crucial when running the trial with the adults with ID. If a participant appeared to be having difficulty identifying or finding the next destination point the assessor provided a set of verbal and visual prompts as shown in Fig. 2. If the participant was still not able to find where they were meant to go the experiment leader pointed out the location and asked the participant to take them there. The accuracy of the calibration and any slipping or movement of the eye tracking glasses that may have occurred during the trial was continuously monitored. This was done by the inclusion of a number of predetermined calibration points, where the participant was asked to look at a calibration point included in the protocol. This allowed provision of calibration points confirming the accuracy of the recorded eye-tracking data.

2.4. Classification of fixations

Fixations and fixation durations were recorded for each participant. It is assumed that the fixation point is a reflection of the individual's visual attention (Yarbus, 1967). For the purpose of this study, a fixation was defined as a mean of the x,y coordinates of the fixation points, within an area of $1^\circ \times 1^\circ$, and lasting a minimum of 100 msec (Falkmer & Gregersen, 2005). Fixations were

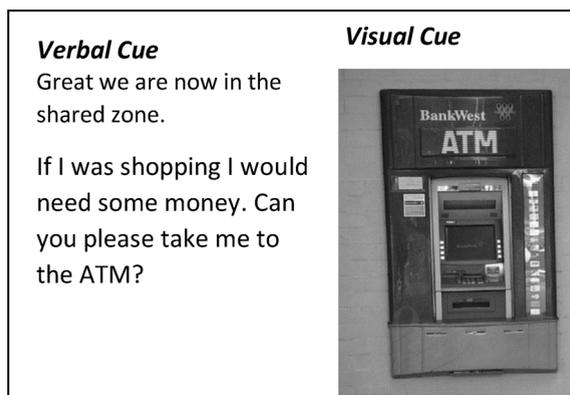


Fig. 2. Example of verbal and visual cues given to participants during the trial.

generated using a dispersion based centroid mode algorithm (Falkmer et al., 2008). For data recorded using the Arrington View Point eye tracker fixations were generated using the View Point Data Analysis program (Arrington Research Inc, 2006). SMI data were converted to its raw form using BeGaze 3.5 (SensoMotoric Instruments (SMI) (2015)), and a specifically designed, Matlab (The Mathworks Inc., 2015) based fixation generation code was used to generate fixations using the centroid dispersion method for the SMI eye tracker data. Shared zones are traffic environments that are characterised by the removal of conventional roadway components. Zebra crossings are a traditional traffic environment characterised by the black and white “zebra” lines on the road. Traffic relevant objects were objects that related directly to the traffic environment, which could include motor vehicles, pedestrians, and traffic signage. Non-traffic relevant objects were objects that did not directly relate to the traffic environment, which could include garden beds, benches, and the shopping centre. Eye contact was classified as any fixation on the eyes or face of an individual All fixations were manually analysed frame-by-frame and coded regarding duration (msec), area and object as defined by a pre-determined matrix (Appendix 1). Fig. 3 demonstrates how an individual fixation may be classified by area and object. A random sample of 100 fixations was re-assessed to ensure reliability by two of the authors (RE and GC) independently and were confirmed to have been analysed accurately.

Objects were then further classified as being either traffic relevant/non-relevant within the shared zone or zebra crossing. Based on the assumption that eye contact is a primary means by which intent to cross the road is communicated in traffic situations between road users, particularly between pedestrians and drivers, the amount of eye contact made with other road users was also considered to be a vital measure. Hence, fixations recorded in a road user’s face/eyes indicating eye contact were included in the classification procedure utilising the same protocol and procedures as in a previous study (Cowan et al., 2018). Eye contact was assumed when a fixation fell on the head of other road users.

2.5. Statistical analysis

Data were analysed using SPSS version 20 (IBM Corp, 2011). The eye-tracking data are presented as absolute values, as medians with interquartile ranges and/ or percentages and 95% confidence intervals. Fixation durations were analysed using a Mann-Whitney *U* test to compare the differences between groups and locations. Generalised Estimating Equations (GEE) were used to explore proportion of fixations that were classified as traffic relevant/ non-traffic relevant, eye contact/ other objects, in relation to a number of factors including group (control/ ID), location, age group, gender and driver status. In all analyses the α -level was set to .05.

