Visual attention in naturalistic scenes across the lifespan

A thesis submitted in partial fulfilment of the requirements of Bournemouth University for the degree of Doctor of Philosophy

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Chapter 1

Ageing and executive function decline lead to performance decline in challenging naturalistic road crossing situations

1.1 Introduction

In this introduction I will give an overview of how visual attentional control declines with age, and how this can impact everyday activities of older adults (OAs). I then focus on how a decline in attentional control abilities specifically affects older adults' road crossing behaviour. I then discuss my findings from Chapter 3 and how these can be built upon using a more complex road crossing task. I finish with the questions that I aim to address with my experiments in this chapter.

As we age many perceptual and cognitive abilities decline. The declining abilities include visual attentional control, such as the ability to suppress task-irrelevant distractors (Milham et al., 2002) or the ability to switch between targets (Hampshire, Gruszka, Fallon, & Owen, 2008). They also include executive functioning abilities such as inhibition (Tipper, 1991; Butler & Zacks, 2006; Nieuwenhuis, Ridderinkhof, De Jong, Kok, & Van Der Molen, 2000; Olincy, Ross, Youngd, & Freedman, 1997; Butler, Zacks, & Henderson, 1999; Harsay, Buitenweg, Wijnen, Guerreiro, & Ridderinkhof, 2010; Beurskens & Bock, 2012; Milham et al., 2002; Hampshire et al., 2008), planning (Allain et al., 2005), working memory (Anders, Fozard, & Lillyquist, 1972; Van der Linden, Brédart, & Beerten, 1994), and cognitive flexibility (Daigneault, Braun, & Whitaker, 1992; Eppinger, Kray, Mecklinger, & John, 2007). Age related decline in visual attention and executive functioning ability have been associated with a reduction in frontal lobe activation (Salat et al., 2004; Gazzaley & D'esposito, 2007; Milham et al., 2002; Hampshire et al., 2008), including the dorsolateral prefrontal cortex (DLPFC, Rypma & D'Esposito, 2000), the ventrolateral PFC (VPFC) and the posterior parietal cortex (PPC, Hampshire et al., 2008).

Age related deficits in visual attentional control and executive functioning have been associated with difficulties in the real world. For example, OAs are more likely to fall over than younger adults (YAs). Visual attentional control has been linked to OAs' risk of falling as OAs tend to fixate stepping targets for longer than YAs (Chapman & Hollands, 2006; Zietz & Hollands, 2009), suggesting that OAs need longer to process the necessary visual information to plan their steps. OAs that had a high risk of falling, however, tended to look away from the stepping target prematurely (Chapman & Hollands, 2006, 2007). This tendency to look away prematurely has been associated with a reduction in the accuracy and precision of OAs steps (Chapman & Hollands, 2006, 2007). One suggested interpretation is that OAs at a higher risk of falling are not taking the time to process the necessary visual information to make an accurate step (Chapman & Hollands, 2006, 2007). The decline in executive function in OAs has also been associated with a decline in general daily living skills (Hart & Bean, 2010). For instance, a decline in certain aspects of executive functioning such as spatial planning has been associated with participants making less safe road crossing decisions (Geraghty, Holland, & Rochelle, 2016).

Focusing on the impact of ageing and declining executive functions on road crossing ability, OAs have been shown to be particularly vulnerable in road crossing situations with almost 50% of road traffic accidents in the EU in 2014 (ERSO, 2018) involving adults aged 65 or above (for more information see Chapter 1). Previous research investigating why OAs are particularly vulnerable have pointed towards visual attentional control and executive functioning, in particular attention switching and spatial planning, as being important factors in OAs ability to make safe crossing decisions (Geraghty et al., 2016; Dommes, Cavallo, & Oxley, 2013; Zito et al., 2015). These studies link executive functioning to performance in realistic tasks. However, they do not provide a fine-grained understanding of how a decline in attentional control affects the visual exploration of the road crossing environment which, in turn, might impact performance.

In the previous chapter I investigated how ageing with maintained executive functioning affected the exploration of the road crossing environment and how this impacted on road crossing performance. I found that OAs were able to make safe crossing decisions, and even took into account their slower response times. In contrast to previous research, my findings suggested that older participants adopt a more conservative crossing strategy characterised by less frequent crossing decisions and larger crossing gaps. The road crossing scene in the previous chapter was relatively simple with one direction of traffic. Therefore, it would be interesting to investigate the impact of healthy ageing and executive functioning level on performance when we parametrically manipulate the situational complexity. Indeed, previous literature has suggested that OAs are able to make safe crossing decisions in simple situations, such as when cars only come from one direction, but have difficulties in more complex situations such as when cars travelled from both directions (Oxley, Fildes, Ihsen, Charlton, & Day, 1997), cars travelled in the far lane (Geraghty et al., 2016; Oxley et al., 1997; Oxley, Ihsen, Fildes, Charlton, & Day, 2005), or when cars travelled quickly (Dommes et al., 2013; Lobjois & Cavallo, 2007; Oxley et al., 2005). These studies have separately addressed the effect of specific traffic situations, such as cars travelling from both directions, and the effect of executive functioning, or the combined effect of car speed and a decline in executive functioning on the ability to make safe crossing decisions. None of them have examined the combined effect of declining executive functioning, cars coming from both directions and car speed or traffic density. In the current experiment I assessed these combined effects to see whether there are specific situations that OAs have difficulties with and whether declining executive functions amplify these difficulties.

To this aim I performed two virtual reality (VR) experiments, assessed participants' spatial planning abilities using the BADS zoo map test (Wilson, Alderman, Burgess, Emslie, & Evans, 1996) and their attention switching abilities using the Rogers and Monsell attention switching (RMA) task (Rogers & Monsell, 1995). I also measured the participants' average walking speed. To increase participants' ability to immerse themselves in the scenario and allow them to integrate information across different hemifields, I presented the stimuli with a large horizontal field of view of 180°. As in previous experiments, I recorded eye movements, and crossing decisions. In this experiment I also recorded head movements to allow us to calculate eye movement positions when participants looked at the screens to their left and right hand sides. I used a VR setup as it enabled participants to be repeatedly exposed to a variety of realistic hazardous traffic situations without the threat of enduring injury (Schwebel, Gaines, & Severson, 2008; Schwebel, Davis, & O'Neal, 2012; Meir, Parmet, & Oron-Gilad, 2013).

As mentioned in Chapter 3, OAs responded to only one lane of traffic and one travel direction. In the VR environment, I included two traffic directions in order to make the task more realistic and more taxing for executive functioning. Thus, if any difference would be observed between both studies, I would be unable to disentangle the influence of the number of lanes from the influence of the number of traffic directions as these variables would be confounded. To address this confound I conducted two experiments. In the first experiment I included only one traffic direction and I manipulated the car speed and the number of lanes, one or two. When only one lane was used, it could either be the near or the far lane. This design allowed us to investigate the effect of task complexity on visual exploration and crossing decisions via the number of traffic lanes, the effect of car speed and their interaction. The near vs far lane contrast also offered a way to explore a potential influence of the distance of the moving vehicle as well as its interaction with speed as suggested by Geraghty et al. (2016); Oxley et al. (1997) and Oxley et al. (2005). The VR environment that I used had an obscured view of the cars on the left-hand side compared to the field of view on the right hand side. This gave us the opportunity to see if OAs have difficulties with a restricted view of the cars in the same way children do (Meir et al., 2013; Ampofo-Boateng & Thomson, 1990). In the second experiment, cars always appeared on both lanes and I manipulated the car speed, cars travelling from one direction or both directions, traffic density, obscured or non-obscured viewpoint, and task-irrelevant distractors.

My overarching question for both experiments is: Do OAs and participants with poorer executive functioning abilities make riskier crossing decisions when task complexity is increased than YAs and participants with better executive functioning abilities?

I define riskier crossing decisions as any decisions that would increase the likelihood of an accident. For example, through making more crossing decisions or leaving less time to impact in a more complex situation than in a simpler situation. For Experiment 1 I increase task complexity in the following ways:

- Increasing car speed.
- Obscuring the viewpoint of the oncoming cars.
- Changing the lane (near/far) cars travel in.
- Change the number of lanes (one/two) cars travel in.

1.2 Methods – Experiment 1

1.2.1 Participants

Fifty-three participants were recruited, 19 aged between 65 and 85 years old (y/o, mean=70.80, SE=1.31), and 34 aged between 18 and 24 y/o (mean=19.94, SE=0.26). The recruitment of OAs was cut short due to the COVID-19 pandemic. All YAs were recruited at Bournemouth University, UK. Older adults were recruited either from the Bournemouth Ageing and Dementia Research Centre (ADRC) participant pool or from the Wimborne branch of the University of the Third Age. All participants had normal or corrected to normal vision. Participants were screened for mild cognitive impairment using the Montreal Cognitive Assessment (MoCA, Nasreddine et al., 2005). No participants scored below the cut off score of 23 (Luis, Keegan, & Mullan, 2009). Therefore all recruited participants were included in the final analyses. The study was approved by Bournemouth University's ethics committee. Informed consent was obtained from participants prior to taking part. Participants took part in exchange for course credits or monetary compensation for their time. This study was performed in accordance with all appropriate institutional and international guidelines and regulations, in line with the principles of the Helsinki Declaration.

1.2.2 Executive function tests

To assess the participants' EF abilities, participants completed the BADS zoo map test (Wilson et al., 1996), and the Rogers and Monsell attention shift paradigm (RMA; Rogers & Monsell, 1995). The BADS zoo map test assessed the participants' spatial planning ability by assessing participants' ability to plan a route around a zoo. In the first trial participants were given a map of a zoo and instructed to plan a route around a zoo, starting at the entrance and finishing with a picnic. Along the route participants had to visit specified locations in any order while they followed set rules, such as only using specified paths twice and not visiting unspecified locations. Participants' planning time and time to complete the task was recorded. In the second trial participants had to plan a route around the same zoo, followed the same rules, and visited the same locations but in a specified order. Again, the participants' planning time and time to complete the task was recorded. Participants' performance was assessed based on visiting the correct locations and points were deducted when participants broke the rules and exceed time limits for planning on the second trial. The scores ranged from zero to four, the higher the score the better participants performed on the test.

The RMA assesses participants' attentional control by getting participants to switch between two similar tasks. Participants were presented with number letter pairs (e.g., 9E) and depending on the position of the stimulus on the screen they either had to identify whether the number was odd or even or whether the letter was a vowel or consonant. For the RMA task I extracted the global and local switch costs as done by Rogers and Monsell (1995). The global switch costs refer to the difference in performance between a block where participants perform the same task and a block where participants are switching between tasks. Local switch costs refer to the differences in performance between switch and non-switch trials. I also extracted the participants' accuracy and response times on each trial of the RMA. Correct responses were scored as one, incorrect responses as zero. Individual performance was then assessed by averaging accuracy over the entire RMA experiment.

These tests have previously been linked to road crossing ability (Dommes et al., 2013; Geraghty et al., 2016) and were designed to assess participants' spatial planning and attention shifting abilities.

1.2.3 Walking speed

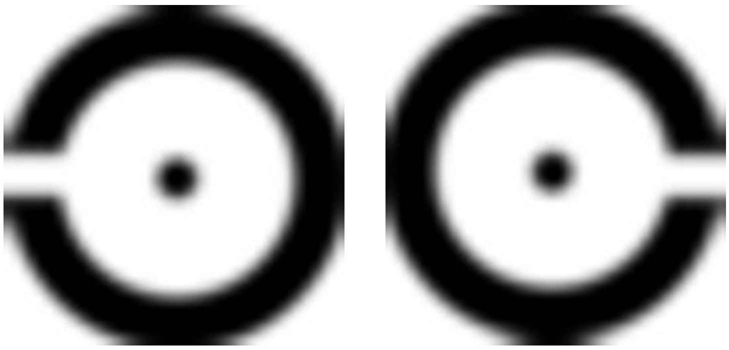
I measured participant's walking speed by asking participants to walk along a nine meter corridor while measuring their walking time. Participants were asked to walk at their normal day to day walking pace. This was done three times and an average walking time was then calculated. The walking speed was then calculated by dividing the nine meter distance by this average walking time.

1.2.4 Apparatus

During the experiment participants' eye movements were recorded at a sampling rate of 250Hz with the SR-Research EyeLink II, which has an average spatial resolution of $< 0.005°$. Only the dominant eye was tracked. Stimuli were presented across three Samsung monitors, each with a screen resolution of 1920 by 1080 pixels, an aspect ratio of 16:9, a width of 88.6cm, and a height of 49.8cm. The left and right screens were placed at 120° to each other. Participants were seated at a distance of 100cm (setup shown in Figure, 1.2a). The screens had a combined horizontal viewing angle of 180° and a vertical viewing angle of 32°. The experiment was coded in Worldviz Vizard 5.0 using Python 2.7 and the PyLink Toolbox extensions (Peirce, 2007). Calibrations for eye fixations were conducted at the beginning of the experiment using a nine-point fixation procedure as implemented in the EyeLink API (see EyeLink Manual). Calibrations were then validated with EyeLink software and repeated until there was less than 1° of error for every calibration point. Head position and orientation were recorded using the Polhemus Fastrak motion tracking system with a sampling rate of 120Hz.

1.2.5 Experimental Procedure

Both experiments used a virtual road crossing environment created in 3DS Max and Maya (Figure. 1.2b) which was made to simulate the road crossing scene used in Nicholls et al. (2019) and Chapter 3, without the roundabout. Prior to the start of the experiment participants' eye movements were calibrated using a custom calibration procedure across all three screens. This procedure involved presenting circles with a break on the left or right side and a dot in the middle (Figure 1.1) at random locations on all three screens. Participants had to look at the circle and indicate whether the break in the circle was on the right or left hand side using the left and right arrow keys on the keyboard. While participants performed this task their eye movements were recorded. Once this was completed participants eye movements were calibrated on one screen using the Eyelink calibration procedure.



(a) Example calibration point left

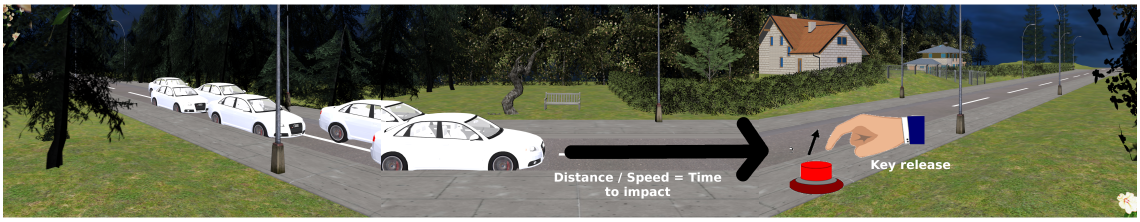
(b) Example calibration point right

Figure 1.1: Example calibration points for the three screen calibration of the Eyelink II. (a) Example calibration point with the break in the circle on the left. (b) Example calibration point with the break in the circle on the right

At the beginning of the experiment participants were informed that they would be presented with a series of road crossing situations on screen and that they would have to indicate by pressing the spacebar on a keyboard when they could cross the road and hold the key pressed for as long as they thought it was safe to cross. At the start of each experimental block participants were informed on which side the cars would appear from – left hand side, right hand side, or both sides (Experiment 2 only). Vehicles travelled at two speeds – 249 (slow) or 583 (fast) virtual world units per second. This was equivalent to approximately 30 and 70 km/h respectively. Each trial started with the presentation of a central fixation cross. Once the participants had fixated on the cross, the virtual environment was presented. Each trial was followed by a black screen with text stating the trial had ended and the participant should press the spacebar to continue. Once the participants pressed the spacebar the next trial would start with the central fixation cross.

(a) Experiment setup

(b) Experiment stimulus



(c) Time to impact explanation

Figure 1.2: VR experiment set up and stimulus

1.2.6 Statistical analyses

All statistical analyses and figures were created and performed using Matlab 2019a (MATLAB, 2019) and R version 3.6.3 (R Core Team, 2020).

Crossing decisions

I defined "time to impact" (TTI) as the time that it would take for the closest approaching vehicle, in each lane, to reach the participants, from the moment when the participants stopped indicating that crossing was safe (i.e. when they released the spacebar indicating that it was no longer safe to cross). This is illustrated in

Figure 1.2c. Previously, it has been shown that YAs and OAs are able to make decisions based on a combination of time and distance to impact (DTI; Lobjois & Cavallo, 2007). As cars were moving at a constant speed with equally sized gaps between the cars, I was not able to investigate this as the DTI was perfectly correlated with the TTI (Figure A.1). To investigate DTI alongside TTI, I could have had cars with different sized gaps between them, moving with changing speeds, or accelerations.

The crossing decisions in both experiments were analysed with linear mixed models (LMMs). In Experiment 1 the model included fixed effects of age group (above or below 60y/o), number of lanes, near or far lane, car speed, car direction, direction of travel (from the left or right), RMA RTs, zoo map score, global switch cost on RMA RTs, local switch cost on RMA RTs. The model included interactions between age and each of the task conditions. There were also interactions between each of the executive functioning measures and each of the task conditions. The model also included random intercepts for each participant and each trial. To begin with, the model contained random slopes for each fixed factor but the model did not converge so all random slopes were removed.

In Experiment 2 the model included fixed effects of age group (above or below 60y/o), traffic density, presence of distractors, car speed, direction of travel (from the left, right, or both directions), RMA RTs, zoo map score, global switch cost on RMA RTs, local switch cost on RMA RTs. The model included interactions between age and each of the task conditions. There were also interactions between each of the executive functioning measures and each of the task conditions. The model also included random intercepts for each participant and each trial. To begin with, the model contained random slopes for each fixed factor but the model did not converge so all random slopes were removed. This model initially included interactions for cars appearing from both directions and car speed, cars appearing from an obscured viewpoint, traffic density, and pedestrian presence. This model did not converge so these interactions were removed. To keep the current chapter concise I focused on the fixed effects that answered my main hypotheses in the results sections for

Experiment 1 and Experiment 2. As the fixed effect of RMA RT was an additional exploratory analysis the results for this effect can be found in Appendix C.

For both experiments LMMs were performed for the number, and duration of button presses, and the TTI. All significant interaction produced by these LMMs were investigated using simple effects LMMs with a Tukey HSD correction for multiple comparisons.

Executive function tests

Differences between older and younger adults on all measures were determined using a bootstrap t-test with 20% trimmed means. Multiple comparisons were corrected using the Hochberg method. I used bootstrap t-tests as they handle skewed distributions and outliers better than the Student's t-test (Rousselet, Pernet, & Wilcox, 2019). Bayes factors were also calculated using the BayesFactor package in R (Morey & Rouder, 2018), after outliers were removed using the median absolute deviation (MAD) rule.

Eye movements

The eye movement analyses are not available at this point in time. My projection of eye positions in the 4D virtual space and time was much more challenging than expected. The Eyelink II is set up to be used for one screen, so gaze coordinates can only be determined for one screen. To use a three screen set up one needs to use head motion and position data measured by a separate motion tracker. One also needs to use the head referenced position data (HREF). HREF measures eye rotation angles relative to the head. However, the output data is not a rotation angle of the eye but x and y coordinates which define a point on the HREF plane which is a constant 15,000 units away from the participant. The eye rotation angle can then be determined from the coordinates using the following equation provided in the Eyelink II manual:

angle = acos((f*f + x1*x2 + y1*y2) / (sqrt((f*f + x1*x1 + y1*y1) * (f*f + x2*x2 + y2*y2)));

f is the constant distance from the participants' eyes to the HREF plane, and x and y are the HREF x and y coordinate values. During the calibration the HREF values were scaled and from there you can related the HREF coordinates to real world coordinates. A new calibration procedure was required to ensure that the HREF values are scaled appropriately for the three screen environment I used. A member of my supervisory team had managed to develop a calibration procedure for three screens, as mentioned in the experimental procedure subsection, but we had not yet developed a way to scale the HREF coordinates after the calibration procedure was completed. The supervisory team, in collaboration with international experts, is currently working on tackling this challenge and offering flexible and robust open source solutions to the vision science community. To give an idea of how much participants shifted their attention I analysed the amount head movements participants made.

Head movements

I analysed head movements by summing the change in angle of the head between each sample recorded on the trial. The summed head movements were then analysed with LMMs using the same models as those used for the crossing decisions for both experiments. As these analyses were additional exploratory analyses the results can be found in Appendix C.

1.2.7 Experiment Design

In this experiment 30 trials were presented to participants, split into two blocks of 15 trials. Each trial lasted 15 seconds. For one block the cars travelled from left to right, and on the other cars travelled from right to left. The view of the cars that travelled from left to right were slightly obscured by trees (Figure 1.2b). The view of the cars that travelled from right to left was not obstructed. On each trial two cars were presented. For half the trials both cars travelled along one lane, either the near or the far lane. For the other half of the trials the cars travelled in both lanes but in the same direction. Four different car models were presented randomly

– Audi S4, Toyota Prius, Volkswagen Polo, and Volkswagen Beetle. All car models were coloured white, except for the Polo that was coloured red. All cars in a given trial were of the same model. The speed of the cars was randomly set to either 30 or 70km/h but all cars presented on a given trial moved at the same speed. A summary of the conditions are presented in Figure 1.3 with the exception of car speed and car model.