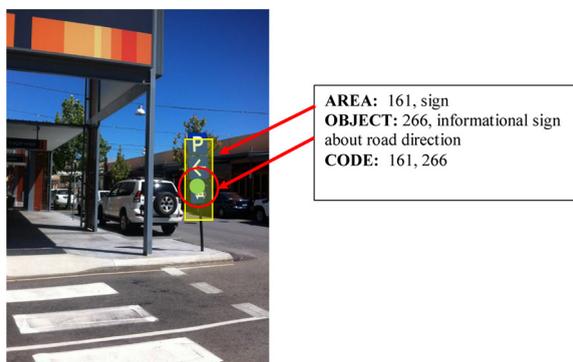


Fig. 3. Example of how eye tracking data were coded. The green dot represents the computer generated fixation point. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

Table 1
Demographic Data for Control and ID group.

	Control (n = 21)	ID (n = 19)	Total (n = 40)
Age range (years)	19–68	19–64	19–68
mean (SD)	36.1 (18.3)	31.4 (12.0)	33.1 (15.1)
Gender (n)			
Female	16 (76.2%)	6 (31.6%)	22 (55%)
Male	5 (23.8%)	13 (68.4%)	18 (45%)
Driver Status (n)			
driver	21 (100%)	3 (15.8%)	24 (60%)
non-driver	0 (0%)	16 (84.2%)	16 (40%)

Percentages displayed are within group percentages unless otherwise stated.

ID = intellectual disability.

3. Results

3.1. Sample demographics

A total of 57 participants participated in the current study. Of these, 28 were adults with an intellectual disability and 29 were typically developing adults. The demographic data for the control and ID groups are presented in Table 1. The mean age (standard deviation) of the control group was 36.1 (18.3) while the ID group had a mean age (SD) of 33.1 (12.0). There was a significant difference in the gender distribution ($p < 0.001$) between the groups with twice the representation of males in the group with ID. There was also a discrepancy in the number of drivers across the groups, with more licensed car drivers in the control group compared ($n = 21$) to the group with ID ($n = 3$).

Of the 57 participants that were tested, 17 produced invalid or incomplete data sets that were unusable for the final analysis. Invalidity was mainly due to equipment malfunction and failure to sufficiently capture eye movements due to an over saturation of infrared light caused by sun light and reflected glare from the ground. The ID group had a greater number of invalid or incomplete trials, ultimately 19 trials from this group were included for analysis while the control group had 21 valid trials included in the final analysis.

3.2. Number of fixations

3.2.1. Crossing type

A total of 40,841 fixations were generated from the 40 trials. Of these, 4750 fixations were measured during the road/ shared zone crossing phase/s of the trial. The distribution of the fixations across the two trial locations are displayed in Table 2. The dwell time reflects the cumulative time of the fixations. The group with ID had a greater number of fixations across both locations and as a consequence of this, also a greater dwell time in both locations.

3.2.2. Traffic relevance

Analysis of the number of fixations revealed that the control group attended to traffic relevant objects nearly two times more often

Table 2

Total number of fixations (dwell time in milliseconds) by the control and ID groups for eye contact, traffic relevance and crossing type. ID = intellectual disability.

	Control	ID	Total
Shared zone	1532 (486.7)	1829 (523.8)	3361 (1010.5)
Zebra Crossing	401 (152.7)	988 (268.5)	1389 (421.2)
Total	1933 (639.4)	2817 (792.3)	1389 (1431.7)
Traffic relevant	928 (205.3)	525 (112.9)	1453 (318.2)
Non-traffic relevant	1005 (260.7)	2294 (631.0)	3299 (891.7)
Total	1933 (466.0)	2817 (743.9)	4750 (1209.9)
Eye contact	18 (3.9)	57 (17.8)	75 (21.7)
Other objects	1915 (635.4)	2760 (774.5)	4675 (1409.9)
Total	1933 (639.4)	2817 (792.3)	4750 (1431.7)

Note: Shared zones are traffic environments that are characterised by the removal of conventional roadway components. Zebra crossings are a traditional traffic environment characterised by the black and white “zebra” lines on the road. Traffic relevant objects were objects that related directly to the traffic environment, which can include motor vehicles, pedestrians, and traffic signage. Non-traffic relevant objects are objects that do not directly relate to the traffic environment, which can include garden beds, benches, and the shopping centre. Eye contact was classified as any fixation on the eyes or face of an individual. Other objects were all other objects that were not classified as eye contact.

Table 3

Comparison of the proportion of fixations on traffic relevant and non-traffic relevant objects based on location and group by gender. ID = intellectual disability.