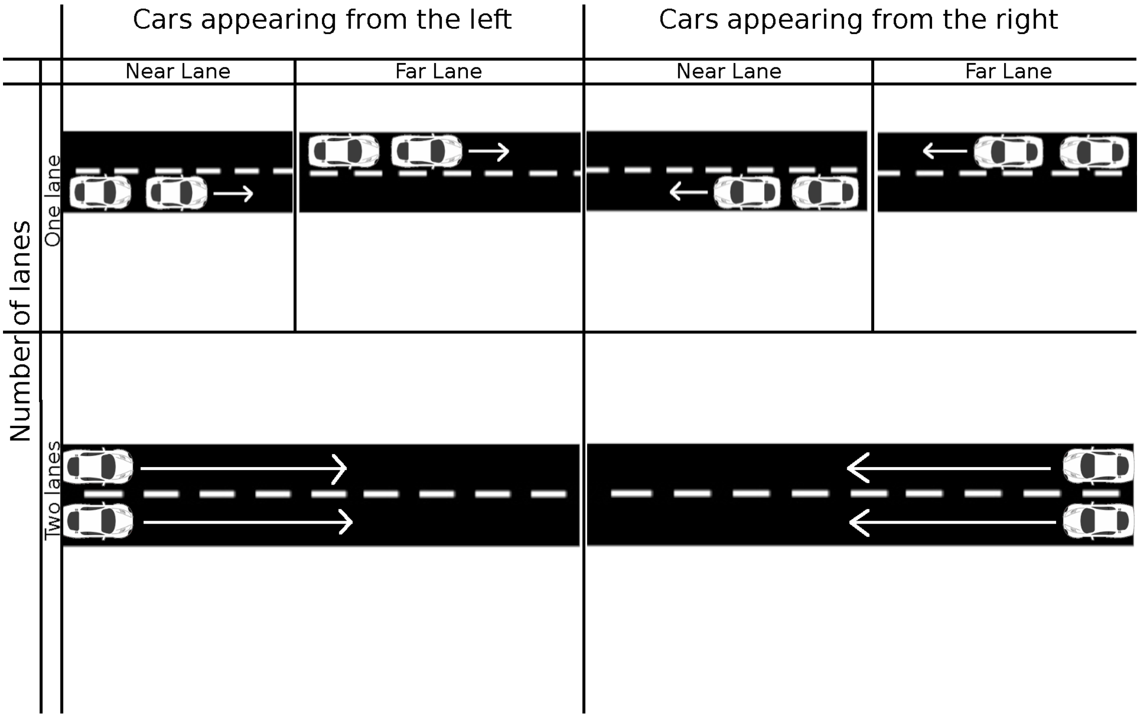


Figure 1.3: Conditions for Experiment 1

1.3 Results – Executive function tests

Bootstrap t-tests and Bayes factors indicated that OAs and YAs had similar walking speeds (Table 1.1, Figure 1.4H), accuracy in the RMA task (Table 1.1, Figure 1.4A), local and global switch costs on RMA task accuracy (Table 1.1, Figure 1.4C, and E respectively), and BADS zoo map scores (Table 1.1, Figure 1.4G). Older adults showed significantly longer response times on the RMA task than YAs (Table 1.1, Figure 1.4B), as well as larger local and global switch costs on their RMA RTs than YAs (Table 1.1, Figure 1.4D, and F respectively).

	Means	*t-value*	*df*	*CIs*	*p-value*	*d*	*Bayes Factor*
Walk speed	YA:1.33, OA:1.37	0.12	17.51	[-0.10, 0.12]	0.903	0.08	0.37
RMA score	YA:0.95, OA:0.94	-0.44	11.34	[-0.07, 0.05]	0.670	0.15	0.30
Local switch cost on RMA score	YA:0.04, OA:0.05	0.47	12.53	[-0.03, 0.41]	0.684	0.13	0.31
Global switch cost on RMA score	YA:0.03, OA:0.03	-0.65	24.87	[-0.02, 0.01]	0.505	0.20	0.30
BADS zoo map score	YA:3.10, OA:2.63	-1.68	12.25	[-1.77, 0.16]	0.099	0.42	1.63
RMA RT	YA:1.42, OA:1.93	3.05	17.36	[0.17, 0.85]	0.005	0.64	27.29
Local switch cost on RMA RT	YA:0.23, OA:0.38	2.68	10.79	[0.03, 0.34]	0.022	0.56	2.25
Global switch cost on RMA RT	YA:0.40, OA:0.94	2.98	14.39	[0.14, 0.74]	0.008	0.70	18.17

Table 1.1: Means, bootstrap t-tests and Bayes Factors for the differences between OAs and YAs for the different executive function measures, testing attention switching ability (local and global switch costs and RMA performance), spatial planning ability (BADS zoo map test), and walking speed. Significant results are highlighted in blue.

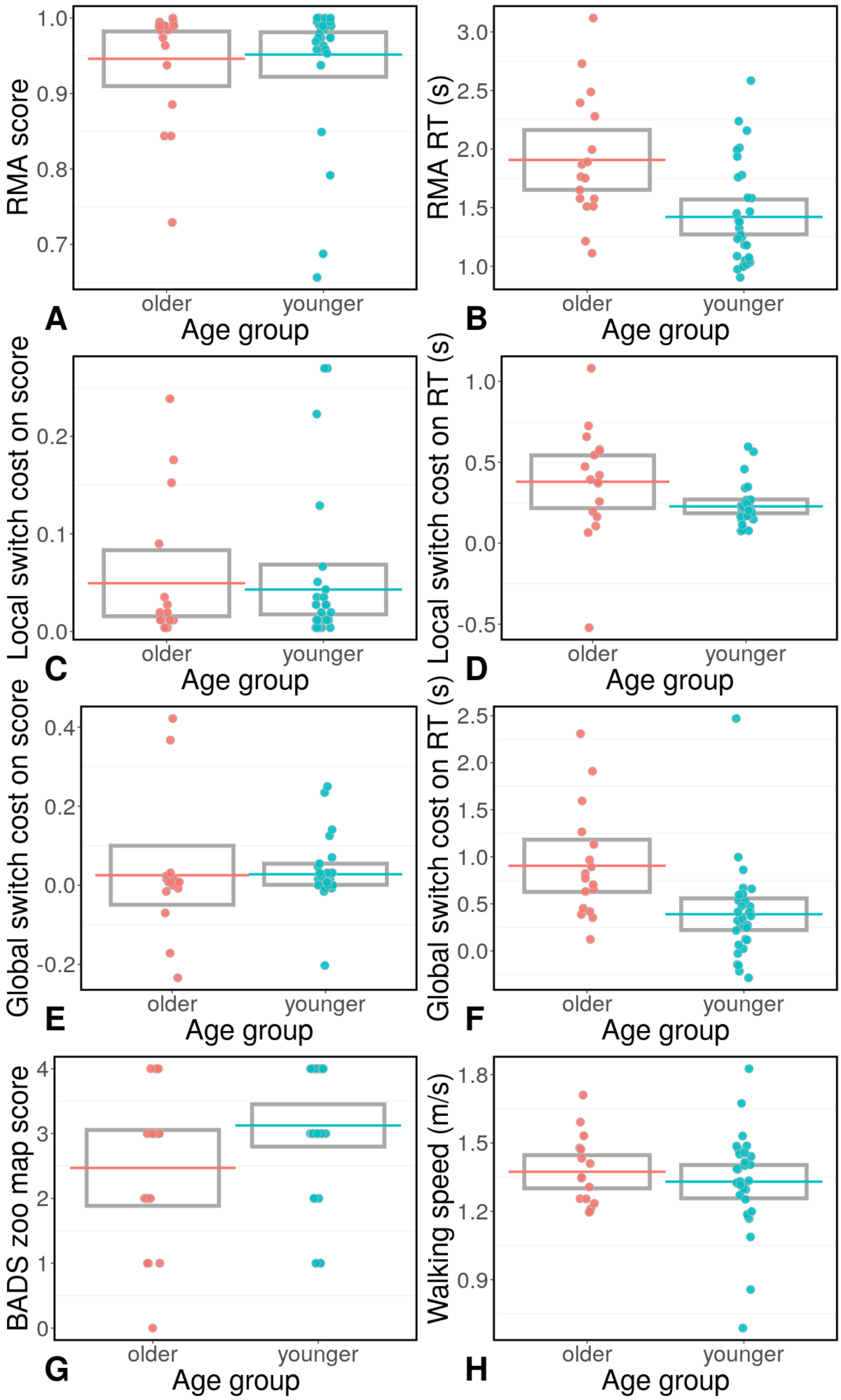


Figure 1.4: Executive function results. Participants' accuracy (A) and RTs (B) on the RMA task. Local switch costs on RMA task accuracy (C) and RT (D). Global switch costs on RMA task accuracy (E), and RT (F). Participants' BADS zoo map scores (G). Participants' walking speed (H). In all panels the red colours indicate OAs and blue colours indicate YAs.

1.4 Results – Experiment 1

1.4.1 Impact of car speed on crossing behaviour

There were main effects of car speed on the number of crossing decisions and TTI (number of crossing decisions: β=0.39, SE=0.17, t=2.32 ,p=0.020, Table A.1; TTI:β=-1.17, SE=0.53, t=-2.19, p=0.029, Table A.27). All participants made more crossing decisions, and had shorter TTI when cars travelled faster compared to slower. This reduction in TTI was larger for OAs, and participants with lower BADS zoo map scores (Table A.27-A.31; Figure 1.5B and A respectively).

The LMM performed on the duration of key presses showed interactions between age and car speed, as well as spatial planning ability and car speed (age: β=-1.16, SE=0.35, t=-3.37, p=0.001; BADS: β=-0.53, SE=0.15, t=-3.36, p=0.000, Table A.2). OAs made longer key presses when cars travelled quickly compared to slowly (Table A.4, Figure A.4C). YAs made shorter key presses when cars travelled quickly compared to slowly (Table A.3, Figure A.4C). Participants with higher BADS zoo map scores made shorter key presses when cars moved faster compared to when cars moved slower (Table A.5, Figure A.4D). Participants with low BADS zoo map scores made longer key presses when cars travelled faster than when cars travelled slower (Table A.6, Figure A.4D).

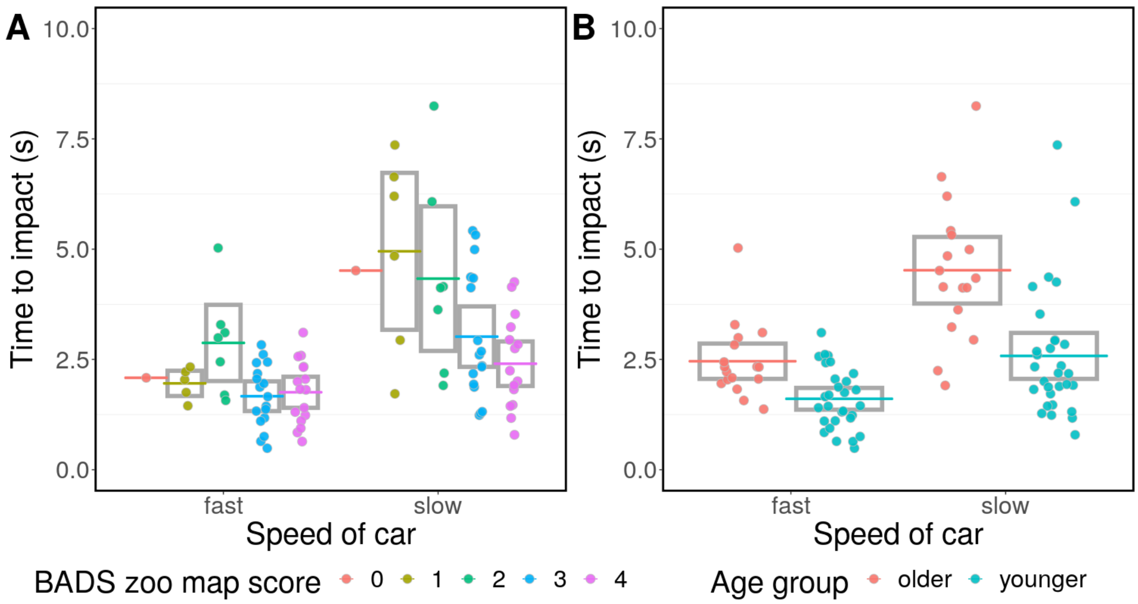


Figure 1.5: The effect of car speed on TTI for OAs and YAs (B), and for participants with low and participants with high BADS zoo map scores (A).

1.4.2 Impacts of cars coming from an obscured view

The LMMs showed a main effect of cars appearing from an obscured view on the number of crossing decisions, and TTI (number of crossing decisions: β=-0.45, SE=0.17, t=-2.72, p=0.007, Table A.1; TTI: β=-1.85, SE=0.52, t=-3.53, p=0.000, Table A.27). All participants decreased their number of crossing decisions and TTI. This decrease in TTI was greater for OAs than YAs, and greater for participants with low BADS zoo map scores than participants with high BADS zoo map scores (Table A.27-A.31; Figure 1.6).

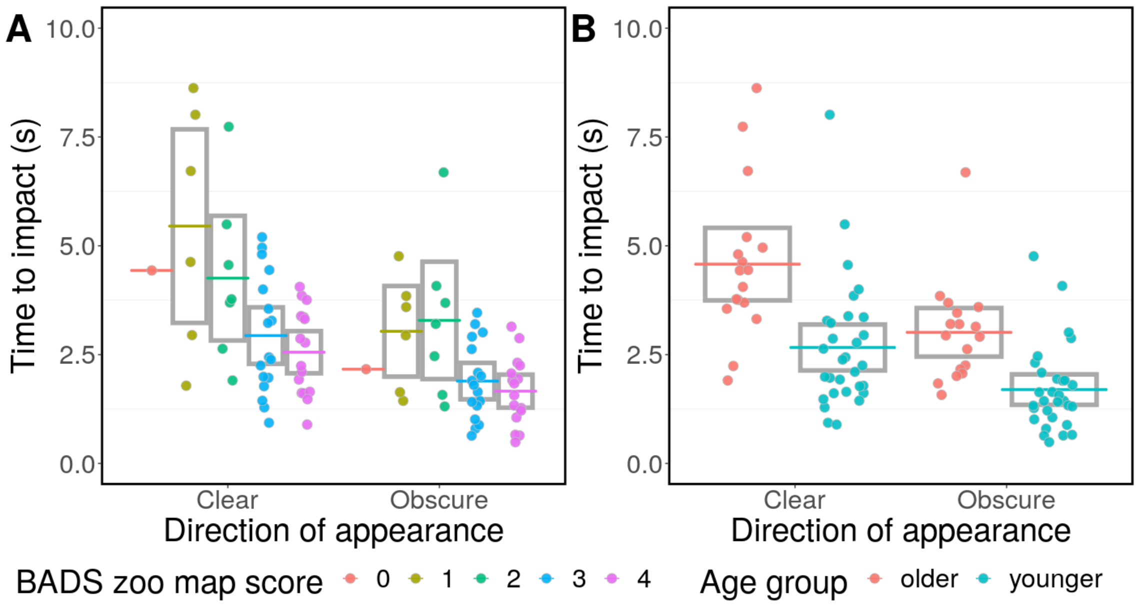


Figure 1.6: The effect of cars coming from an obscured view on the TTI for OAs and YAs (B), and participants with high and low BADS zoo map scores (A)

1.4.3 Number of lanes

There were no significant effects of cars coming from two lanes compared to one lane. For a summary of these results see Tables A.1, A.2, and A.27 in Appendix C.

1.4.4 Near or far lane

There were no significant effects of which lane the cars travelled in. For a summary of these results see Tables A.1, A.2, and A.27 in Appendix C.

1.5 Discussion – Experiment 1

1.5.1 Do OAs and participants with poorer executive functioning abilities show riskier crossing behaviour when task complexity is increased?

The results from Experiment 1 reveal that all participants show riskier crossing behaviour when task complexity is increased, as participants reduced their TTI when task complexity increased. I consider a reduction in TTI to be risky as for all participants as decreasing their TTI would leave participants less time to cross at a real road crossing. The impact of increased task complexity was greater for OAs and participants with poorer executive functioning abilities than YAs and participants with better executive functioning abilities. The increase in risky crossing behaviour did not occur for all conditions. The increase in risky crossing behaviour occurred when cars travelled quickly, and when the viewpoint of the cars was obscured. The increase did not occur when cars travelled in the far lane or both lanes simultaneously.

1.5.2 Conditions that impact negatively on crossing behaviour

When cars came from an obscured viewpoint, the cars were closer to participants when they became visible, leaving participants less time to make a decision on whether they could cross safely. Similarly, when cars travel faster this leaves participants less time to make a decision on whether they should cross safely. Therefore, the vehicles in both conditions would have been closer to the participants when they made their crossing decision, resulting in a reduction in their TTI. The reason OAs may have been more impacted by cars travelling quickly or from an obscured viewpoint than YAs is that OAs had longer RTs than YAs. This was determined from the RMA task where OAs had longer RTs than YAs across the whole task. Therefore, a larger reduction in TTI compared to YAs may be due to OAs reacting slower than YAs. This behaviour would be risky as OAs are not able to properly take into account their slower RTs in difficult situations such as when cars come from an obscured view or travelled quickly. Further research should be done to determine how aware OAs are of their declining mental and physical functioning and if they attempt to account for these in their everyday decisions.

An alternate explanation for the larger reduction in TTI for OAs may be because OAs have slower visual processing than YAs (Bock, Brustio, & Borisova, 2015; Di Fabio, Greany, & Zampieri, 2003; Di Fabio et al., 2005; Salthouse, 1996; Ritchie, Tucker-Drob, & Deary, 2014). If OAs have slower processing speeds then they might need to look at cars for longer to determine their speed and an appropriate TTI. Therefore, when cars travel quickly, or from an obscured viewpoint the cars would be closer to the participants when they released the button leading to a shorter TTI compared to when cars travel slowly or from a clear viewpoint.

Even though OAs were more impacted by cars coming from an obscured view and cars travelling quickly, in that they reduced their TTI in both conditions, they still left more TTI than YAs in all situations. Moreover, YAs also reduced their TTI when cars travel quickly or come from an obscured view. This reduction in TTI suggests that YAs also have difficulties in these situations and these may be the sorts of situations that lead to YAs being involved in pedestrian accidents. More research should be done to determine which situations not only children and OAs have accidents in but YAs as well, and as a result what infrastructure or training methods can be developed to improve the safety of all road users.

Similarly to OAs, participants with poorer executive functioning abilities, specifically spatial planning abilities showed a greater reduction in TTI than participants with better spatial planning abilities. This suggests participants with poorer spatial planning abilities were more impacted by cars travelling quickly or coming from an obscured view than participants with better spatial planning abilities. Participants with poorer spatial planning might have been more impacted than participants with better spatial planning abilities in the obscured view and fast car conditions because they are less efficient at executing a plan than participants with better spatial planning abilities (Shallice, 1982; Allain et al., 2005). As they are less efficient at executing the planned action they may not release the button as early as participants with better spatial planning abilities, causing participants with poorer spatial planning abilities to reduce their TTI by more than participants with better spatial planning abilities. Even though the reduction in TTI was greater for participants with poorer spatial planning abilities than participants with better spatial planning abilities, they still left more TTI than participants with better spatial planning abilities. This suggests that although participants with poorer spatial planning abilities were more impacted it was not to the extent where they made riskier crossing decisions than participants with better spatial planning abilities. In a more complex task such as cars travelling from both an obscured direction and a clear direction at the same, where there are more cars to take into account when planning a crossing decision, participants with poorer spatial planning abilities might start to make riskier crossing decisions than participants with better spatial planning abilities.

1.5.3 Conditions that did not impact on crossing behaviour

Increasing task complexity through cars travelling from the far lane or both lanes did not impact on participants' crossing behaviour. If the participants had a more risky strategy when cars travelled in the far lane or on both lanes I would expect them to make more crossing decisions or leave less TTI. However, participants did not change their crossing behaviour when cars travelled in the far lane or on both lanes. Therefore, it seems that all participants are able to make as safe crossing decisions in these situations as in less complex situations such as cars travelling in one lane or the close lane only.

These results contrast to previous findings that OAs make more errors when cars travel in the far lane (Geraghty et al., 2016; Oxley et al., 1997; Dommes, Cavallo, Dubuisson, Tournier, & Vienne, 2014). The previous findings that OAs make more errors in the far lane may, therefore, result from keeping track of cars coming from both directions rather than the number or type of lane.

When cars travel in the far lane or in both lanes the time participants have to determine a safe TTI is not reduced, therefore leaving participants with enough time to determine the TTI they require to cross. The amount of objects that participants have to keep track of also does not change so the complexity of the task in these two conditions is not increased. In conditions where there are more cars, cars travel from both directions, or pedestrian distractors are present may provide more difficulty for participants by increasing the amount of information participants need to hold in their working memory. For example, when cars travel in both directions and both lanes participants need to initially look towards one side of the road, take in the position of the cars, make an estimate of their speed so they can predict when the cars would reach the participants' position. All this information has to be taken in and held in the memory while participants look to the other side of the road and make the same judgements about the cars coming from the left. Participants then also need to plan when they would cross the road. Given OAs typically show a decline in working memory capacity (Schneider-Garces et al., 2010; Bopp & Verhaeghen, 2005) and planning abilities (Phillips, Gilhooly, Logie, Sala, & Wynn, 2003) they may find it difficult to hold the necessary amount of information and plan out the cars' trajectories when cars travel from both directions, while ignoring pedestrian distractors. Therefore, OAs might have a particular challenge with making crossing decisions when there are more objects to keep track of in a scene such as when cars travel from both directions, traffic density is high or pedestrian distractors are present. I investigated the impact of each of these three conditions in Experiment 2.

1.5.4 Summary Experiment 1

In sum, I added to the results in Chapter 3 by investigating the impact of task complexity on crossing decisions. I found that all participants have difficulties when task complexity is increased by cars travelling quickly or from an obscured viewpoint as all participants reduced their TTI. I also found that participants were not impacted by increasing the task complexity through cars travelling in the far lane or travelling in both lanes.

1.6 Introduction – Experiment 2

In Chapter 3 and in Experiment 1 of this chapter I find that OAs are able to make safe crossing decisions with cars travelling from one direction, irrelevant of whether the cars travel in the near or far lane, or in both lanes. In Chapter 3 I suggested that OAs may have difficulties when the complexity of the task is increased by having cars travel along two directions. Indeed, OAs have previously been shown to make riskier crossing decisions when cars came from two directions (Dommes et al., 2013; Geraghty et al., 2016; Oxley et al., 1997, 2005).

OAs have also been shown to not be as able as YAs at tracking objects when their attention is divided between multiple objects, especially when these objects travel quickly (Tsang, 1998; Trick, Jaspers-Fayer, & Sethi, 2005; Sekuler, McLaughlin, & Yotsumoto, 2008). In road crossing situations there are often varying levels of traffic and distractors such as other pedestrians that individuals have to keep track of or ignore. Even though I find no effect of traffic density on crossing decisions, and eye movement behaviour in Chapter 3, the combination of having to divide attention between cars coming from both directions quickly, and with many cars on the road, OAs may find it more difficult to continue to make safe crossing decisions. In Chapter 3 I found that OAs attention was captured by pedestrian distractors but this was not associated with riskier crossing decisions. Pedestrian distractors may have more of an influence when cars come from both directions as OAs attention will be split between the pedestrian distractors and attending to cars coming from multiple directions, rather than cars just coming from one direction.

In this experiment I assessed the influence of cars travelling from both lanes, cars travelling quickly, traffic density, and the presence of pedestrian distractors on the visual attentional control and the crossing behaviour of OAs and participants with reduced executive functioning abilities. I used the same VR set up as in Experiment 1, but in this experiment cars always travelled along both lanes and I manipulated the car speed, cars travelling from one side or both sides of the road, cars travelling from an obscured or non-obscured viewpoint, traffic density, and the presence of task-irrelevant pedestrian distractors.

As with Experiment 1 the overarching research question was: Do OAs and participants with better executive functioning abilities show riskier crossing behaviour when task complexity is increased than YAs and participants with better executive functioning abilities?

In this experiment I increase task complexity in the following ways:

- Increasing car speed.
- Cars travelling from both the left and right hand sides of the participants.
- Obscuring the viewpoint of the cars.
- Increasing traffic density.
- Having pedestrian distractors present.

1.7 Methods – Experiment 2

All participants, apparatus, and the experimental procedure was the same as in Experiment 1. The statistical analysis is in the Methods for Experiment 1.

1.7.1 Experimental Design

In this experiment 120 trials were presented to participants, split into three blocks of 40 trials, each trial lasted for 15 seconds. On each trial cars travelled along both lanes, the car travel direction was different for each block and the order was altered for each participant. On one block cars travelled from left to right, another from right to left, and one from both directions. The view of the cars that travelled from left to right were slightly obscured by trees. The view of the cars that travelled from right to left was not obstructed. The number of cars presented on each trial varied between two, four, and six cars. On half the trials in each block the car speed was fast (70 km/h) and on the other half the car speed was slow (30 km/h). All cars presented in a trial travelled at the same speed. In half the trials in each block pedestrian avatars were present that walked along the near or far sidewalk, or stood still. The number of pedestrians presented on the trials varied randomly between one and two pedestrians. The same four car models as in Experiment 1 were used in this experiment and were also randomly varied. A summary of the conditions are presented in Figure 1.7 with the exception of car speed.

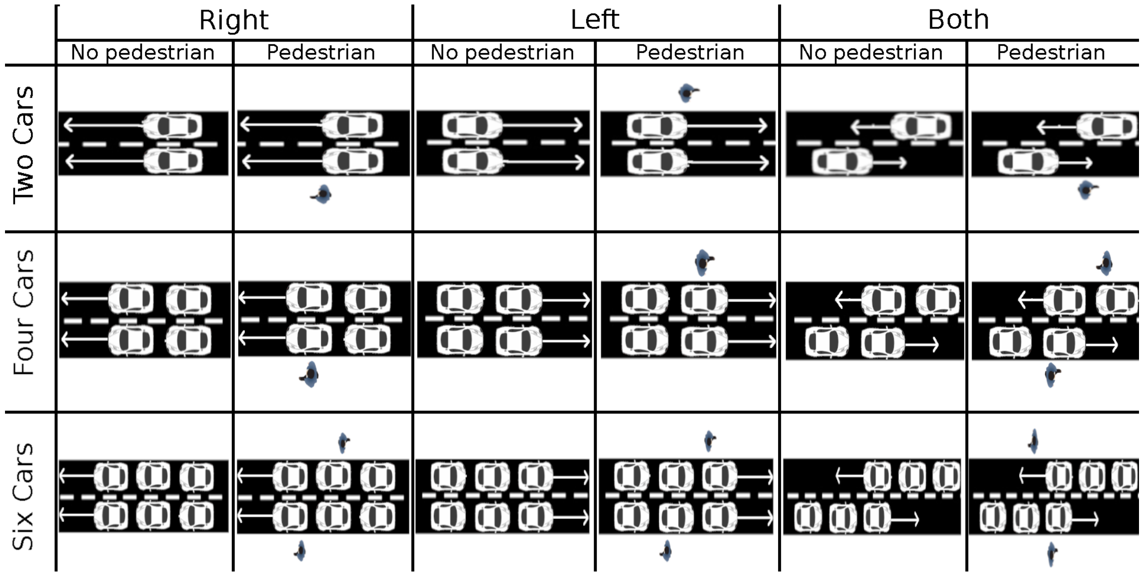


Figure 1.7: Conditions for Experiment 2

1.8 Results – Experiment 2

1.8.1 Impacts of car speed on crossing behaviour

There were main effects of car speed on the number of crossing decisions, duration of key presses, and TTI (number of crossing decisions: β=0.34, SE=0.10, t=3.44, p=0.001, Table A.7; duration of key presses: β=3.57, SE=0.48, t=7.37, p=0.000, Table A.18; TTI: β=-2.32, SE=0.36, t=-6.92, p=0.000, Table A.34). All participants made more crossing decisions, had shorter TTI, and had longer key presses when cars travelled quickly compared to slowly. The decrease in TTI was larger for OAs than YAs, and for participants with lower BADS zoo map scores than participants with higher BADS zoo map scores (Tables A.36, A.35, A.40, and A.39; Figures 1.8B, and D). The increase in the duration of key presses was greater for OAs than YAs, and for participants with larger switch costs (global and local) than participants with smaller switch costs on the RMA task (Tables A.19-A.26; Figures A.8B, E, and F).

The LMM on the number of crossing decisions showed an interaction between age group and car speed, between spatial planning ability and car speed, and between attention switching ability and car speed (age group: β=-0.08, SE=0.04, t=-2.18, p=0.029; BADS: β=-0.07, SE=0.02, t=-4.42, p=0.000; attenion switching: β=-0.29, SE=0.07, t=-3.85, p=0.000, Table A.7). YAs decreased their number of crossing decisions but OAs did not significantly change their number of crossing decisions when cars travelled quickly compared to slowly (Tables A.9, and A.8; Figure 1.8A). Participants with high BADS zoo map scores decreased their number of crossing decisions while participants with low BADS zoo map scores did not significantly change their number of crossing decisions (Tables A.12, and A.13; Figure 1.8C). Participants with larger and participants with smaller local switch costs increased their number of crossing decisions when cars travelled quickly compared to slowly (Figure 1.8E). This increase was larger for participants with larger local switch costs than participants with smaller local switch costs on the RMA task (Tables A.16, and A.17).

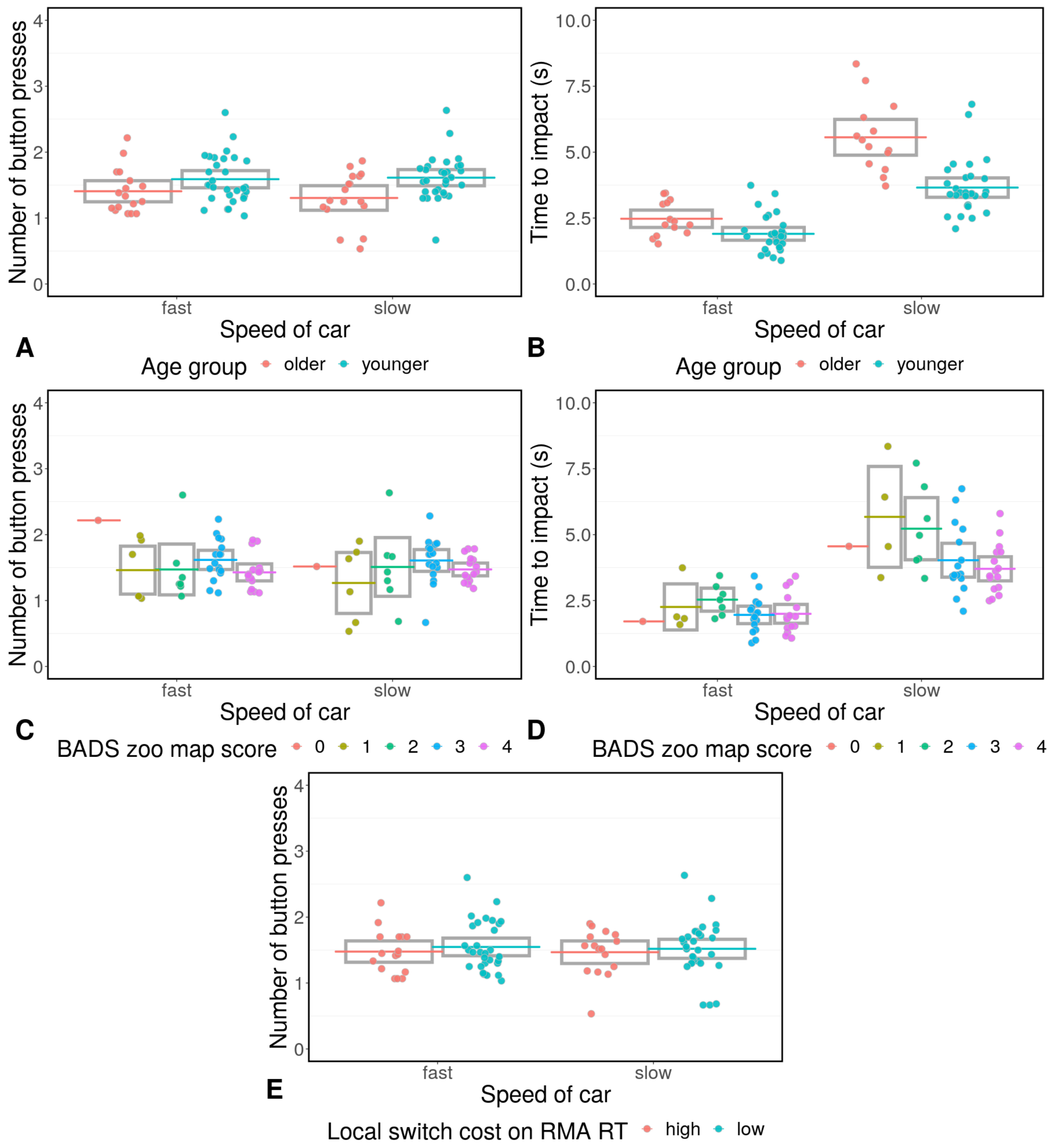


Figure 1.8: The effect of car speed on the number of crossing decisions (A), and TTI (B) for OAs and YAs. The effect of car speed on number of crossing decisions (C), and TTI (D) for participants with low and participants with high scores on the BADS zoo map test. The effect of car speed on the number of crossing decisions (E) for participants with large and small local switch costs on the RMA task.

1.8.2 Impact of cars coming from both directions on crossing behaviour

The LMMs showed main effects of travel direction on the number of crossing decisions participants made (β=0.37, SE=0.12, t=3.03, p=0.002, Table A.7). All participants made more crossing decisions when cars came from both directions compared to just one direction. The difference in the number of crossing decisions was greater for participants with higher BADS zoo map scores than participants with lower scores (Table A.12 and A.13; Figure 1.9C). The LMMs showed an interaction between age group and travel direction on the number of crossing decisions made (β=0.34, SE=0.05, t=7.32, p=0.000, Table A.7). YAs increased their number of crossing decisions while OAs did not significantly change their number of crossing decisions (Tables A.8, and A.9 Figure 1.9A).

The LMM on TTI showed an interaction between age group and car travel direction, between spatial planning ability and car travel direction, and between attention switching ability and car travel direction (age group: β=-0.55, SE=0.17, t=-3.33, p=0.0001; BADS: β=0.15, SE=0.06, t=2.43, p=0.015; attention switching: β=1.85, SE=0.37, t=4.98, p=0.000, Table A.34). All participants had longer TTI when cars travelled from both directions compared to just one direction. The differences were greater for YAs than OAs, for participants with higher BADS zoo map scores than participants with lower scores, and for participants with larger local switch costs than participants with smaller local switch costs on the RMA task (Table A.34-A.40, Figures 1.9B, D, and E).

The LMMs also showed an interaction between age group and car travel direction on the duration of key presses (β=-1.18, SE=0.23, t=-5.21, p=0.000, Table A.18). OAs and YAs both made shorter key presses when cars travelled from both directions compared to one direction. This difference in key press duration was greater for YAs than OAs (Tables A.19, and A.20; Figure A.8C).

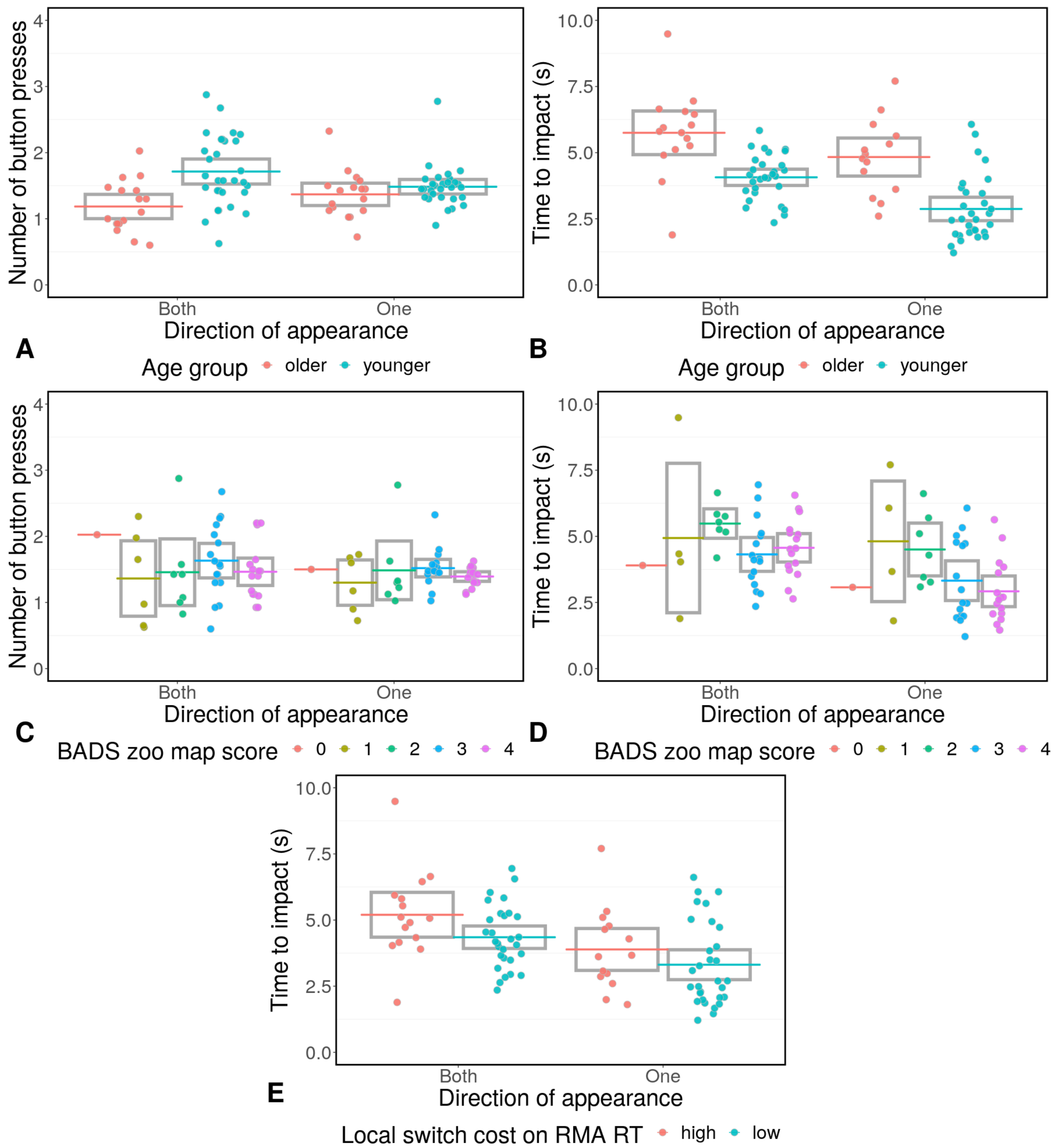


Figure 1.9: The effect of cars coming from both directions on the number of crossing decisions, and TTI for OAs and YAs (A,B); particpants with low and high BADS zoo map scores (C,D). The effect of cars coming from both directions on TTI for participants with small and large local switch costs on the RMA task (E).

1.8.3 Impact of cars coming from an obscured view on crossing behaviour

The LMMs showed main effects of travel direction on the duration of key presses and TTI (duration of key presses: β=1.83, SE=0.59, t=3.13, p=0.002, Table A.18; TTI: β=-1.70, SE=0.39, t=-4.32, p=0.000, Table A.34). All participants increased their duration of key presses and decreased their TTI when cars travelled from an obscured view compared to a clear view. The decrease in TTI was greater for OAs than YAs and for participants with larger local switch costs than participants with smaller local switch costs on the RMA task (Tables A.35-A.38; Figures 1.10A, and B). The LMMs on key press duration showed an interaction between travel direction and age group (β=-0.73, SE=0.22, t=-3.32, p=0.001, Table A.18). OAs increased their key press duration when cars travelled from an obscured viewpoint compared to a clear one (Table A.20, Figure A.8D). YAs did not significantly change their key press duration when cars travelled from an obscured viewpoint compared to a clear one (Tables A.19, Figure A.8D).

The LMM on the number of crossing decisions showed an interaction between attention switching ability and travel direction (β=-0.11, SE=0.05, t=-2.13, p=0.033, Table A.7). Participants with smaller global switch costs increased their number of crossing decisions when cars travelled from an obscured viewpoint compared to a clear one (Table A.15, Figure 1.10C). Participants with larger global switch costs did not significantly change their number of crossing decisions when cars travelled from an obscured viewpoint compared to a clear one (Table A.14, Figure 1.10C).