	Traffic Relevant	Non-traffic Relevant	Odds Ratio	p-value
Location				
Zebra Crossing	34.4%	65.6%	2.1 (1.5–3.0)	< .001
Shared Zone	29.0%	71.0%	1	
Gender by Group				
ID male	14.1%	85.9%	9.0 (4.4–18.7)	< .001
ID female	25.0%	75.0%	1.8 (1.1–2.8)	.011
Control male	49.2%	50.8%	0.9 (0.4–1.7)	.657
Control female	47.5%	52.5%	1	

Note: Shared zones are traffic environments that are characterised by the removal of conventional roadway components. Zebra crossings are a traditional traffic environment characterised by the black and white “zebra” lines on the road. Traffic relevant objects were objects that related directly to the traffic environment, which can include motor vehicles, pedestrians, and traffic signage. Non-traffic relevant objects are objects that do not directly relate to the traffic environment, which can include garden beds, benches, and the shopping centre. Percentages displayed are the within group percentage unless otherwise stated.

compared to the group with ID. Conversely, the group with ID attended to non-traffic relevant objects over two times more often than the control group. Furthermore, the participants with ID were seen to attend to non-traffic relevant objects over four times more often than traffic relevant objects when either crossing the zebra crossing or traversing the shared zone. The number of fixations by traffic relevance are displayed in [Table 2](#).

3.2.3. Eye contact

The number of fixations classified by eye contact and other objects for each group are presented in [Table 2](#). Overall, the number of fixations classified as eye contact across both groups was miniscule compared to other objects ($n[\text{eye contact}] = 75$, $n[\text{other objects}] = 4675$). The control group attended less to eye contact ($n = 18$) compared to the ID group ($n = 57$).

3.2.4. Areas of interest

[Table 3](#) presents the proportion of fixations on traffic relevant and non-traffic relevant objects in the zebra crossing and the shared zone. Initial analysis found that group was not a significant factor in determining the number of fixations on traffic relevant objects in each zone ($p = .133$) however, the gender imbalance across the groups warranted further investigation. When gender was accounted for across the two groups the analysis revealed that males and females with ID were significantly less likely to look at traffic relevant objects in crossing situations compared to the control group ($p < .001$, $p = .011$ respectively). Males with ID were 9 times more likely whereas females were twice as likely to look at non-traffic relevant objects compared with traffic relevant objects. All participants were also more likely to look at traffic relevant objects at the zebra crossing compared with in the shared zone ($p < .001$).

Overall the proportion of fixations that were eye contact was far less than that of other objects as seen in [Table 4](#). Location was the

Table 4

Comparison the proportion of fixations on eye contact and other objects based on group, location, age group, gender and driver status. ID = intellectual disability.

	Eye contact	Other objects	Odds Ratio (\pm 95%CI)	p-value
Group				
ID	2.0%	98.0%	1.8 (0.3–12.4)	.535
Control	0.9%	99.1%	1	
Location				
Zebra Crossing	0.4%	99.6%	4.2 (1.3–13.5)	.018
Shared Zone	2.1%	97.9%	1	
Age Group				
26 and over	1.6%	98.4%	0.8 (0.3–2.6)	.758
18-25 years	1.5%	98.5%	1	
Gender				
Male	0.9%	99.1%	1.9 (0.6–5.9)	.279
Female	2.1%	97.9%	1	
Driver Status				
Non-Driver	2.2%	97.8%	0.2 (0.03–1.0)	.1
Driver	0.9%	99.1%	1	

Note: Shared zones are traffic environments that are characterised by the removal of conventional roadway components. Zebra crossings are a traditional traffic environment characterised by the black and white “zebra” lines on the road. Eye contact was classified as any fixation on the eyes or face of an individual. Other objects were all other objects that were not classified as eye contact. Percentages displayed are the within group percentage unless otherwise stated.

Table 5

The median (25th to 75th percentile) fixation duration (ms) for each group by zone and traffic relevance. ID = intellectual disability.

	Control	ID
Shared zone	149 (116-233)	134 (100-232)
Zebra Crossing	134 (116-233)	133 (115-215)
Traffic relevant	135 (116-233)	133 (100-200)
Non-traffic relevant	166 (130-233)	142 (101-232)
Eye contact	149 (100-30)	166 (116-267)

Note: Shared zones are traffic environments that are characterised by the removal of conventional roadway components. Zebra crossings are a traditional traffic environment characterised by the black and white “zebra” lines on the road. Traffic relevant objects were objects that related directly to the traffic environment, which can include motor vehicles, pedestrians, and traffic signage. Non-traffic relevant objects are objects that do not directly relate to the traffic environment, which can include garden beds, benches, and the shopping centre. Eye contact was classified as any fixation on the eyes or face of an individual. Other objects were all other objects that were not classified as eye contact.

only factor that had a significant effect on the proportion of fixations on eye contact, with participants significantly more likely to make eye contact in the shared zone (2.1%) compared to the zebra crossing (0.4%) ($p = .016$). No other factor was seen to have a significant effect on making eye contact (Table 6). The effect of gender by group was not significant ($p = .064$) as in the analysis of traffic relevant fixations and was therefore excluded from the final analysis of eye contact.