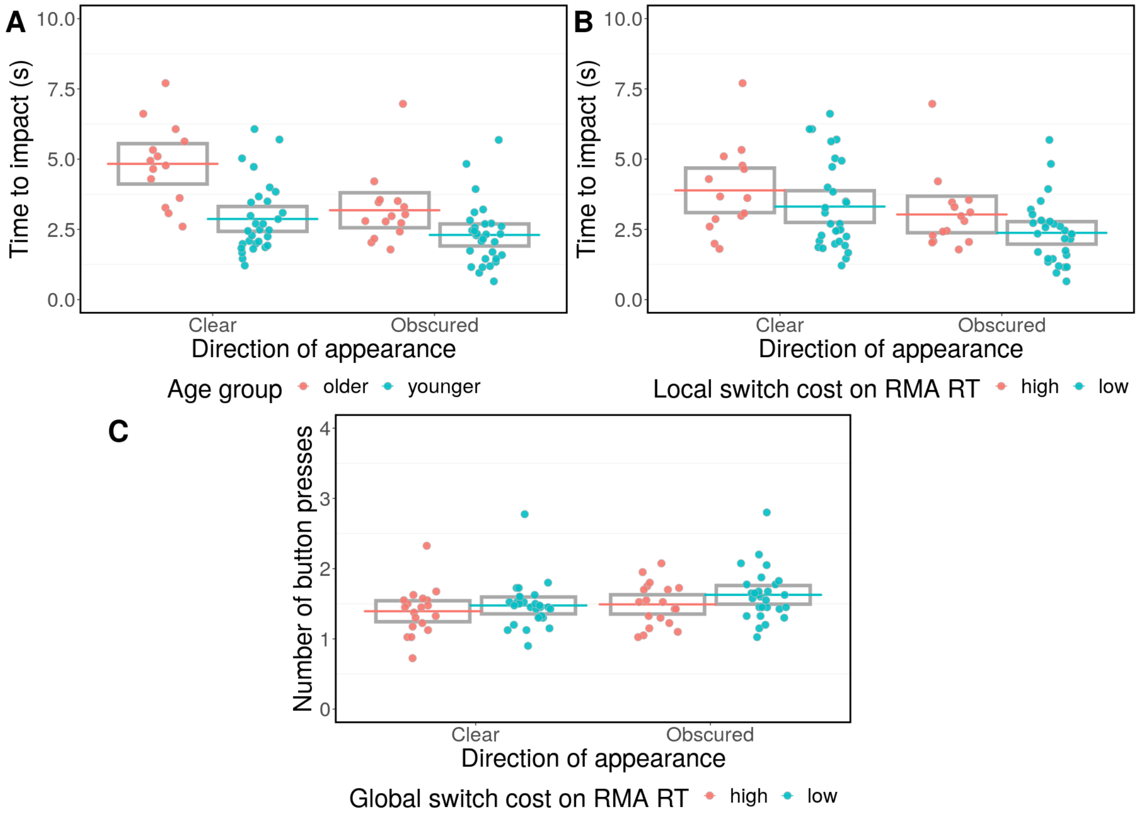


Figure 1.10: The effect of cars coming from an obscured view on the TTI (A) made by OAs and YAs, and participants with large and small local swith costs on the RMA task (B). The effect of cars coming from an obscured view on the number of crossing decisions made by participants with large and small global switch costs on the RMA task (C).

1.8.4 Impact of traffic density on crossing behaviour

There was an interaction between executive functioning ability (spatial planning and attention switching) and traffic density on the number of crossing decisions participants made (BADS: β=-9.65e-03, SE=4.81e-03, t=-2.01, p=0.045; attention switching: β=0.03, SE=0.01, t=2.30, p=0.022, Table A.7). All participants made fewer crossing decisions when traffic density was high compared to when traffic density was low. This decrease was greater for participants with high BADS zoo map scores, and participants with smaller global switch costs compared to participants with low BADS scores, and participants with larger global switch costs (Table A.7, A.12-A.16; Figures 1.11B, and A respectively).

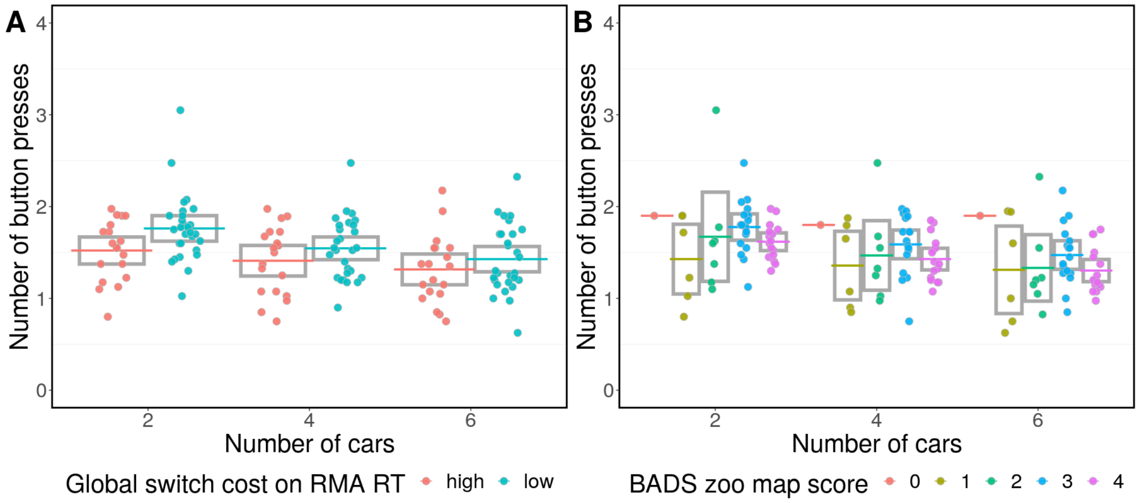


Figure 1.11: The effect of traffic density on the number of crossing decisions for participants with large and small global switch cost scores (A), high and low BADS zoo map scores (B).

1.8.5 Impact of pedestrian distractors on crossing behaviour

I found no effects of pedestrian presence on the number, or duration of key presses participants made, or the TTI participants left (see Tables A.7, A.18, and A.34).

1.9 Discussion – Experiment 2

1.9.1 Do OAs and participants with poorer executive functioning abilities show riskier crossing behaviour when task complexity is increased?

In line with the results from Experiment 1 the results from Experiment 2 reveal that all participants show riskier crossing behaviour when task complexity is increased, as participants reduced their TTI when task complexity increased. The impact of increased task complexity was again greater for OAs and participants with poorer executive functioning abilities than YAs and participants with better executive functioning abilities. The increase in risky crossing behaviour did not occur for all the ways in which task complexity was modulated. The increase in risky crossing behaviour occurred when cars travelled quickly, and when the viewpoint of the cars was obscured. The increase did not occur when cars travelled from both directions, traffic density was high, and pedestrian distractors were present.

1.9.2 Conditions that negatively impact on crossing behaviour

As mentioned in Experiment 1 when cars travel faster or from an obscured direction the time participants have to determine a safe TTI is reduced due to the cars moving faster or the cars are closer to the participants when they become visible. As discussed in Experiment 1, reasons for the riskier behaviour come from participants having less time to react or to process the speed of the cars. Another reason for this behaviour may come from evidence showing that participants mainly base their time to contact judgements on distance rather than speed (Andrea, Fildes, & Triggs, 2000; Hunt, Harper, & Lie, 2011; Connelly, Conaglen, Parsonson, & Isler, 1998; Simpson, Johnston, & Richardson, 2003). Therefore, participants in this experiment may be releasing the button when the cars reach a certain point along the road, irrelevant of the speed of the vehicles. Releasing the button when cars get to this point along the road may give safe TTIs when cars are travelling slowly but not when they are travelling quickly. Had participants focused on the speed of the vehicles they would have realised that they needed to release the button earlier, which would have reduced their TTI. Training participants to use both speed and distance information may help participants adapt their safe crossing distance to different car speeds, and improve the safety of their crossing behaviour.

In the case where the viewpoint of the cars was obscured the distance participants decided was safe was forcibly reduced. The safest strategy in this situation would have been to not cross at all or release the button prior to the appearance of the car. In a real road crossing situation participants may not have crossed in a place where their view of the cars is obscured but in a laboratory setting they may feel they need to make a crossing decision, as they may feel that is what is expected of them. Future research investigating the differences between crossing decisions in a laboratory setting and a real road crossing would need to be conducted to determine if participants feel the need to cross more often in the laboratory.

Looking specifically at when cars travelled quickly, in Experiment 1 I found that even though participants with poorer spatial planning abilities were more impacted than participants with better spatial planning abilities, they still had longer TTI than participants with better spatial planning abilities. In this experiment participants with poorer spatial planning abilities reduced their TTI to a point where it was similar to the amount of TTI left by participants with better spatial planning abilities. As discussed in Experiment 1 participants with poorer spatial planning abilities may have longer TTI than participants with better spatial planning abilities because they might be taking into account their slower ability to plan or execute their plans. In this experiment participants with poorer spatial planning abilities had the same TTI as participants with better spatial planning abilities. This suggests participants with poorer spatial planning are no longer able to compensate for their slower execution or planning, perhaps as a result of having to take into account both cars travelling from both directions and cars travelling quickly. Therefore, individuals with poorer spatial planning abilities may be more at risk when cars travel quickly than individuals with better spatial planning abilities as they are no longer able to take the extra time they need to cross safely.

When cars travelled quickly all participants reduced their TTI but OAs did not change their number of crossing decisions while YAs decreased their number of crossing decisions. Shorter TTI would increase the likelihood of an accident as it would leave participants less time to cross in a real road crossing. YAs might be mitigating this increased likelihood of an accident by making fewer crossing decisions, therefore reducing their likelihood of an accident by reducing their exposure (Keall, 1995). OAs are not mitigating the increased likelihood of an accident resulting from a reduced TTI by reducing their exposure as YAs do. Therefore, the likelihood of an accident may be higher for OAs than YAs when cars travel quickly.

When cars travelled from an obscured viewpoint I found that participants with poorer attention switching abilities were more impacted than participants with better attention switching abilities, as they reduced their TTI by more than participants with better attention switching abilities. As participants with poorer attention switching abilities were typically OAs, the larger reduction in TTI for participants with poorer attention switching abilities may also result from the slower RTs among OAs than YAs.

1.9.3 Conditions that do not impact or impact positively on crossing behaviour

When cars travelled from both directions, traffic density was high, or pedestrians were present, participants' crossing behaviour did not become more risky as participants did not decrease their TTI or increase their number of crossing decisions in these conditions. When traffic density was high and when cars travelled from both directions participants tended to behave more cautiously as they either reduced their number of crossing decisions or increased their TTI in these conditions.

When cars travelled from both directions, traffic density was high or pedestrians were present the task complexity is increased for the participants as there are more objects in the scene that participants have to keep track of. For example, when cars travel in both directions and both lanes participants need to initially look towards one side of the road, take in the position of the cars, make an estimate of their speed so they can predict when the cars would reach the participants position, and ignore pedestrian distractors. All this information has to be taken in and held in the memory while participants look to the other side of the road and make the same judgements about the cars coming from the left. Therefore, the working memory load for the participants is higher in these conditions than when cars come from one direction, no pedestrian distractors are present or traffic density is low. Despite the increased working memory load all participants were still able to maintain the same level of TTI, or had longer TTI compared to when the task complexity was not as high. This was even the case for OAs and participants with poorer executive functioning abilities that are known to have smaller working memory capacities than YAs and participants with better executive functioning abilities (Schneider-Garces et al., 2010; Bopp & Verhaeghen, 2005; Phillips et al., 2003; Carpenter, Just, & Shell, 1990; Owen, Downes, Sahakian, Polkey, & Robbins, 1990; Welsh, Cicerello, Cuneo, & Brennan, 1995). However, when cars appeared from both directions and pedestrians were present there was only one to two additional objects that participants had to keep track of compared to when cars appeared from on direction or no pedestrians were present. Therefore, these conditions may not have increased the working memory load enough to exceed the working memory capacity of OAs and participants with poorer executive functioning.

When traffic density increased the number of cars increased from two to a maximum of six cars. This would be four additional items participants had to keep track of. However, as all the cars travelled together participants may have visually grouped the cars and so treated them as one object (Wertheimer, 1923; Palmer, 1992; Gillam, 1992). This would mean that the working memory load on the participants would not have increased with an increase in traffic density and the task would not have been more complex. Future research should be done to investigate the role of working memory capacity in realistic scenarios and what the working memory capacity limit is for OAs and participants with poorer executive functions in these scenerios.

Participants might be better at identifying that a road crossing situation is more dangerous when there are more objects in the scene for example when cars appear from both directions, than when cars travel quickly or from an obscured viewpoint. If participants identify situations such as high traffic, cars coming from both directions, or pedestrian being present as dangerous then they would behave more cautiously and increase their TTI or reduce their number of crossing decisions. By contrast, if participants are less able to identify that cars travelling quickly or from an obscure viewpoint are dangerous situations than conditions where there are more objects on the screen, they may not behave more cautiously. Future research should determine whether participants find particular scenarios easier to determine the level of danger present and how this affects participants' crossing behaviour.

The findings for cars travelling from both directions are in contrast to the findings in the literature that OAs and participants with reduced executive functions made riskier decisions when cars travel along both directions (Geraghty et al., 2016; Dommes et al., 2013). This may be due to the current experiment only having one wave of cars appear on the trial with a consistent gap between them. Dommes et al. (2013) had two waves of cars at different speeds and varied the gaps between the first and second wave, while Geraghty et al. (2016) used a video recording of a natural scene with natural traffic flow. A natural traffic flow would be more challenging as participants would not be able to just wait until all cars have passed by before making a decision, they would need to cross between two vehicles. OAs may have more difficulties picking appropriate gaps between vehicles. This could be investigated by randomising the gap between the cars and the time points they appear on the trial or by performing the experiment at a real crossing but preventing participants from actually crossing the road to maintain participant safety.

Focusing on the pedestrian distractor condition, participants did not change their crossing behaviour in response to pedestrian distractors being present. These results match those in Chapter 3 where participants' crossing decisions were not impacted by pedestrian distractors. As I were unable to analyse eye tracking data it is unclear whether OAs gaze would have been drawn by pedestrians as in Chapter 3. The results for this experiment may have been similar to those in Chapter 3 in that OAs' gaze may have been captured by the pedestrians but OAs were still able to make safe crossing decisions or OAs may have chosen to gaze at the pedestrians once the cars have passed the OAs or prior to the appearance of the cars. Alternatively, OAs may not have had their gaze captured by pedestrians at all. If pedestrian distractors did not capture the overt attention of OAs then further research should be done to determine why pedestrians do not capture attention.

1.10 Conclusion

In summary, I find that although participants are able to make safe crossing decisions in simple situations, in more complex situations all participants have more difficulties. When cars travelled quickly or from an obscured viewpoint participants, in particular OAs and participants with poorer spatial planning abilities, showed riskier crossing behaviour. These findings can be used to determine whether training methods can be developed for not only OAs but also YAs to see whether this would help them improve the safety of their crossing decisions when cars travel faster. Alternatively, infrastructure changes, such as speed limits, could be implemented in more locations around cities and especially by retirement homes and villages.

Once the eye tracking data is available I will also be able to investigate whether OAs and YAs or participants with different executive functioning abilities have different attentional crossing strategies and how this relates to crossing behaviour. Not only this, but whether participants change their strategies in situations such as when cars travel quickly and if these strategy changes lead to the riskier crossing behaviour. This would also allow us to develop training methods based on the optimum gaze strategy either overall or for specific situations.

Appendix A

Supplementary materials for chapter 4

A.1 Supplementary Figures

A.1.1 Relationship between TTI and DTI

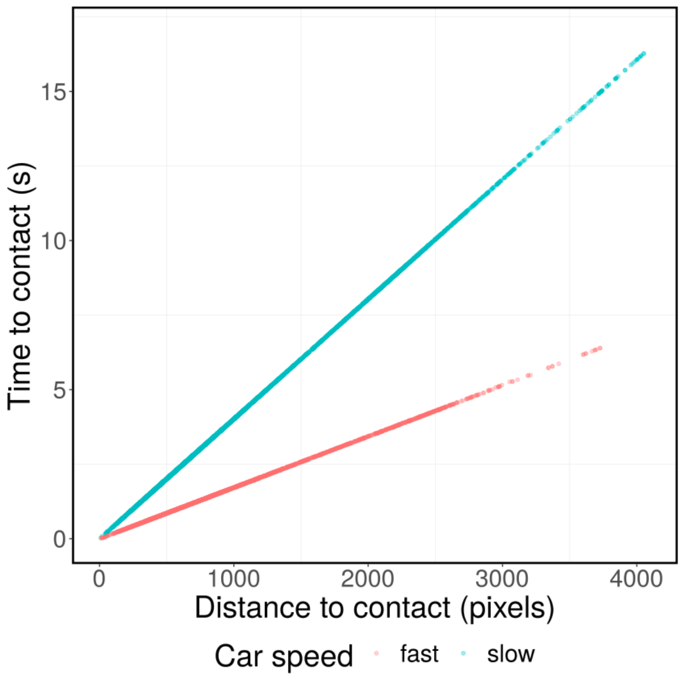


Figure A.1: The relationship between TTI and DTI when cars travelled quickly compared to slowly.

Supplementary Figures for Experiment 1

A.1.2 Main effects

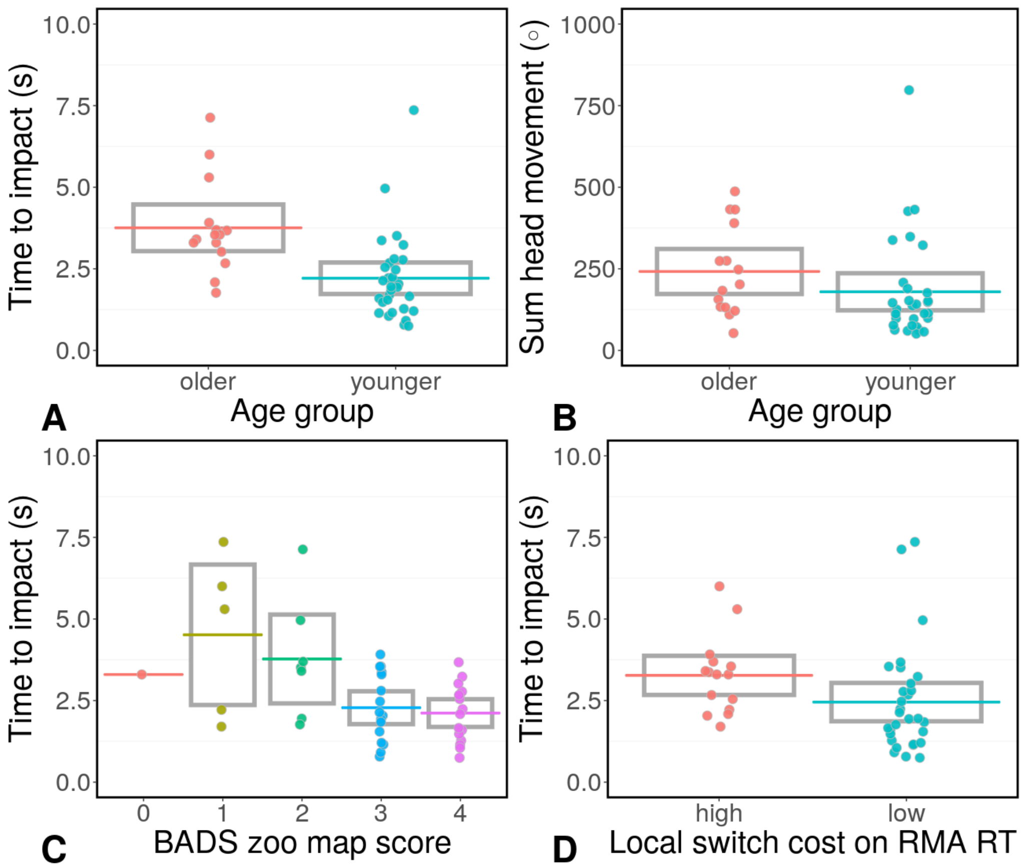


Figure A.2: Main effects of age group (A), BADS zoo map score (C), and local switch costs on the RMA task (D) on TTI. Main effect of age on amount of head movements participants made (B).

OAs had consistently longer TTI than YAs (Table A.27, Figure A.2A), and made shorter key presses than YAs (Table A.2, Figure A.4A). The LMM showed that OAs made more head movements than YAs (Table A.41, Figure A.2B). There was no difference between the number of crossing decisions made by OAs and YAs (Table A.1).

Participants with low BADS zoo map scores had longer TTI, and made shorter key presses than participants with higher scores (TTI: Table A.27, Figure A.2C; key presses: Table A.2, Figure A.4B).

Participants with larger local switch costs had longer TTIs than participants with smaller switch costs (Table A.27, Figure A.2D).

A.1.3 Head Movements

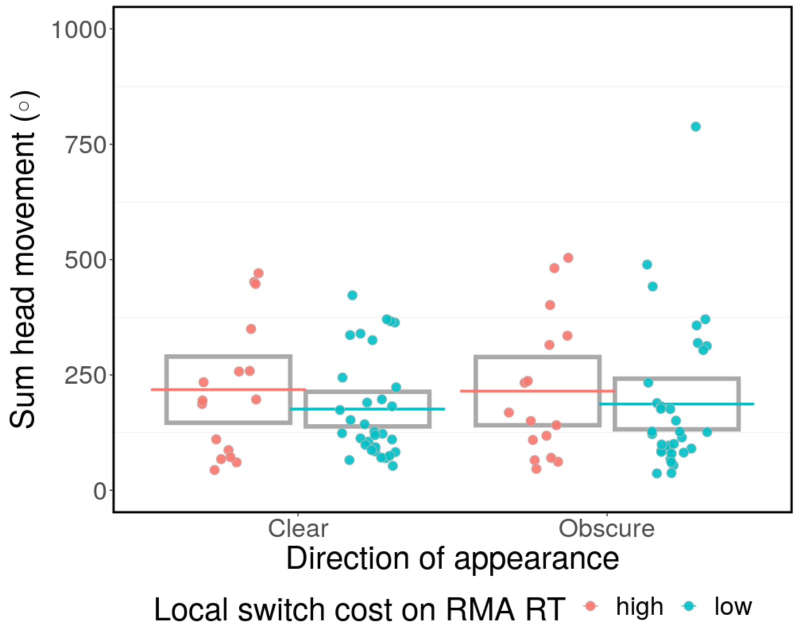


Figure A.3: The effect of travel direction on the number of head movements made by participants with small and participants with large local switch costs on the RMA task.

I analysed the head movements participants made by summing the change in angle of the head between each sample recorded on the trial. The LMM on head movements revealed a significant interaction between attention switching abilities, specifically local switch costs on the RMA task, and cars travelling from an obscured view, but this was not significant at each level of the local switch costs measure (Table A.41, A.43 and A.42; Figure A.3).

A.1.4 Duration of key presses

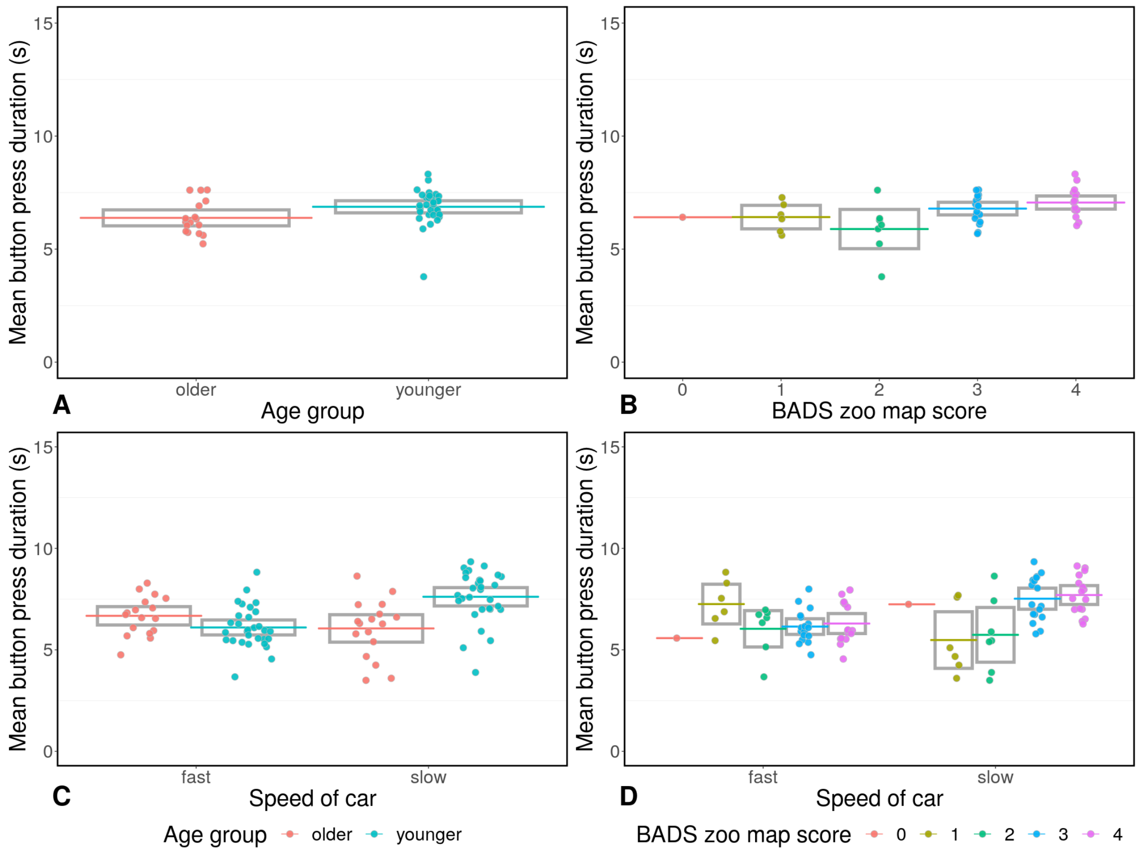


Figure A.4: Main effect of age group (A) and BADS zoo map score (B) on key press duration. Interaction between age group and car speed on key press duration (C). Interaction between BADS zoo map score and car speed on key press duration (D).

A.1.5 RMA RT results

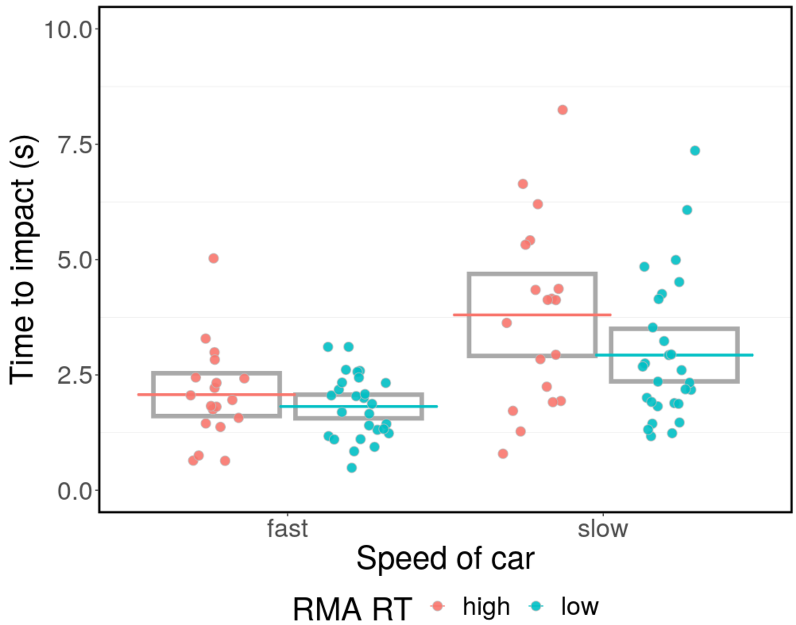


Figure A.5: Interaction between participants' RTs on the RMA task and car speed on TTI.

All participants reduced their TTI when cars travelled quickly compared to slowly (Table A.27). This reduction was greater for participants with slower RTs on the RMA task than participants with faster RTs (Tables A.33, and A.32, Figure A.5).

Supplementary Figures for Experiment 2

A.1.6 Main effects

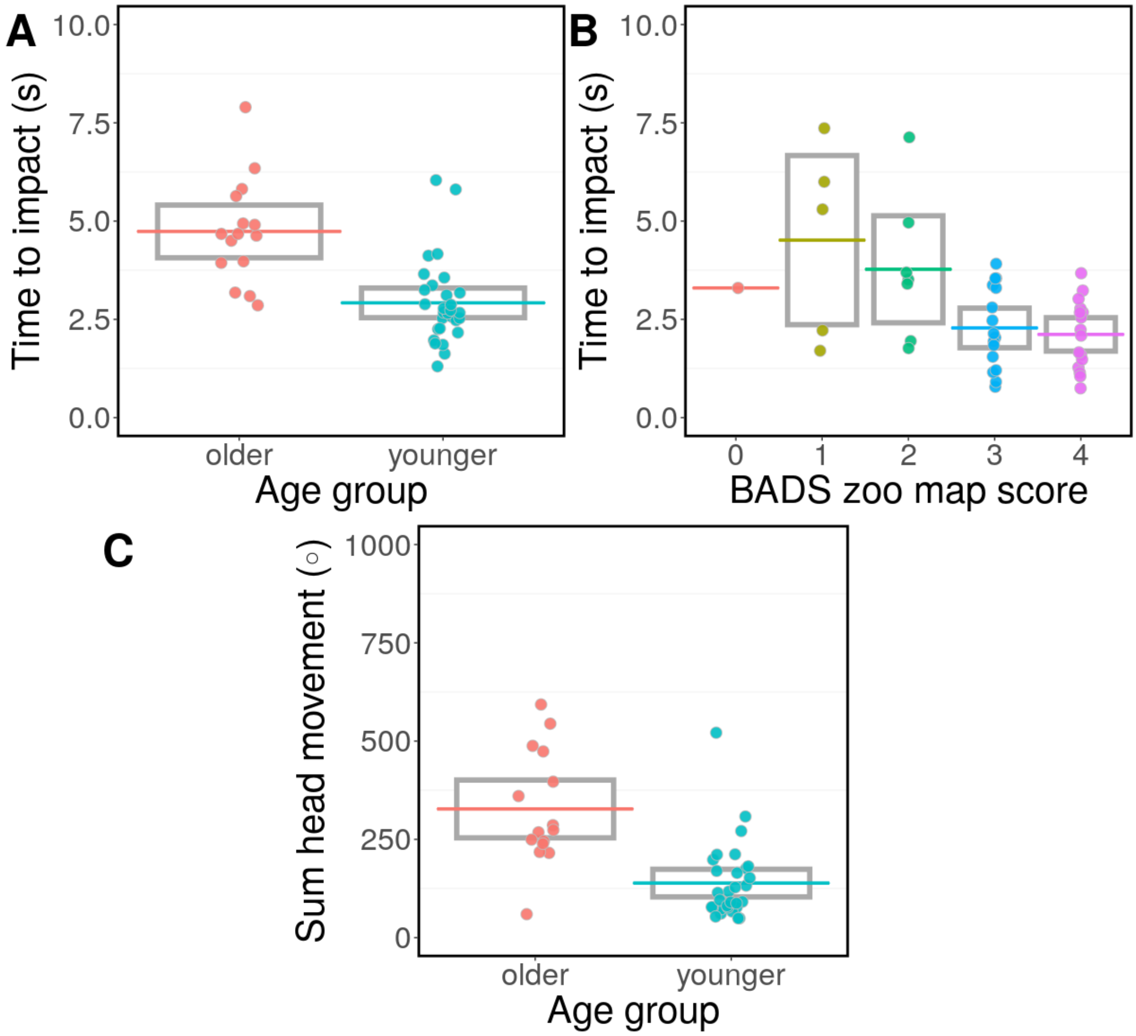


Figure A.6: Main effects of age group (A) and BADS zoo map score (B) on TTI. Main effect of age group on the amount of head movements participants made (C)

There were main effects of age on the duration of key presses, TTI, and amount of head movements participants made (Table A.18, A.34, and A.44). OAs made shorter key presses, had longer TTI, and made more head movements than YAs (Table A.20, A.19, A.36, A.35, A.46, and A.45; Figure A.8A, A.6A, and A.6C).

There were main effects of spatial planning ability on the TTI participants made (Table A.34). Participants with low BADS zoo map scores had shorter TTI than participants with high scores (Table A.40, and A.39; Figure A.6B).

A.1.7 Head Movements

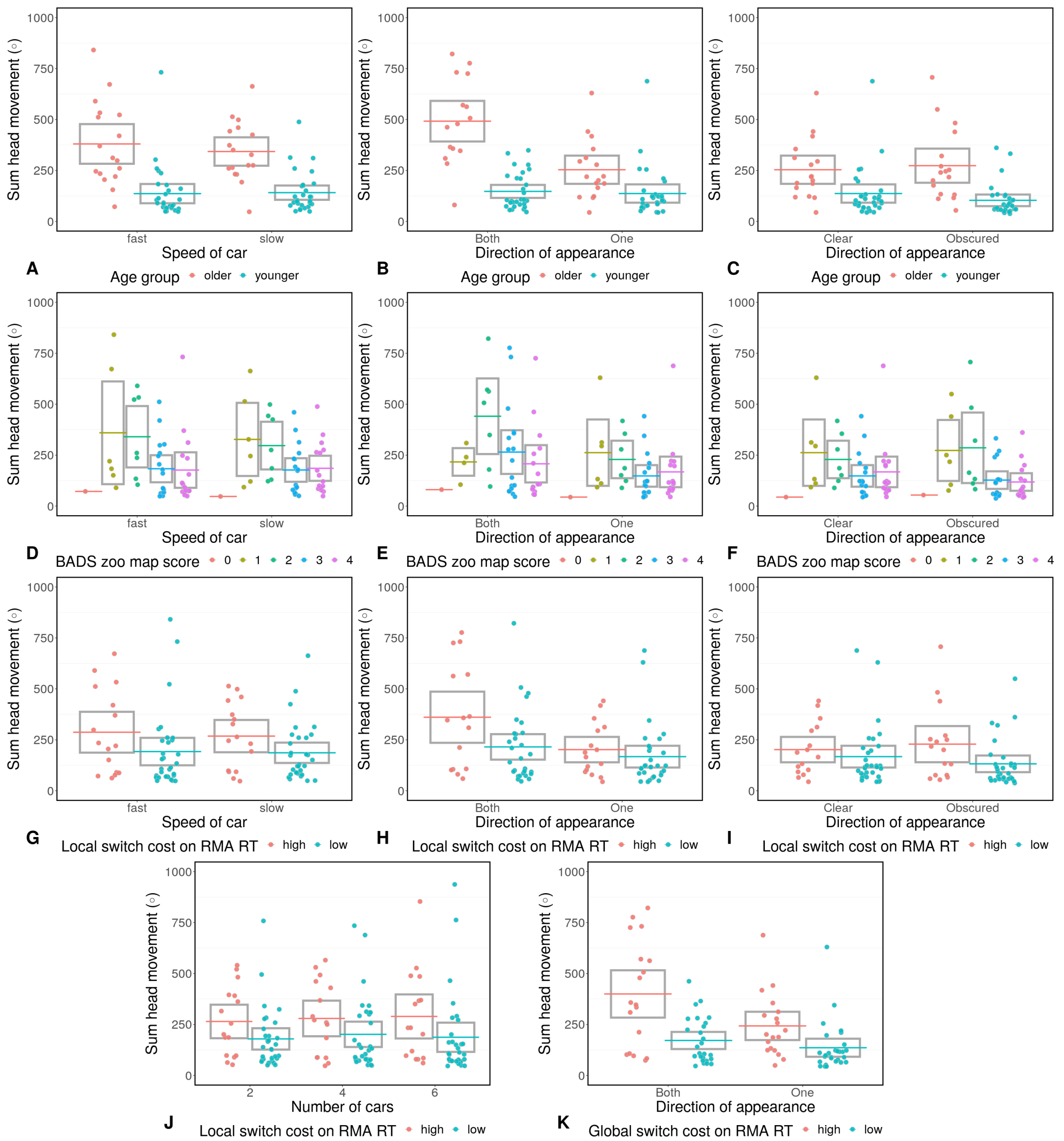


Figure A.7: The effect of car speed on the amount of head movements made by OAs and YAs (A), participants with high and low BADS zoo map scores (D), and participants with small and large local switch costs on the RMA task (G). The effect of cars coming from both directions on the amount of head movements made by OAs and YAS (B), participants with high and low BADS zoo map scores (E), and participants with small and large local and global switch costs on the RMA task (H,K). The effect of cars coming from an obscured viewpoint on the amount of head movements made by OAs and YAs (C), participants with high and low BADS zoo map scores (F), and participants with large and small local switch costs (I). The effect of traffic density on the amount of head movements made by participants with large and small local switch costs (J).

The LMMs on the amount of head movements participants made showed interactions between car speed and age group, and between car speed and spatial planning ability (Table A.44). OAs made more head movements, while YAs made fewer head movements when cars travelled quickly compared to slowly (Tables A.46, and A.45; Figure A.7A). Participants with low BADS zoo map scores made more head movements when cars travelled quickly compared to slowly (Table A.49, Figure A.7D). Participants with high BADS zoo map scores did not significantly change their amount of head movements (Tables A.50, Figure A.7D). The LMM on the amount of head movements participants made also showed a significant interaction between car speed and local switch costs on the RMA task but the simple effects LMMs showed that this was not significant at each level of the local switch costs measure (Tables A.44, A.54, and A.53; Figure A.7G).

The LMMs showed main effects of travel direction on the amount of head movements participants made (Table A.44). All participants made more head movements when cars came from both directions compared to just one direction. The increase in amount head movements was greater for OAs than YAs, for participants with lower BADS zoo map scores, and for participants with larger switch costs (global and local) than participants with smaller switch costs on the RMA task (Tables A.45-A.54; Figures A.7B, E, H, and K).

The LMM on head movements showed a significant interaction between age group and travel direction, spatial planning ability and travel direction, and between attention switching ability and travel direction (Table A.44). Participants with low BADS zoo map scores made more head movements when cars travelled from an obscured view compared to a clear one (Table A.49, Figure A.7F). Participants with high BADS zoo map scores made fewer head movements when cars travelled from an obscured view compared to a clear one (Table A.50, Figure A.7F). The change in head movements was not significant for OAs or YAs, or participants with smaller or larger local switch costs on the RMA task (Table A.46, A.45, A.53, and A.54; Figures A.7C, and I).

The LMM on head movements showed an interaction between traffic density and local switch costs on the RMA task (Table A.44). Participants with small local switch costs made less head movements when traffic density was high compared to when it was low (Table A.53, Figure A.7J). Participants with large local switch costs did not significantly differ in the amount of head movements they made when traffic density was high compared to when traffic density was low (Table A.54, Figure A.7J).

A.1.8 Duration of key presses

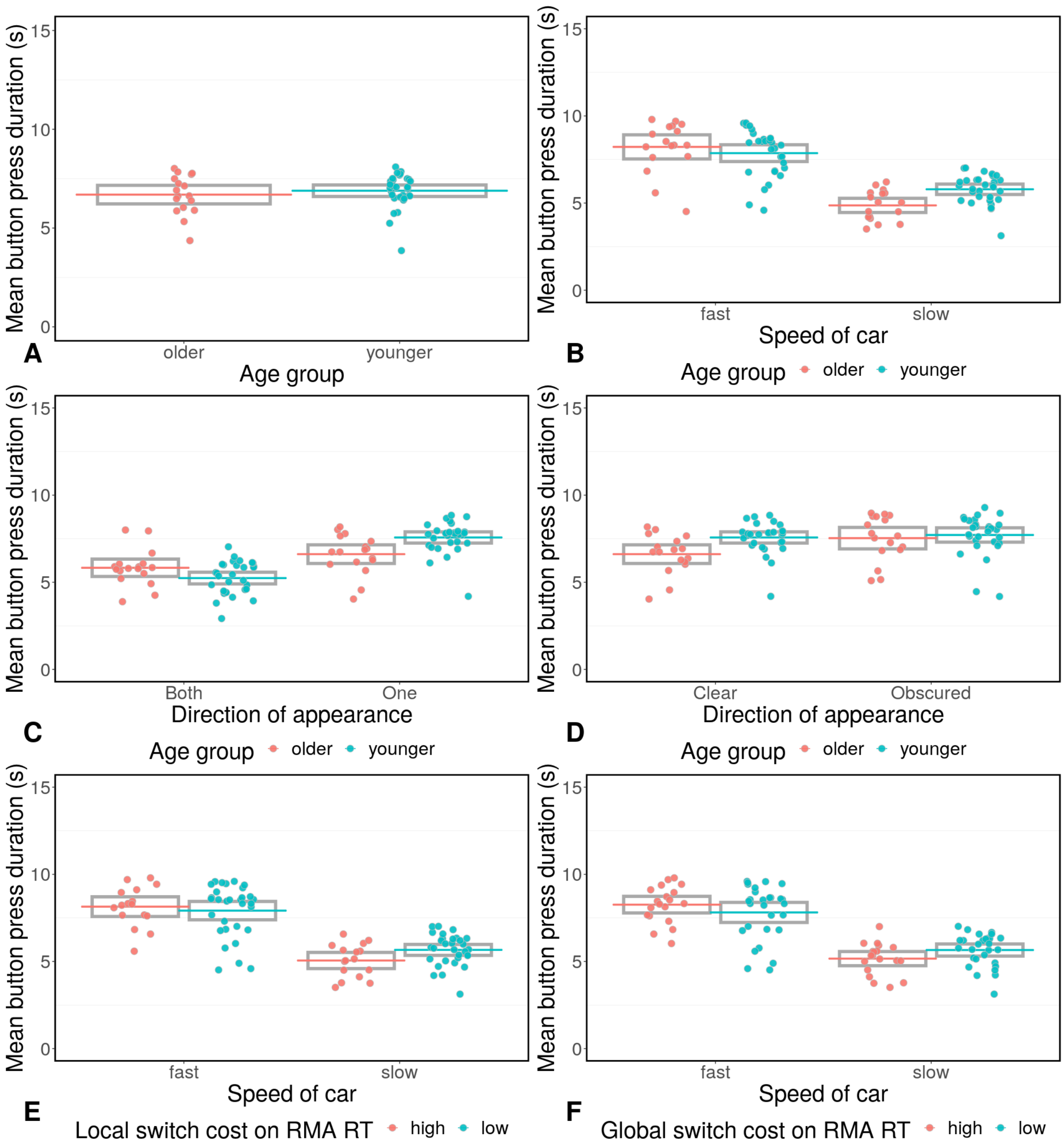


Figure A.8: Main effect of age group on key press duration (A). Interaction between age group and car speed on the duration of key presses (B). Interaction between age group and cars coming from both directions on the duration of key presses (C). Interaction between age group and cars coming from an obscured viewpoint on the duration of key presses (D). Interaction between local switch costs on the RMA task and car speed on the duration of key presses (E). Interaction between global switch costs on the RMA task and car speed on the duration of key presses (F).