3.3. Fixation duration

3.3.1. Areas of interest

The control group had significantly longer fixation durations in both the shared zone ($p < .001$) and at the zebra crossing ($p < .001$) compared to the ID group. The median fixation duration for each group across the two trial locations are presented in Table 5. The median fixation duration for the control group was 15 msec longer compared to the ID group in the shared zone. At the zebra crossing this difference was far less with the median fixation duration of the control group being only 1 msec longer than the ID group.

3.3.2. Traffic relevance

Table 5 presents the fixation durations as medians and percentiles for each group by area of interest. With regard to the traffic relevant/ not traffic relevant objects the control group had significantly longer fixation durations compared to the ID group ($p < .001$, $p < .001$, respectively). The duration of fixations on eye contact between groups was not significant however, the median fixation duration of the ID group was 15 msec longer than the control group.

4. Discussion

This study sought to investigate how individuals with and without ID visually scan the environment in a shared zone and a traditional marked crossing (zebra crossing). The main finding was that participants with ID were less likely to look at traffic relevant objects compared with the control group. Furthermore, males with ID were almost four times less likely to look at traffic relevant objects compared to females with ID. There was no difference in the proportion of eye contact made between the ID group and the control group. Both groups made little eye contact with drivers, and were more likely to look at the faces of drivers at the zebra crossing compared with the shared zone. The ID participants generally had shorter fixations than the control. It also appeared that zebra crossings acted as a cue to draw the pedestrians' visual attention to the traffic environment, with both groups more likely to look at traffic relevant objects on/ at the zebra crossing.

These findings suggest that shared zones could, in fact, increase potential risk of injury for pedestrians, but significantly more so for those with ID, as they were not attending to salient traffic information nearly as frequently as they were at/on the zebra crossing. It may be that the area surrounding the shared zone offered greater distraction, diverting participants' attention away from the traffic relevant objects, regardless of cognitive functioning. This is important to note as it supports the need for shared zones to continue to be considered in a case-by-case manner, rather than as a universal solution (Institute Of Highway Incorporated Engineers, 2002; Moody & Melia, 2014; Roads & Maritime Services, 2016). The area surrounding the shared zone needs to be carefully considered so as not to overly distract pedestrians', and potentially drivers', attention away from the traffic environment. Alternative crossing points that are more familiar/ traditional, i.e., zebra crossings, may also be needed at the periphery of a shared zone to provide an optional crossing point with an added and distinct cue for pedestrians with ID, as it would draw their attention to traffic relevant objects in the environment. Future research should aim to explore how drivers attend to shared zones and zebra crossings in order to better understand potential safety benefits or hazards presented by these two types of uncontrolled crossing.

The close proximity of pedestrians and vehicles within the shared zone requires all users to be able to rapidly and accurately

attend to, interpret and act upon salient visual information, in order to maintain personal safety (Danielsson, 2006; Falkmer & Gregersen, 2005; Havik et al., 2015; Itier & Batty, 2009). Despite the fact that the differences in fixation durations between the groups were small, the longer durations in the shared zone may suggest that shared zones place added cognitive demand on top of the already complex task of crossing the road for all road users. Previous research identified that persons with ID are able to accurately interpret information in the same way as their typically developed peers, however they do require increased time to process this same information (Danielsson, 2006). Furthermore, persons with ID have demonstrated increased difficulty when required to attend to and retain information from multiple tasks simultaneously (Danielsson, Henry, Rönnerberg, & Nilsson, 2010). It was found in this study however, that statistically the group with ID had shorter durations compared to the control group, but in terms of milliseconds the differences were between 1–16 msec and the real life implications of such differences in these traffic environments remain to be explored. More worrying is the finding that this group had fewer fixations on traffic relevant objects, suggesting that individuals with ID are potentially at increased risk of harm in the shared zone because they are not adequately attending and responding to traffic relevant information in the environment. Future planning of shared zones needs to consider how to address the need for additional cognitive processing time for traffic relevant objects in shared zone users with ID and if reducing vehicle speeds allows for sufficient additional cognitive processing time. Additionally, strategies for ensuring adherence to reduced speed limits need to be further explored and evaluated. The findings from this study suggest that shared zones should be implemented with caution and continue to be carefully assessed on a case-by-case basis, in order to assure that the shared zone has the desired effect on safety and physical activity.