A.1.9 RMA RT results

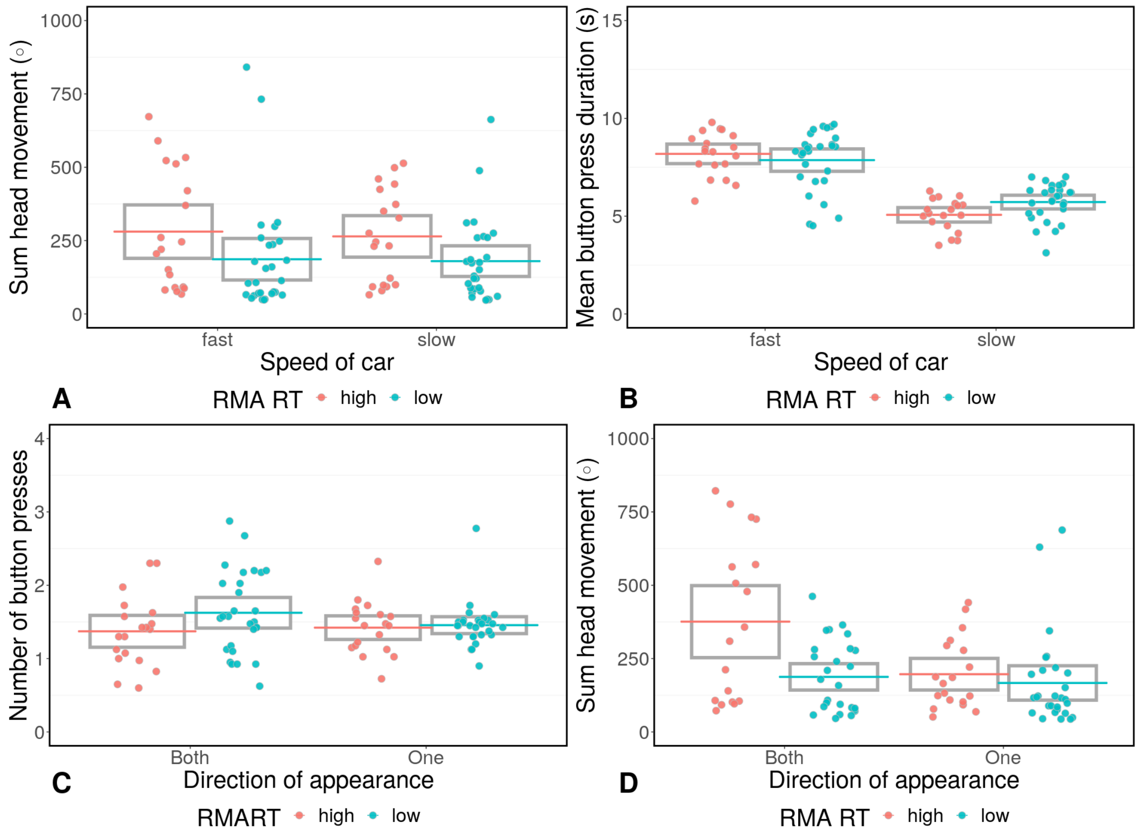


Figure A.9: Interaction between participants RTs on the RMA task and car speed on the amount of head movements (A) and on the duration of key presses (B) participants made. Interaction between RTs on the RMA task and car travel direction on the number of crossing decisions (C) and the amount of head movements (D) participants made.

There was an interaction between RTs on the RMA task and car speed on the duration of key presses and amount head movements participants made (Tables A.18, A.44). All participants made longer key presses when cars travelled quickly compared to slowly. This difference was larger for participants with slower RTs than participants with faster RTs on the RMA task (Tables A.25, and A.22; Figure A.9B). Participants with slow RTs on the RMA task made more head movements when cars travelled quickly compared to slowly (Table A.48, Figure A.9A). A simple effects LMM revealed that participants with fast RTs on the RMA task did not change their head movements when cars travelled quickly compared to slowly (Table A.47, Figure A.9B).

There was an interaction between RTs on the RMA task and the travel direction on the number of crossing decisions and amount of head movements participants made (Tables A.7, and A.44). All participants made more crossing decisions and head movements when cars came from both directions compared to one direction only. The difference in crossing decisions was greater for participants with faster RTs than participants with slower RTs on the RMA task (Tables A.11, and A.10; Figure A.9C). The difference in crossing decisions was not significant for participants with slower RTs on the RMA task (Table A.10, Figure A.9C). The difference in head movements was greater for participants with slower RTs than participants with faster RTs on the RMA task (Tables A.48, and A.47; Figure A.9D).

A.2 Supplementary Tables

LMMs on the crossing decisions on Experiment 1

LMMs on the number of crossing decisions on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
RMA RT	1.12e-03	0.17	0.01	0.995
Car Speed	0.39	0.17	2.32	0.020
Lane number	0.18	0.20	0.88	0.378
Lane type	-0.15	0.20	-0.75	0.453
Car direction	-0.45	0.17	-2.72	0.007
Local switch cost	0.04	0.23	0.19	0.853
Global switch cost	-0.11	0.15	-0.71	0.479
BADS zoo map score	-0.02	0.05	-0.40	0.693
Age group	-0.05	0.12	-0.44	0.658
RMA RT * car speed	-0.12	0.09	-1.36	0.173
RMA RT * lane number	-0.04	0.11	-0.34	0.735
RMA RT * lane type	0.07	0.11	0.62	0.533
RMA RT * car direction	0.02	0.09	0.18	0.855
Local switch cost * car speed	-0.14	0.12	-1.12	0.265
Local switch cost * lane number	-0.07	0.15	-0.47	0.641
Local switch cost * lane type	0.06	0.15	0.41	0.685
Local switch cost * car direction	-0.04	0.12	-0.37	0.714
Global switch cost * car speed	-0.01	0.08	-0.13	0.895
Global switch cost * lane number	-0.05	0.09	-0.57	0.569
Global switch cost * lane type	-0.03	0.09	-0.35	0.728
Global switch cost * car direction	0.09	0.08	1.14	0.253
BADS zoo map score * car speed	5.58e-03	0.03	0.21	0.834
BADS zoo map score * lane number	-7.91e-03	0.03	-0.24	0.807
BADS zoo map score * lane type	2.60e-03	0.03	0.08	0.936
BADS zoo map score * car direction	0.01	0.03	0.56	0.573
Age group * car speed	0.07	0.06	1.18	0.237
Age group * lane number	-0.13	0.08	-1.73	0.084
Age group * lane type	0.13	0.08	1.66	0.097
Age group * car direction	0.04	0.06	0.68	0.498

Table A.1: Results for the LMM run on the number of crossing decisions for Experiment 1. Significant results are highlighted in blue. Model fit: AIC = 2322.93, Pseudo-R^2 = 0.36. See Methods for the model that was run.

LMMs on the duration of key presses on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
RMA RT	-0.12	0.59	-0.20	0.845
Car Speed	1.09	0.92	1.19	0.235
Lane number	-0.73	1.12	-0.65	0.514
Lane type	0.41	0.12	0.37	0.715
Car direction	1.09	0.91	1.20	0.232
Local switch cost	1.27	0.80	1.59	0.112
Global switch cost	-0.06	0.52	-0.11	0.909
BADS zoo map score	0.44	0.18	2.46	0.014
Age group	-0.83	0.42	-1.99	0.048
RMA RT * car speed	0.06	0.48	0.12	0.906
RMA RT * lane number	0.45	0.59	0.76	0.447
RMA RT * lane type	-0.32	0.59	-0.54	0.589
RMA RT * car direction	0.04	0.48	0.08	0.936
Local switch cost * car speed	-0.02	0.66	-0.04	0.971
Local switch cost * lane number	0.34	0.79	0.43	0.665
Local switch cost * lane type	-0.41	0.80	-0.51	0.609
Local switch cost * car direction	-0.28	0.66	-0.43	0.668
Global switch cost * car speed	0.76	0.42	1.83	0.068
Global switch cost * lane number	-0.22	0.51	-0.44	0.660
Global switch cost * lane type	0.26	0.51	0.52	0.604
Global switch cost * car direction	-0.44	0.42	-1.06	0.288
BADS zoo map score * car speed	-0.53	0.15	-3.63	0.000
BADS zoo map score * lane number	0.11	0.18	0.65	0.517
BADS zoo map score * lane type	-0.05	0.18	-0.30	0.764
BADS zoo map score * car direction	0.15	0.14	1.04	0.298
Age group * car speed	-1.16	0.35	-3.37	0.001
Age group * lane number	0.41	0.42	0.99	0.324
Age group * lane type	-0.20	0.42	-0.47	0.638
Age group * car direction	0.51	0.34	1.49	0.137

Table A.2: Results for the LMM run on the duration of key presses for Experiment 1. Significant results are highlighted in blue. Model fit: AIC = 7121.04, Pseudo-R^2 = 0.20. See Methods for the model that was run.

Simple effects LMM on the duration of key presses for YAs on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-1.34	0.18	-7.61	0.000
Car Direction	1.88	0.18	10.75	0.004

Table A.3: Results for the simple effects LMM run on the duration of key presses made by YAs on Experiment 1. Significant results are highlighted in blue.

Simple effects LMM on the duration of key presses for older adults on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
Car speed	0.58	0.23	2.50	0.025
Car Direction	1.01	0.23	4.33	0.000

Table A.4: Results for the simple effects LMM run on the duration of key presses made by OAs on Experiment 1. Significant results are highlighted in blue

Simple effects LMM on the duration of key presses for participants with high BADS zoo map scores on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-1.23	0.17	-7.30	0.000
Car direction	1.78	0.17	10.60	0.000

Table A.5: Results for simple effects LMM on duration of key presses by participants with high BADS zoo map scores on Experiment 1. Significant results are highlighted in blue.

Simple effects LMM on the duration of key presses for participants with low BADS zoo map scores on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
Car speed	0.72	0.26	2.80	0.010
Car direction	1.03	0.26	4.00	0.000

Table A.6: Results for the simple effects LMM on the duration of key presses made by participants with low BADS zoo map scores on Experiment 1. Significant results are highlighted in blue.

LMMs on the crossing decisions on Experiment 2

LMM for the number of crossing decisions

	β	*Standard Error*	*T-value*	*P-value*
RMA RT	0.25	0.17	1.49	0.140
Car speed	0.34	0.10	3.44	0.001
Traffic density	-0.04	0.03	-1.34	0.179
Car Direction – obscure	0.11	0.12	0.92	0.357
Car Direction – both	0.37	0.12	3.03	0.002
Pedestrian presence	-0.02	0.10	-0.24	0.809
BADS zoo map score	0.07	0.05	1.33	0.188
Age group	0.19	0.12	1.57	0.122
Global switch cost	-0.28	0.14	-1.91	0.060
Local switch cost	0.23	0.23	1.01	0.317
RMA RT * Car speeds	-0.03	0.05	-0.53	0.597
RMA RT * traffic density	1.15e-03	0.02	0.07	0.942
RMA RT * Car Direction – obscure	0.04	0.06	0.62	0.533
RMA RT * Car Direction – both	-0.14	0.06	-2.17	0.030
RMA RT * pedestrian presence	0.13	0.05	0.25	0.804
BADS zoo map score * car speed	-0.07	0.02	-4.42	0.000
BADS zoo map score * traffic density	-9.65e-03	4.81e-03	-2.01	0.045
BADS zoo map score * car direction – obscure	-3.05e-03	0.02	-0.16	0.872
BADS zoo map score * car direction – both	-0.07	0.02	-3.95	0.000
BADS zoo map score * pedestrian presence	5.17e-03	0.02	0.33	0.741
Age group * car speed	-0.08	0.04	-2.18	0.029
Age group * traffic density	-7.76e-03	0.01	-0.68	0.497
Age group * car direction – obscure	-0.04	0.04	-0.81	0.419
Age group * car direction – both	0.34	0.05	7.32	0.000
Age group * pedestrian presence	-0.04	0.04	-1.17	0.241
Global switch cost * car speed	-0.02	0.04	-0.47	0.638
Global switch cost * traffic density	0.03	0.01	2.30	0.022
Global switch cost * car direction – obscure	-0.11	0.05	-2.13	0.033
Global switch cost * car direction – both	-0.05	0.05	-0.90	0.370
Global switch cost * pedestrian presence	-0.05	0.04	-1.06	0.288
Local switch cost * car speed	-0.29	0.07	-3.85	0.000
Local switch cost * traffic density	-0.02	0.02	-0.90	0.369
Local switch cost * car direction – obscure	0.09	0.09	0.99	0.322
Local switch cost * car direction – both	0.09	0.09	0.95	0.343
Local switch cost * pedestrian presence	0.05	0.07	0.66	0.512

Table A.7: Results of the LMM run on the number of crossing decisions on Experiment 2. See Methods for the model that was run. Significant results are highlighted in blue. Model fit: AIC = 10107.71, Pseudo-R^2 = 0.29.

Simple effects LMM for the number of crossing decisions made by YAs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-0.08	0.02	-4.19	0.000
Traffic density	-0.07	5.81e-03	-12.01	0.000
Car Direction – obscure	0.10	0.02	4.37	0.000
Car Direction – both	0.27	0.02	11.36	0.000

Table A.8: Results of the simple effects LMM run on the number of crossing decisions made by YAs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM for the number of crossing decisions made by OAs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	4.97e-04	0.03	0.02	0.999
Traffic density	-0.04	7.65e-03	-5.57	0.000
Car Direction – obscure	0.13	0.03	4.16	0.000
Car Direction – both	-0.07	0.03	-2.39	0.060

Table A.9: Results of the simple effects LMM run on the number of crossing decisions made by OAs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM for the number of crossing decisions made by participants with slow RTs on the RMA task on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-0.02	0.03	-0.59	0.557
Traffic density	-0.05	7.72e-03	-6.18	0.000
Car Direction – obscure	0.10	0.03	3.24	0.001
Car Direction – both	-0.04	0.03	-1.32	0.187

Table A.10: Results of the simple effects LMM on the number of crossing decisions by participants with slow RTs on the RMA task on Experiment 2. See Methods for the model that was run.

Simple effects LMM for the number of crossing decisions made by participants with fast RTs on the RMA task on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	0.04	0.02	1.88	0.061
Traffic density	-0.07	5.86e-03	-11.66	0.000
Car Direction – obscure	0.10	0.02	4.21	0.000
Car Direction – both	0.02	0.02	6.64	0.000

Table A.11: Results of the simple effects LMM on number of crossing decisions by participants with fast RTs on the RMA task on Experiment 2. Significant results are highlighted in blue. See Methods for the model that was run.

Simple effects LMM on the number of crossing decisions made by participants with high BADS zoo map scores on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-0.07	0.02	4.24	0.000
Traffic density	-0.07	5.42e-03	-12.54	0.000
Car Direction – obscure	0.11	0.02	5.32	0.000
Car Direction – both	0.17	0.02	7.59	0.000

Table A.12: Results of the simple effects LMM on the number of crossing decisions made by participants with high BADS zoo map scores on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on the number of crossing decisions made by participants with low BADS zoo map scores on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-5.89e-03	0.03	0.19	0.997
Traffic density	-0.04	9.29e-03	-4.58	0.000
Car Direction – obscure	0.06	0.04	1.77	0.244
Car Direction – both	0.12	0.04	3.25	0.004

Table A.13: Results of the simple effects LMM run on the number of crossing decisions made by participants with low BADS zoo map scores on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on the number of crossing decisions made by participants with large global switch costs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	0.08	0.02	3.56	0.001
Traffic density	-0.04	7.16e-03	-5.87	0.000
Car Direction – obscure	0.05	0.03	1.79	0.235
Car Direction – both	0.06	0.03	2.10	0.124

Table A.14: Results of the simple effects LMM run on the number of crossing decisions made by participants with large global switch costs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on the number of crossing decisions made by participants with small global switch costs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-0.04	0.02	1.81	0.071
Traffic density	-0.07	6.17e-03	-11.97	0.000
Car Direction – obscure	0.13	0.02	5.36	0.000
Car Direction – both	0.22	0.02	8.69	0.000

Table A.15: Results of the simple effects LMM run on the number of crossing decisions made by participants with small global switch costs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on the number of crossing decisions made by participants with large local switch costs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	0.07	0.03	2.47	0.049
Traffic density	-0.05	8.31e-03	-5.45	0.000
Car Direction – obscure	0.08	0.03	2.33	0.070
Car Direction – both	0.04	0.03	1.25	0.548

Table A.16: Results of the simple effects LMM run on the number of crossing decisions made by participants with large local switch costs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on the number of crossing decisions made by participants with small local switch costs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	0.05	0.02	2.81	0.019
Traffic density	-0.07	5.66e-03	-12.15	0.000
Car Direction – obscure	0.11	0.02	4.88	0.000
Car Direction – both	0.02	0.02	9.15	0.000

Table A.17: Results of the simple effects LMM run on the number of crossing decisions made by participants with small local switch costs on Experiment 2. Significant results are highlighted in blue.

LMM for the duration of key presses on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
RMA RT	0.31	0.56	0.57	0.572
Car speed	3.57	0.48	7.37	0.000
Traffic density	0.22	0.15	1.48	0.140
Car Direction – obscure	1.83	0.59	3.13	0.002
Car Direction – both	-0.91	0.60	-1.53	0.127
Pedestrian presence	-0.05	0.48	-0.10	0.920
BADS zoo map score	0.22	0.17	1.28	0.201
Age group	1.46	0.40	3.66	0.000
Global switch cost	-0.52	0.48	-1.09	0.279
Local switch cost	0.45	0.77	0.59	0.559
RMA RT * Car speeds	-0.86	0.25	-3.42	0.001
RMA RT * traffic density	-0.09	0.08	-1.20	0.231
RMA RT * Car Direction – obscure	0.43	0.31	-1.42	0.157
RMA RT * Car Direction – both	-0.03	0.31	-0.09	0.929
RMA RT * pedestrian presence	0.04	0.25	0.16	0.875
BADS zoo map score * car speed	0.08	0.08	1.10	0.274
BADS zoo map score * traffic density	0.01	0.02	0.58	0.565
BADS zoo map score * car direction – obscure	-0.13	0.09	-1.38	0.167
BADS zoo map score * car direction – both	-0.10	0.09	-1.08	0.281
BADS zoo map score * pedestrian presence	-2.90e-03	0.08	-0.04	0.970
Age group * car speed	-1.00	0.18	-5.47	0.000
Age group * traffic density	-0.08	0.06	-1.41	0.159
Age group * car direction – obscure	-0.73	0.22	-3.32	0.001
Age group * car direction – both	-1.18	0.23	-5.21	0.000
Age group * pedestrian presence	0.19	0.18	1.03	0.304
Global switch cost * car speed	1.09	0.22	4.98	0.000
Global switch cost * traffic density	0.02	0.07	0.23	0.819
Global switch cost * car direction – obscure	0.46	0.26	1.74	0.081
Global switch cost * car direction – both	0.32	0.27	1.20	0.230
Global switch cost * pedestrian presence	0.22	0.22	1.00	0.319
Local switch cost * car speed	0.73	0.36	2.00	0.046
Local switch cost * traffic density	-0.08	0.11	-0.74	0.459
Local switch cost * car direction – obscure	-0.36	0.43	-0.85	0.394
Local switch cost * car direction – both	-0.33	0.45	-0.72	0.469
Local switch cost * pedestrian presence	-0.44	0.36	-1.23	0.220

Table A.18: Results for the LMM run on duration of key presses on Experiment 2. See Methods for the model that was run. Significant results are highlighted in blue. Model fit: AIC = 28080.07, Pseudo-R^2 = 0.32.

Simple effects LMM for the duration of key presses made by YAs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	2.25	0.09	24.20	0.000
Traffic density	0.04	0.03	1.57	0.116
Car Direction – obscure	0.18	0.11	1.62	0.319
Car Direction – both	-2.41	0.11	-20.94	0.000

Table A.19: Results of the simple effects LMM run on the duration of key presses made by YAs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM for the duration of key presses made by OAs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	3.31	0.12	27.14	0.000
Traffic density	0.05	0.04	1.38	0.168
Car Direction – obscure	0.90	0.15	6.13	0.000
Car Direction – both	-1.06	0.15	-7.10	0.000

Table A.20: Results of the simple effects LMM run on the duration of key presses made by OAs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM for the duration of key presses on Experiment 2 made by participants with slow RTs on the RMA task

	β	*Standard Error*	*T-value*	*P-value*
Car speed	3.13	0.12	26.26	0.000
Traffic density	0.05	0.04	1.28	0.200
Car Direction – obscure	0.72	0.14	5.02	0.000
Car Direction – both	-1.44	0.15	-9.80	0.000

Table A.21: Results of the simple effects LMM on the duration of key presses made by participants with slow RTs on the RMA task on Experiment 2. Significant results are highlighted in blue. See Methods for the model that was run.

Simple effects LMM for the duration of key presses on Experiment 2 made by participants with fast RTs on the RMA task

	β	*Standard Error*	*T-value*	*P-value*
Car speed	2.27	0.10	23.78	0.000
Traffic Density	0.05	0.03	1.73	0.084
Car Direction – obscure	0.27	0.12	2.36	0.019
Car Direction – both	-2.25	0.12	-19.16	0.000

Table A.22: Results of the simple effects LMM on the duration of key presses by participants with fast RTs on the RMA task on Experiment 2. See Methods for the model that was run.