4.1. Implications for future planning

The needs of persons with ID must be carefully considered when implementing a shared zone to ensure inclusive, satisfactory and safe participation. There are currently mixed views on the effectiveness of shared zones as a traffic management design. Advocates of shared zones report that they increase safety by slowing traffic and fostering a sense of equality between all road users (Hamilton-Baillie, 2005). Others, however, are less confident, reporting that the effectiveness of shared zones is a result of pedestrian intimidation and avoidance and suggesting further research is needed to fully understand human behaviour within shared zones globally (Kaparias, Bell, Miri, Chan, & Mount, 2012; Moody & Melia, 2014). The findings of this study suggest that shared zones may present a barrier to safety and active community participation for those with ID because of the need to rapidly and accurately interpret vast amounts of environmental stimuli. Reduced visual processing ability means that this group is potentially at increased risk of making poor/ unsafe road crossing decisions, increasing their likelihood of being in a collision. While a recent study exposing the viewpoints of pedestrians regarding shared zones revealed that on the whole they would not avoid a shared zone if they were to come across it, some pedestrians were still wary of the action of drivers, indicating that in reality they would avoid a shared zone in preference of a more traditional crossing point if available (Earl, Girdler, Falkmer, Morris, & Falkmer, 2016). As the pedestrians in this study were “forced” to cross the shared zone it is recommended that further research focuses on the actual observed behaviour of pedestrians, including those with ID, in shared zones to get a better understanding of pedestrian movements in and around shared zones and the implication on safety.

4.2. Study limitations

Shared zones, while not new internationally, are a relatively new and novel design concept in Western Australia, with many of the participants having never previously seen or heard of a shared zone prior to participation in this study. It is possible that in areas with more established shared zones that both pedestrian and driver behaviour would be different and therefore it is difficult to generalise these findings to a wider population. Further research is required to investigate the increased cognitive demand of shared zones and the possible safety implications for pedestrians in larger, longer established shared zones controlling for factors such as the flow of road users.

Further studies would also benefit from measuring the effect of IQ and severity of impairment. Due to the nature of this study it was neither practical nor feasible to measure IQ of the participant who took part in the trial. Furthermore, future studies should aim to target a greater age range, specifically older adults to explore the effect that age and age related cognitive decline might have on visual processing in shared zones and zebra crossings.

The sample size of this study is relatively small and the control group was not matched to the ID group, in accordance with a previous similar study (Cowan et al., 2018). Finally, there were invalid data from 17 trials, which was the result of infrared light caused by direct sun light and reflected glare from the ground. The split of the 17 invalid trials between the two groups was 9 versus 8 and most likely a random error.

Another limitation was that the participants were not screened for their experiences of traffic in general, nor in particular with regard to shared zones. While such screenings will inherently be challenging from a quantitative perspective, they could have added information to explain, for example the significant gender differences in participants with ID.

5. Conclusion

In summary, the finding of this study suggest that the search strategies of people with ID (particularly males) may place them at risk when negotiating traffic because they do not appear to attend appropriately to traffic relevant objects. This problem may be more evident in shared zones where distraction to non-traffic relevant objects appears to be higher for all participants.

The future implementation of shared zones needs to be carefully considered in relation to the safety of road users with ID and their capacity to identify and assess salient environmental information. It appears that the inclusion of a marked crossing point may be beneficial to help direct all pedestrians' attention to the traffic environment, not only those with ID. In theory, shared zones do have the potential to encourage social engagement and physical activity, but the added risk of encouraging people into these areas where they are in close proximity to motorised traffic needs to be carefully considered and assessed on a case-by-case basis to ensure safe and satisfactory travel for all members of the community regardless of functioning, cognitive or otherwise. Finally, future research needs to explore how drivers' direct their attention in a shared zone. This will allow for better understanding of if and how shared zones promote drivers to be more aware of their surroundings, or if, as found in this study, the design of a shared zone actually create more distraction, drawing the traffic users' attention away from traffic relevant objects, potentially further increasing risk of injury to pedestrians.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.ridd.2019.103493>.

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