Simple effects LMM for the duration of key presses on Experiment 2 made by participants with large global switch costs

	β	*Standard Error*	*T-value*	*P-value*
Car speed	3.21	0.11	28.22	0.000
Traffic density	0.07	0.03	1.95	0.051
Car Direction – obscure	0.91	0.14	6.63	0.000
Car Direction – both	-1.41	0.14	-10.00	0.000

Table A.23: Results of the simple effects LMM on the duration of key presses made by participants with large global switch costs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM for the duration of key presses on Experiment 2 made by participants with small global switch costs

	β	*Standard Error*	*T-value*	*P-value*
Car speed	2.19	0.10	22.35	0.000
Traffic density	0.04	0.03	1.39	0.165
Car Direction – obscure	0.13	0.12	1.09	0.653
Car Direction – both	-2.31	0.12	-19.16	0.000

Table A.24: Results of the simple effects LMM on the duration of key presses made by participants with small global switch costs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM for the duration of key presses on Experiment 2 made by participants with large local switch costs

	β	*Standard Error*	*T-value*	*P-value*
Car speed	3.09	0.13	23.67	0.000
Traffic density	0.02	0.04	0.44	0.661
Car Direction – obscure	0.75	0.16	4.76	0.000
Car Direction – both	-1.60	0.16	-9.95	0.000

Table A.25: Results of the simple effects LMM on the duration of key presses made by participants with large local switch costs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM for the duration of key presses on Experiment 2 made by participants with small local switch costs

	β	*Standard Error*	*T-value*	*P-value*
Car speed	2.36	0.09	25.95	0.000
Traffic density	0.07	0.03	2.38	0.018
Car Direction – obscure	0.30	0.11	2.68	0.028
Car Direction – both	-2.11	0.11	-18.80	0.000

Table A.26: Results of the simple effects LMM on the duration of key presses made by participants with small local switch costs on Experiment 2. Significant results are highlighted in blue.

LMMs on TTI on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
RMA RT	-0.09	0.58	-0.15	0.878
Car Speed	-1.17	0.53	-2.19	0.029
Car direction	-1.85	0.52	3.53	0.000
Lane number	-0.43	0.64	-0.67	0.501
Lane type	0.01	0.63	0.02	0.986
Local switch cost	-1.76	0.85	-2.06	0.042
Global switch cost	0.62	0.51	1.23	0.223
BADS zoo map score	-0.47	0.18	-2.66	0.010
Age group	1.02	0.42	2.43	0.018
RMA RT * car speed	-0.68	0.30	-2.26	0.024
RMA RT * car direction	0.02	0.30	0.05	0.957
RMA RT * lane number	0.19	0.36	0.52	0.607
RMA RT * lane type	0.16	0.35	0.45	0.653
Local switch cost * car speed	0.04	0.56	0.08	0.940
Local swith cost * car direction	0.18	0.50	0.36	0.716
Local switch cost * lane number	-0.04	0.62	-0.06	0.953
Local switch cost * lane type	0.59	0.60	0.99	0.325
Global switch cost * car speed	0.43	0.28	1.57	0.117
Global switch cost * car direction	-0.18	0.27	-0.69	0.492
Global switch cost * lane number	0.11	0.33	0.34	0.736
Global switch cost * lane type	-0.32	0.31	-1.04	0.297
BADS zoo map score * car speed	0.30	0.09	3.25	0.001
BADS zoo map score * car direction	-0.25	0.09	-2.81	0.005
BADS zoo map score * lane number	0.04	0.11	0.36	0.719
BADS zoo map score * lane type	-0.03	0.11	-0.26	0.794
Age group * car speed	-0.82	0.22	-3.68	0.000
Age group * car direction	0.52	0.22	2.37	0.018
Age group * lane number	0.37	0.27	1.40	0.163
Age group * lane type	0.04	0.26	0.17	0.864

Table A.27: Results for the LMM run on TTI for Experiment 1. See Methods for the model that was run. Significant results are highlighted in blue. Model fit: AIC = 4730.78, Pseudo-R^2 = 0.55.

Simple effects LMM for YAs on TTI on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-0.97	0.09	-10.26	0.000
Car direction	-1.02	0.09	-10.90	0.000

Table A.28: Simple effects LMM run on the TTI for YAs on Experiment 1. Significant results are highlighted in blue

Simple effects LMM for OAs on the TTI on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-2.15	0.10	-11.38	0.000
Lane number	-1.70	0.19	-9.19	0.000

Table A.29: Simple effects LMM on the TTI for OAs on Experiment 1. Significant results are highlighted in blue.

Simple effects LMM for participants with low BADS zoo map scores on TTI on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-2.06	0.22	9.57	0.000
Car Direction	-1.78	0.21	-8.48	0.000

Table A.30: Simple effects LMM on the TTI for participants with low BADS zoo map scores on Experiment 1. Significant results are highlighted in blue.

Simple effects LMM for participants with high BADS zoo map scores on TTI on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-1.10	0.09	-11.77	0.000
Car direction	-1.08	0.09	-11.64	0.000

Table A.31: Simple effects LMM on the TTI decisions for participants with high BADS zoo map scores on Experiment 1. Significant results are highlighted in blue.

Simple effects LMM for participants with fast RTs on the RMA task on TTI on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-1.01	0.11	9.45	0.000
Car direction	-1.11	0.11	-10.49	0.000

Table A.32: Simple effects LMM on the TTI decisions for participants with fast RTs on the RMA task on Experiment 1. Significant results are highlighted in blue. See Methods for the model that was run.

Simple effects LMM for participants with slow RTs on the RMA task on time TTI on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-1.76	0.15	-11.67	0.000
Car direction	-1.40	0.15	-9.36	0.000

Table A.33: Simple effects LMM on TTI decisions for participants with slow RTs on the RMA task on Experiment 1. Significant results are highlighted in blue. See Methods for the model that was run.

LMM for TTI on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
RMA RT	-0.18	0.52	-0.34	0.736
Car speed	-2.32	0.36	-6.92	0.000
Traffic density	-0.07	0.10	-0.69	0.491
Car Direction – obscure	-1.70	0.39	-4.32	0.000
Car Direction – both	0.45	0.36	1.25	0.211
Pedestrian presence	-0.12	0.30	-0.39	0.701
BADS zoo map score	-0.54	0.16	-3.29	0.002
Age group	2.04	0.39	5.27	0.000
Global switch cost	0.56	0.44	1.26	0.212
Local switch cost	-1.33	0.77	-1.71	0.090
RMA RT * Car speed	-0.24	0.18	-1.38	0.169
RMA RT * traffic density	-0.06	0.05	-1.23	0.219
RMA RT * Car Direction – obscure	0.17	0.21	0.80	0.423
RMA RT * Car Direction – both	-0.37	0.19	-1.95	0.051
RMA RT * pedestrian presence – present	0.14	0.16	0.88	0.378
BADS zoo map score * car speed	0.26	0.06	4.36	0.000
BADS zoo map score * traffic density	1.26e-03	0.02	0.08	0.940
BADS zoo map score * car direction – obscure	0.09	0.07	1.31	0.189
BADS zoo map score * car direction – both	0.15	0.06	2.43	0.015
BADS zoo map score * pedestrian presence	-0.02	0.05	-0.41	0.684
Age group * car speed	-0.78	0.15	-5.04	0.000
Age group * traffic density	-0.03	0.04	-0.65	0.514
Age group * car direction – obscure	-0.72	0.17	-4.25	0.000
Age group * car direction – both	-0.55	0.17	-3.33	0.001
Age group * pedestrian presence	-0.08	0.13	-0.57	0.570
Global switch cost * car speed	0.14	0.16	0.89	0.373
Global switch cost * traffic density	0.02	0.04	0.35	0.725
Global switch cost * car direction – obscure	-0.22	0.18	-1.18	0.237
Global switch cost * car direction – both	0.20	0.17	1.17	0.240
Global switch cost * pedestrian presence	-0.07	0.14	-0.52	0.603
Local switch cost * car speed	-0.06	0.37	-0.16	0.877
Local switch cost * car direction – obscure	0.96	0.47	2.03	0.042
Local switch cost * car direction – both	1.85	0.37	4.98	0.000
Local switch cost * traffic density	0.06	0.11	0.52	0.603
Local switch cost * pedestrian presence	0.08	0.34	0.23	0.821

Table A.34: Results for the LMM on TTI on Experiment 2. See Methods for the model that was run. Significant results are highlighted in blue. Model fit: AIC = 33367.01, Pseudo-R^2 = 0.39.

Simple effects LMM for YAs on TTI on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-1.86	0.07	-28.07	0.000
Traffic density	-0.14	0.02	-7.37	0.000
Car Direction – obscure	-1.03	0.08	-13.22	0.000
Car Direction – both	0.89	0.07	13.00	0.000

Table A.35: Simple effects LMM run on the TTI for YAs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM for OAs on TTI on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-2.83	0.11	-24.70	0.000
Traffic density	-0.18	0.03	-5.75	0.000
Car Direction – obscure	-1.68	0.12	-13.88	0.000
Car Direction – both	0.53	0.12	4.31	0.000

Table A.36: Simple effects LMM run on the TTI for OAs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on the TTI for participants with small local switch costs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-1.88	0.07	-26.88	0.000
Traffic density	-0.14	0.02	-7.32	0.000
Car Direction – obscure	-1.20	0.08	-14.79	0.000
Car Direction – both	0.78	0.07	10.45	0.000

Table A.37: Simple effects LMM run on the TTI for participants with small local switch costs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on the TTI for participants with large local switch costs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-2.59	0.10	25.83	0.000
Traffic density	-0.16	0.03	-5.67	0.000
Car Direction – obscure	-1.28	0.11	-11.45	0.000
Car Direction – both	0.88	0.11	8.38	0.000

Table A.38: Simple effects LMM run on the TTI for participants with large local switch costs on Experiment 2. Significant results are highlighted in blue

Simple effects LMM on the TTI for participants with high BADS zoo map scores on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-1.91	0.06	-30.12	0.000
Traffic density	-0.15	0.02	-8.39	0.000
Car Direction – obscure	-1.13	0.07	-15.59	0.000
Car Direction – both	0.88	0.07	13.24	0.000

Table A.39: Simple effects LMM run on the TTI for participants with high BADS zoo map scores on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on TTI for participants with low BADS zoo map scores on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-2.72	0.13	-21.05	0.000
Traffic density	-0.17	0.04	-4.71	0.000
Car Direction – obscure	-1.53	0.15	-10.20	0.000
Car Direction – both	0.53	0.13	4.04	0.000

Table A.40: Simple effects LMM run on the TTI for participants with low BADS zoo map scores on Experiment 2. Significant results are highlighted in blue.

LMMs for the amount of head movements on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
RMA RT	-8.42	60.27	-0.14	0.890
Car Speed	-37.59	29.42	-1.28	0.202
Lane number	24.49	36.02	0.68	0.497
Lane type	-28.47	35.92	-0.79	0.428
Car direction	-7.47	29.31	-0.26	0.799
Local switch cost	-6.67	81.68	-0.08	0.935
Global switch cost	-14.45	52.07	-0.28	0.783
BADS zoo map score	-7.83	18.11	-0.43	0.667
Age group	110.13	43.04	2.56	0.014
RMA RT * car speed	20.63	16.43	1.26	0.209
RMA RT * lane number	-20.23	20.17	-1.00	0.316
RMA RT * lane type	31.64	20.05	1.58	0.115
RMA RT * car direction	-28.15	16.42	-1.72	0.087
Local switch cost * car speed	19.57	22.51	0.87	0.385
Local switch cost * lane number	26.35	26.97	0.98	0.329
Local switch cost * lane type	-21.12	27.24	-0.78	0.438
Local switch cost * car direction	96.41	22.36	4.31	0.000
Global switch cost * car speed	-3.24	14.31	-0.23	0.821
Global switch cost * lane number	21.45	17.33	1.24	0.216
Global switch cost * lane type	-13.34	17.29	-0.77	0.440
Global switch cost * car direction	19.84	14.25	1.39	0.164
BADS zoo map score * car speed	-0.42	4.96	-0.08	0.933
BADS zoo map score * lane number	2.66	6.03	0.44	0.659
BADS zoo map score * lane type	-4.95	6.06	-0.82	0.414
BADS zoo map score * car direction	6.79	4.92	1.38	0.168
Age group * car speed	9.82	11.74	0.84	0.403
Age group * lane number	-26.76	14.25	-1.88	0.061
Age group * lane type	2.45	14.27	0.17	0.864
Age group * car direction	-11.44	11.71	-0.98	0.329

Table A.41: Results for the LMM run on the amount of head movements participants made on Experiment 1. See Methods for the model that was run. Significant results are highlighted in blue. Model fit: AIC = 17264.96, Pseudo-R^2 = 0.67.

Simple effects LMM for participants with small local switch costs on head movements on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-8.00,	3.88	-2.06	0.077
Car Direction	1.71	3.99	0.45	0.880

Table A.42: Simple effects LMM run on the amount of head movements made by participants with small local switch costs on Experiment 1. Significant results are highlighted in blue.

Simple effects LMM for participants with large local switch costs on head movements on Experiment 1

	β	*Standard Error*	*T-value*	*P-value*
Car speed	12.14	7.37	1.65	0.188
Car Direction	-11.62	7.21	-1.61	0.203

Table A.43: Simple effects LMM on the amount of head movements made by participants with large local switch costs on Experiment 1. Significant results are highlighted in blue.

LMMs on the amount of head movements on Experiment 2

LMM for the amount of head movements made on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
RMA RT	-8.19	61.30	-0.13	0.894
Car speed	-6.44	16.87	-0.38	0.703
Traffic density	-5.67	5.20	-1.09	0.276
Car Direction – obscure	-12.79	20.99	-0.61	0.542
Car Direction – both	-72.46	21.06	-3.44	0.001
Pedestrian presence	-18.24	17.98	-1.02	0.310
BADS zoo map score	-7.16	18.45	-0.39	0.700
Age group	119.24	43.80	2.72	0.009
Global switch cost	4.93	52.82	0.09	0.926
Local switch cost	-59.27	83.16	-0.71	0.479
RMA RT * Car speed	24.98	9.42	2.65	0.008
RMA RT * traffic density	0.32	2.90	0.11	0.913
RMA RT * Car Direction – obscure	14.38	11.81	1.22	0.223
RMA RT * Car Direction – both	70.37	11.77	5.98	0.000
RMA RT * pedestrian presence – present	5.66	9.44	0.60	0.549
BADS zoo map score * car speed	-6.84	2.84	-2.41	0.016
BADS zoo map score * traffic density	-0.20	0.87	-0.23	0.820
BADS zoo map score * car direction – obscure	-9.69	3.45	-2.81	0.005
BADS zoo map score * car direction – both	10.16	3.47	2.93	0.003
BADS zoo map score * pedestrian presence	5.04	2.84	1.77	0.076
Age group * car speed	33.32	6.76	4.93	0.000
Age group * traffic density	-1.07	2.07	-0.51	0.607
Age group * car direction – obscure	-20.78	8.32	-2.50	0.013
Age group * car direction – both	216.70	8.30	26.11	0.000
Age group * pedestrian presence	4.11	6.72	0.61	0.541
Global switch cost * car speed	-11.20	8.14	-1.38	0.169
Global switch cost * traffic density	-0.13	2.50	-0.05	0.958
Global switch cost * car direction – obscure	13.32	9.90	1.35	0.179
Global switch cost * car direction – both	25.90	9.94	2.61	0.009
Global switch cost * pedestrian presence	-1.50	8.14	-0.19	0.853
Local switch cost * car speed	-43.78	12.88	-3.40	0.001
Local switch cost * car direction – obscure	11.21	3.96	2.83	0.004
Local switch cost * car direction – both	69.07	15.74	4.39	0.000
Local switch cost * traffic density	-94.48	15.70	-6.02	0.000
Local switch cost * pedestrian presence	3.32	7.87	-0.42	0.673

Table A.44: Results for the LMM run on the amount of head movements participants made on Experiment 2. See Methods for the model that was run. Significant results are highlighted in blue. Model fit: AIC = 71413.21, Pseudo-R^2 = 0.76.

Simple effects LMM on the amount of head movements made by YAs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-6.67	1.96	-3.40	0.003
Traffic density	-3.36	0.60	-5.59	0.000
Car Direction – obscure	-0.57	2.38	-0.24	0.994
Car Direction – both	46.60	2.39	19.54	0.000

Table A.45: Simple effects LMM run on the amount of head movements made by YAs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on the amount of head movements made by OAs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	31.92	7.03	4.54	0.000
Traffic density	-2.13	2.16	-0.99	0.324
Car Direction – obscure	6.18	8.44	0.73	0.863
Car Direction – both	288.10	8.44	34.15	0.000

Table A.46: Simple effects LMM run on the amount of head movements made by OAs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM for participants with fast RTs on the RMA task on head movements on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	1.29	3.06	0.42	0.673
Traffic density	-2.31	0.94	-2.46	0.014
Car Direction – obscure	-3.03	3.78	-0.80	0.423
Car Direction – both	88.25	3.79	23.32	0.000

Table A.47: Simple effects LMM on head movements for participants with fast RTs on the RMA task on Experiment 2. Significant results are highlighted in blue. See Methods for the model that was run.

Simple effects LMM for participants with slow RTs on the RMA task on head movements on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	15.02	6.34	2.37	0.018
Traffic density	-4.57	2.00	-2.34	0.019
Car Direction – obscure	5.37	8.08	0.67	0.506
Car Direction – both	201.39	8.07	24.97	0.000

Table A.48: Simple effects LMM on head movements for participants with slow RTs on the RMA task on Experiment 2. See Methods for the model that was run.

Simple effects LMM on the amount of head movements made by participants with low BADS zoo map scores on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	30.40	7.56	4.02	0.000
Traffic density	-2.27	2.34	-0.97	0.332
Car Direction – obscure	26.85	9.13	2.94	0.013
Car Direction – both	173.10	9.42	18.38	0.000

Table A.49: Simple effects LMM run on the amount of head movements made by participants with low BADS zoo map scores on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on the amount of head movements made by participants with high BADS zoo map scores on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	-2.48	3.13	-0.79	0.833
Traffic density	-2.86	0.96	-2.98	0.003
Car Direction – obscure	-10.62	3.82	-2.78	0.021
Car Direction – both	110.82	3.82	28.98	0.000

Table A.50: Simple effects LMM run on the amount of head movements made by participants with high BADS zoo map scores on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on the amount of head movements made by participants with small global switch costs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	2.46	3.09	0.79	0.832
Traffic density	-1.96	0.95	-2.07	0.038
Car Direction – obscure	-6.60	3.77	-1.75	0.251
Car Direction – both	79.94	3.81	20.98	0.000

Table A.51: Simple effects LMM run on the amount of head movements made by participants with small global switch costs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on the amount of head movements made by participants with large global switch costs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	12.60	6.09	2.07	0.131
Traffic density	-4.10	1.87	-2.19	0.029
Car Direction – obscure	11.64	7.50	1.55	0.355
Car Direction – both	206.56	7.56	27.33	0.000

Table A.52: Simple effects LMM run on the amount of head movements made by participants with large global switch costs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on the amount of head movements made by participants with small local switch costs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	3.88	3.27	1.19	0.588
Traffic density	-3.30	1.00	-3.30	0.001
Car Direction – obscure	-3.83	3.99	-0.96	0.737
Car Direction – both	105.98	3.99	26.57	0.000

Table A.53: Simple effects LMM run on the amount of head movements made by participants with small local switch costs on Experiment 2. Significant results are highlighted in blue.

Simple effects LMM on the amount of head movements made by participants with large local switch costs on Experiment 2

	β	*Standard Error*	*T-value*	*P-value*
Car speed	11.27	6.87	1.64	0.307
Traffic density	-1.02	2.10	-0.49	0.626
Car Direction – obscure	6.65	8.43	0.79	0.835
Car Direction – both	184.16	8.35	22.06	0.000

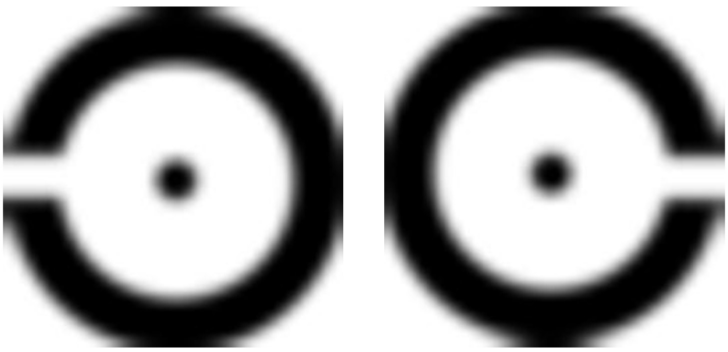
Table A.54: Simple effects LMM run on the amount of head movements made by participants with large local switch costs on Experiment 2. Significant results are highlighted in blue.

A.3 Response to examiners' comments

A.3.1 Response to external examiner's comments

Was the tracker calibrated on all three screens?

The tracker was initially calibrated using a custom calibration procedure presented on all three screens. This procedure involved presenting circles with a break on the left or right side and a dot in the middle (Figure A.10) at random locations on all three screens. Participants had to look at the circle and indicate whether the break in the circle was on the right or left hand side using the left and right arrow keys on the keyboard. While participants did this their eye movements were recorded. This was followed by the Eyelink calibration procedure performed only on the centre screen.



(a) Example calibration point left

(b) Example calibration point right

Figure A.10: Example calibration points for the three screen calibration of the Eyelink II. (a) Example calibration point with the break in the circle on the left. (b) Example calibration point with the break in the circle on the right

I have added the calibration procedure to the methods section of Chapter 4.

Since the eye movement data is missing for these experiments (see general comment), a lot more information could be given here about why this is difficult and what the data look like

The Eyelink II is set up to be used for one screen, so gaze coordinates can only be determined for one screen. To use a three screen set up one needs to use head motion and position data measured by a separate motion tracker. One also needs to use the head referenced position data (HREF). HREF measures eye rotation angles relative to the head. However, the output data is not a rotation angle of the eye but x and y coordinates which define a point on the HREF plane which is a constant 15,000 units away from the participant. The eye rotation angle can then be determined from the coordinates using the following equation provided in the Eyelink II manual:

angle = acos((f*f + x1*x2 + y1*y2) / (sqrt((f*f + x1*x1 + y1*y1) * (f*f + x2*x2 + y2*y2)));

f is the constant distance from the participants' eyes to the HREF plane, and x and y are the HREF x and y coordinate values. During the calibration the HREF values are scaled and from there you can related the HREF coordinates to real world coordinates. A new calibration procedure was required to ensure that the HREF values are scaled appropriately for the three screen environment I used. One of my supervisors had managed to develop a calibration procedure for three screens, as mentioned above, but we had not yet developed a way to scale the HREF coordinates after the calibration procedure was completed. Once this is completed then I will be able to analyse the eye tracking data.

I have added the above details about the missing eye movement data to the methods section of Chapter 4.

The bit about DTI and TTI should be rephrased because you say that you want to look at them separately, but you then say that you designed the task so that they were perfectly correlated. It would be better to explain that this is something you could/should have done differently

This has been altered to the following: " Previously, it has been shown that YAs and OAs are able to make decisions based on a combination of time and distance to impact (DTI; Lobjois & Cavallo, 2007). As my study had cars moving at a constant speed with the same size gaps between the cars, I was not able to investigate this as the DTI would be perfectly correlated with the TTI. To investigate this I could have had cars move with different sized gaps between them, moving with changing speeds, or accelerations."

Here, but also elsewhere in the thesis, I found it difficult to follow some of the LMM models being fit. One issue is that overall model fit is not reported. I normally do this by testing nested models and using maximum likelihood comparisons, which is what most LMER tutorials do, I think

I have added model fit values (AIC and Pseudo-R^2) to the table captions.

The other issue is that the reader has to dig deep into the many tables in the appendix to find these interactions, I would recommend putting some of the key numbers in the main text

I have added main effect and interaction values to the results of experiments one and two in Chapter 4.

A.3.2 Response to internal examiner's comments

Why complicate experiment 2 stimuli with so many factors? Up to this point the progression from one experiment to the next was gradual which helped with analysis and interpretation

The reason experiment 2 had so many factors was for a combination of replicating previous findings and expanding upon them. In Chapter 3 I found that in simple situations older adults without declining executive functions were able to make safe crossing decisions. However, these older adults may have more difficulties in more complex road crossing situations, as older adults typically have slower processing speeds and lower cognitive loads (Phillips et al., 2003; Park & Festini, 2017) which may affect them when traffic density is high, cars are travelling from a number of different directions or cars are travelling quickly. I wanted to start with the same factors that I used in Chapter 3, pedestrian presence and traffic density. Pedestrian presence captured the eye movement of older adults in Chapter 2 but did not impact on crossing decisions. As mentioned in Chapter 3, this may be because the task was simple enough that older adults could be distracted by pedestrians but still be able to disengage their attention from the pedestrians with enough time to take in the information they need to make a safe crossing decision. However, if older adults were distracted when multiple cars are travelling down the road or the cars are travelling quickly they may not be able to take in enough information or react quickly enough to make a safe crossing decision. Similarly with traffic density, although it showed no impact on crossing behaviour in Chapter 2, it may have an impact in combination with an additional factor such as car speed or cars travelling from multiple directions. I chose to combine the factors from Chapter 2 with additional factors of car speed, cars travelling in the far lane or both lanes, and cars travelling from an obscured direction. These factors were chosen based on the results from previous studies which had all shown they had an impact on the crossing behaviour of older adults (Oxley et al., 1997; Geraghty et al., 2016; Oxley et al., 2005; Dommes et al., 2013; Lobjois & Cavallo, 2007). I felt it would be more appropriate to test all these combinations of factors in one study rather than in three separate studies.

It is a shame that the eye movement data were not useful. I don't completely understand what the issue with data processing is. Is it the case that gaze coordinates are not possible to determine in Jan's lab setup?

The Eyelink II is set up to be used for one screen, so gaze coordinates can only be determined for one screen. To use a three screen set up one needs to use head motion and position data measured by a separate motion tracker. One also needs to use the head referenced position data (HREF). HREF measures eye rotation angles relative to the head. However, the output data is not a rotation angle of the eye but x and y coordinates which define a point on the HREF plane which is a constant 15,000 units away from the participant. The eye rotation angle can then be determined from the coordinates using the following equation provided in the Eyelink II manual:

angle = acos((f*f + x1*x2 + y1*y2) / (sqrt((f*f + x1*x1 + y1*y1) * (f*f + x2*x2 + y2*y2)));

f is the constant distance from the participants' eyes to the HREF plane, and x and y are the HREF x and y coordinate values. During the calibration the HREF values are scaled and from there you can related the HREF coordinates to real world coordinates. A new calibration procedure was required to ensure that the HREF values are scaled appropriately for the three screen environment I used. One of my supervisors had managed to develop a calibration procedure for three screens, as mentioned above, but we had not yet developed a way to scale the HREF coordinates after the calibration procedure was completed. Once this is completed then I will be able to analyse the eye tracking data.

If you could change something about chapter 4 exp 1 what would it be?

I would not change anything about Chapter 4 experiment one. I think that it was a well controlled study that allowed me to address critical confounds. Specifically, experiment one allowed me to separate any effects of cars travelling along the far lane from effects of cars travelling from both directions. The study also allowed me to differentiate any effects of cars travelling in both lanes from cars travelling in one lane only. Previous studies showed that participants had difficulties making decisions for traffic travelling in the far lane, only used traffic situations coming from both directions (Geraghty et al., 2016; Oxley et al., 1997, 2005). Therefore, it is not possible to differentiate the impact of making decisions on both lanes from making decisions on only the far lane, and two cars versus one car. The design of Chapter 4 experiment one allowed me to differentiate these effects. However, the experiment did produce a large number of findings and organising the narrative was challenging but it does not take anything away from the design of the experiment.

It would be good to provide some context about the BADS scores and RMA scores. I assume higher is better but the figures show these can only be between 0 and 4

For the BADS zoo map scores, higher is better, but they only range from 0 to 4. For the RMA scores, accuracy was reported as 0 or 1 for each trial. The local switch cost on scores was the difference between average accuracy on switch trials and average accuracy on non-switch trials. The global switch cost on score was the difference between the average accuracy on blocks where participants switch between tasks and the average accuracy on blocks where participants were doing the same task. These values could range anywhere from 0 to 1.

I have added further details on the scoring of the executive functioning tests to the executive function tests subsection of the methods for Chapter 4.

Regarding the null findings in exp 1 for number of lanes and near or far lane, does this mean that crossings are riskier when cars are travelling in both lanes or in the far lane since such cases would require more time to clear the cars?

It is possible that these decisions could be considered risky, as they should leave more time to cross the far lane as this takes more time to cross than the near lane. However, this assumes that participants do not leave enough time to cross both lanes as a precaution or habit when they cross the near lane. Therefore, as the results are not significantly different rather than a reduction in TTI, then I would err on the side of these decisions being safe crossing decisions.

Perhaps figures showing data could also indicate what differences were significant

I have only shown the significant results in the figures.

References

Allain, P., Nicoleau, S., Pinon, K., Etcharry-Bouyx, F., Barré, J., Berrut, G., ... Le Gall, D. (2005). Executive functioning in normal aging: A study of action planning using the zoo map test. *Brain and Cognition*, *57*(1), 4–7.

Ampofo-Boateng, K., & Thomson, J. A. (1990). Child pedestrian accidents: A case for preventive medicine. *Health Education Research*, *5*(2), 265–274.

Anders, T. R., Fozard, J. L., & Lillyquist, T. D. (1972). Effects of age upon retrieval from short-term memory. *Developmental Psychology*, *6*(2), 214–217.

Andrea, D. J., Fildes, B. N., & Triggs, T. J. (2000). The sensitivity and bias of older driver judgements in an arrival-time task. In *Kursiust, editor proceedings of the road safety research, policing & enforcement conference.*

Beurskens, R., & Bock, O. (2012). Age-related decline of peripheral visual processing: The role of eye movements. *Experimental Brain Research*, *217*(1), 117–124.

Bock, O., Brustio, P. R., & Borisova, S. (2015). Age-related differences of the gaze pattern in a realistic pedestrian traffic task. *International Journal of Applied Psychology*, *5*(1), 13–19.

Bopp, K. L., & Verhaeghen, P. (2005). Aging and verbal memory span: A meta-analysis. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *60*(5), 223–233.

Butler, K. M., & Zacks, R. T. (2006). Age deficits in the control of prepotent responses: Evidence for an inhibitory decline. *Psychology and Aging*, *21*(3), 638–643.

Butler, K. M., Zacks, R. T., & Henderson, J. M. (1999). Suppression of reflexive saccades in younger and older adults: Age comparisons on an antisaccade task.

Memory & Cognition, *27*(4), 584–591.

Carpenter, P. A., Just, M. A., & Shell, P. (1990). What one intelligence test measures: A theoretical account of the processing in the raven progressive matrices test. *Psychological Review*, *97*(3), 404–431.

Chapman, G. J., & Hollands, M. A. (2006). Evidence for a link between changes to gaze behaviour and risk of falling in older adults during adaptive locomotion. *Gait & Posture*, *24*(3), 288–294.

Chapman, G. J., & Hollands, M. A. (2007). Evidence that older adult fallers prioritise the planning of future stepping actions over the accurate execution of ongoing steps during complex locomotor tasks. *Gait & Posture*, *26*(1), 59–67.

Connelly, M. L., Conaglen, H. M., Parsonson, B. S., & Isler, R. B. (1998). Child pedestrians' crossing gap thresholds. *Accident, Analysis & Prevention*, *30*(4), 443–453.

Daigneault, S., Braun, C. M., & Whitaker, H. A. (1992). Early effects of normal aging on perseverative and non-perseverative prefrontal measures. *Developmental Neuropsychology*, *8*(1), 99–114.

Di Fabio, R. P., Greany, J. F., & Zampieri, C. (2003). Saccade-stepping interactions revise the motor plan for obstacle avoidance. *Journal of Motor Behavior*, *35*(4), 383–397.

Di Fabio, R. P., Zampieri, C., Henke, J., Olson, K., Rickheim, D., & Russell, M. (2005). Influence of elderly executive cognitive function on attention in the lower visual field during step initiation. *Gerontology*, *51*(2), 94–107.

Dommes, A., Cavallo, V., Dubuisson, J.-B., Tournier, I., & Vienne, F. (2014). Crossing a two-way street: Comparison of young and old pedestrians. *Journal of Safety Research*, *50*, 27–34.

Dommes, A., Cavallo, V., & Oxley, J. A. (2013). Functional declines as predictors of risky street-crossing decisions in older pedestrians. *Accident Analysis & Prevention*, *59*, 135–143.

Eppinger, B., Kray, J., Mecklinger, A., & John, O. (2007). Age differences in task switching and response monitoring: Evidence from ERPs. *Biological Psychology*, *75*(1), 52–67.

ERSO. (2018). *Traffic safety basic facts on pedestrians.* European Commission, Directorate General for Transport.

Gazzaley, A., & D'esposito, M. (2007). Top-down modulation and normal aging. *Annals of the New York Academy of Sciences*, *1097*(1), 67–83.

Geraghty, J., Holland, C., & Rochelle, K. (2016). Examining links between cognitive markers, movement initiation and change, and pedestrian safety in older adults. *Accident Analysis & Prevention*, *89*, 151–159.

Gillam, B. (1992). The status of perceptual grouping 70 years after Wertheimer. *Australian Journal of Psychology*, *44*(3), 157–162.

Hampshire, A., Gruszka, A., Fallon, S. J., & Owen, A. M. (2008). Inefficiency in self-organized attentional switching in the normal aging population is associated with decreased activity in the ventrolateral prefrontal cortex. *Journal of Cognitive Neuroscience*, *20*(9), 1670–1686.

Harsay, H. A., Buitenweg, J. I., Wijnen, J. G., Guerreiro, M. J., & Ridderinkhof, K. R. (2010). Remedial effects of motivational incentive on declining cognitive control in healthy aging and Parkinson's disease. *Frontiers in Aging Neuroscience*, *2*, 144.

Hart, R. P., & Bean, M. K. (2010). Executive function, intellectual decline and daily living skills. *Aging, Neuropsychology, and Cognition*, *18*(1), 64–85.

Hunt, M., Harper, D. N., & Lie, C. (2011). Mind the gap: Training road users to use speed and distance when making gap-acceptance decisions. *Accident Analysis & Prevention*, *43*(6), 2015–2023.

Keall, M. D. (1995). Pedestrian exposure to risk of road accident in New Zealand. *Accident Analysis & Prevention*, *27*(5), 729–740.

Lobjois, R., & Cavallo, V. (2007). Age-related differences in street-crossing decisions: The effects of vehicle speed and time constraints on gap selection in an estimation task. *Accident Analysis & Prevention*, *39*(5), 934–943.

Luis, C. A., Keegan, A. P., & Mullan, M. (2009). Cross validation of the Montreal Cognitive Assessment in community dwelling older adults residing in the Southeastern US. *International Journal of Geriatric Psychiatry*, *24*(2), 197–201.

MATLAB. (2019). *version 9.6.0 (r2019a).* Natick, Massachusetts: The MathWorks Inc.

Meir, A., Parmet, Y., & Oron-Gilad, T. (2013). Towards understanding child-pedestrians' hazard perception abilities in a mixed reality dynamic environment. *Transportation Research Part F: Traffic Psychology and Behaviour*, *20*, 90–107.

Milham, M. P., Erickson, K. I., Banich, M. T., Kramer, A. F., Webb, A., Wszalek, T., & Cohen, N. J. (2002). Attentional control in the aging brain: Insights from an fMRI study of the stroop task. *Brain and Cognition*, *49*(3), 277–296.

Morey, R. D., & Rouder, J. N. (2018). BayesFactor: Computation of Bayes Factors for Common Designs [Computer software manual]. Retrieved from `https://CRAN.R-project.org/package=BayesFactor` (R package version 0.9.12-4.2)

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., ... Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699.

Nicholls, V. I., Jean-Charles, G., Lao, J., de Lissa, P., Caldara, R., & Miellet, S. (2019). Developing attentional control in naturalistic dynamic road crossing situations. *Scientific Reports*, *9*(1), 4176.

Nieuwenhuis, S., Ridderinkhof, K. R., De Jong, R., Kok, A., & Van Der Molen, M. W. (2000). Inhibitory inefficiency and failures of intention activation: Age-related decline in the control of saccadic eye movements. *Psychology and Aging*, *15*(4), 635–647.

Olincy, A., Ross, R., Youngd, D., & Freedman, R. (1997). Age diminishes performance on an antisaccade eye movement task. *Neurobiology of Aging*, *18*(5), 483–489.

Owen, A. M., Downes, J. J., Sahakian, B. J., Polkey, C. E., & Robbins, T. W. (1990). Planning and spatial working memory following frontal lobe lesions in man. *Neuropsychologia*, *28*(10), 1021–1034.

Oxley, J. A., Fildes, B., Ihsen, E., Charlton, J., & Day, R. (1997). Differences in traffic judgements between young and old adult pedestrians. *Accident Analysis & Prevention*, *29*(6), 839–847.

Oxley, J. A., Ihsen, E., Fildes, B. N., Charlton, J. L., & Day, R. H. (2005). Crossing roads safely: An experimental study of age differences in gap selection by pedestrians. *Accident Analysis & Prevention*, *37*(5), 962–971.

Palmer, S. E. (1992). Common region: A new principle of perceptual grouping. *Cognitive Psychology*, *24*(3), 436–447.

Park, D. C., & Festini, S. B. (2017). Theories of memory and aging: A look at the past and a glimpse of the future. *The Journals of Gerontology: Series B*, *72*(1), 82–90.

Peirce, J. W. (2007). Psychopy—psychophysics software in python. *Journal of Neuroscience Methods*, *162*(1-2), 8–13.

Phillips, L., Gilhooly, K., Logie, R., Sala, S. D., & Wynn, V. (2003). Age, working memory, and the Tower of London task. *European Journal of Cognitive Psychology*, *15*(2), 291–312.

R Core Team. (2020). R: A language and environment for statistical computing [Computer software manual]. Vienna, Austria. Retrieved from `https://www.R-project.org/`

Ritchie, S. J., Tucker-Drob, E. M., & Deary, I. J. (2014). A strong link between speed of visual discrimination and cognitive ageing. *Current Biology*, *24*(15), 681–683.

Rogers, R. D., & Monsell, S. (1995). Costs of a predictible switch between simple cognitive tasks. *Journal of experimental psychology: General*, *124*(2), 207–231.

Rousselet, G. A., Pernet, C., & Wilcox, R. R. (2019). A practical introduction to the bootstrap: A versatile method to make inferences by using data-driven simulations.

Rypma, B., & D'Esposito, M. (2000). Isolating the neural mechanisms of age-related changes in human working memory. *Nature Neuroscience*, *3*(5), 509–515.

Salat, D. H., Buckner, R. L., Snyder, A. Z., Greve, D. N., Desikan, R. S., Busa, E., ... Fischl, B. (2004). Thinning of the cerebral cortex in aging. *Cerebral Cortex*, *14*(7), 721–730.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review*, *103*(3), 403–428.

Schneider-Garces, N. J., Gordon, B. A., Brumback-Peltz, C. R., Shin, E., Lee, Y., Sutton, B. P., ... Fabiani, M. (2010). Span, CRUNCH, and beyond: Working memory capacity and the aging brain. *Journal of Cognitive Neuroscience*, *22*(4), 655–669.

Schwebel, D. C., Davis, A. L., & O'Neal, E. E. (2012). Child pedestrian injury: A review of behavioral risks and preventive strategies. *American Journal of Lifestyle Medicine*, *6*(4), 292–302.

Schwebel, D. C., Gaines, J., & Severson, J. (2008). Validation of virtual reality as a tool to understand and prevent child pedestrian injury. *Accident Analysis & Prevention*, *40*(4), 1394–1400.

Sekuler, R., McLaughlin, C., & Yotsumoto, Y. (2008). Age-related changes in attentional tracking of multiple moving objects. *Perception*, *37*(6), 867–876.

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London. B, Biological Sciences*, *298*(1089), 199–209.

Simpson, G., Johnston, L., & Richardson, M. (2003). An investigation of road crossing in a virtual environment. *Accident Analysis & Prevention*, *35*(5), 787–796.

Tipper, S. P. (1991). Less attentional selectivity as a result of declining inhibition in older adults. *Bulletin of the Psychonomic Society*, *29*(1), 45–47.

Trick, L. M., Jaspers-Fayer, F., & Sethi, N. (2005). Multiple-object tracking in children: The "catch the spies" task. *Cognitive Development*, *20*(3), 373–387.

Tsang, P. S. (1998). Age, attention, expertise, and time-sharing performance. *Psychology and Aging*, *13*(2), 323–347.

Van der Linden, M., Brédart, S., & Beerten, A. (1994). Age-related differences in updating working memory. *British Journal of Psychology*, *85*(1), 145–152.

Welsh, M., Cicerello, A., Cuneo, K., & Brennan, M. (1995). Error and temporal patterns in Tower of Hanoi performance: Cognitive mechanisms and individual differences. *The Journal of General Psychology*, *122*(1), 69–81.

Wertheimer, M. (1923). Untersuchungen zur Lehre von der Gestalt. II. *Psychologische Forschung*, *4*(1), 301–350.

Wilson, B. A., Alderman, N., Burgess, P. W., Emslie, H., & Evans, J. (1996). *Behavioural assessment of the dysexecutive syndrome.* Thames Valley Test Company.

Zietz, D., & Hollands, M. (2009). Gaze behavior of young and older adults during stair walking. *Journal of Motor Behavior*, *41*(4), 357–366.

Zito, G. A., Cazzoli, D., Scheffler, L., Jäger, M., Müri, R. M., Mosimann, U. P., ... Nef, T. (2015). Street crossing behavior in younger and older pedestrians: An eye-and head-tracking study. *BMC geriatrics*, *15*(1), 176.