A study investigating the comparative Situation Awareness of older and younger drivers when driving a route with extended periods of cognitive taxation.

Highlights

- Younger drivers performed comparatively better than older drivers in Situation Awareness related scoring.
- Perceptions of task difficulty appeared to be an important influential factor for SA proficiency.
- Textual analysis of driver commentaries found that older drivers were less aware of what was behind their vehicles and enunciated less safety-related concepts.

Abstract

This study sought to measure and compare the Situation Awareness (SA) of a younger group of 11 drivers (average age 28.2 years) to that of an older group of 10 drivers (average age 77.2 years), as they traversed a route that included many cognitively taxing elements. This was achieved by recording a participant's continual commentary of what s/he felt to be of relevance during the drive. These recordings were then transcribed and assessed by computer software capable of abstracting the main concepts from each individual's or group's narrative, and calculating scores indicative of Situation Awareness. It was found that the younger drivers scored significantly higher ($p<0.024$) than their older counterparts. Furthermore, when the results from the participants who undertook both this and previous studies in the series were compared (see Key et al., 2016), it was found that SA scoring could be importantly influenced by perceptions of a task's difficulty, rather than its actual difficulty. It was also indicative from the narratives, that the younger driving group had demonstrated a better 360-degree awareness, and enunciated more safety-related concepts.

Keywords

Situation Awareness; Older drivers; 'Think aloud' method.

1. Introduction

According to St.Pierre et al. (2016), Situation Awareness involves being aware of what is happening in the vicinity, comprehending the relevance of aspects within the current situation, and predicting the future status of the situation. And that, inter alia, "complexity of the situation impair[s] the formation of adequate situation awareness" (p.169). In Key et al. (2016) and this present work, that assertion has been considered within a driving context. In a previous study in this series, it was found that scores demonstrative of Situation Awareness (SA) whilst driving a cognitively non-taxing, and uncomplicated, route were very similar between an older and younger group. However, when the narratives from which those SA scores were derived were evaluated and compared, the younger group was surprisingly found to have given three times as many safety-related, and twice as many rearward looking, concepts and words. In addition, they appeared, perhaps advantageously, to focus more on specific driving actions and roadway artefacts. This was in contrast to the older group, who exhibited less rigorous information processing and a reliance on more general, directional-based, cues. These findings extended previous research, which has tended to focus more on age-related performance variability, such as with contrast sensitivity (Greene & Madden, 1987; Owsley, Sekuler, & Siemsen, 1983), useful field of view (Ball, Owsley, & Beard, 1990; Scialfa, Kline, & Lyman, 1987), stereopsis (Schieber, 1991), and overall attention capacity (Madden, 1986). However, in regards to 360-degree awareness, the study supported findings by Bao & Boyle (2009), who found older drivers to exhibit less usage of their review mirrors.

An argument was made that if older drivers do undertake more cursory observation, and process, potentially, an insufficient number of safety-related cues, then whilst this may not necessarily impact upon them driving safely in less demanding conditions, as was evident in Key et al. (2016), it could if those conditions became more cognitively demanding. After all, driving is a complex task, requiring a driver to employ a range of cognitive processes. These include: perception and pattern recognition (Kass et al., 1991); attention and comprehension (Kass et al., 2007; Wickens & Hollands, 2000); and decision-making (Endsley, 1995b; Ma & Kaber, 2005). However, due to age-related declines, these may become impaired and be revealed through, for example, slower motor responses (Rinalducci, Smither, & Bowers, 1993) and poorer judgement of gaps (Darzentas, McDowell, & Cooper, 1980). Thus within roadway environments considered as more cognitively taxing, or indeed complex, it would seem reasonable to contend that older driver groups will exhibit poorer SA and driving-related performance (e.g. Kaber et al, 2012, Zhang et al, 2009, Ho et al, 2001). But is this the case?

To investigate this further, Key et al. (2016) evaluated an older against a younger driving group from commentaries of two car journeys, viewed on video, that all participants confirmed as having different levels of roadway and peripheral activity. It was assumed, on the basis of the above research, that the more cognitively taxing journey would be more difficult to provide a commentary for. And furthermore, due to age-related processing deficits, that it would impact more on the older group's performance, and thus their Situation Awareness indicative scores.

The results, however, were contrary to expectation, with the older driving group actually demonstrating better SA for both journeys, and particularly so when their narratives were combined and evaluated as one entity ($p<0.062$). In addition, those older participants who undertook a previous study in this series, where they provided a commentary for a non-complex route whilst driving, showed a significant improvement in their SA scoring for the video trails ($p<0.015$).

It is thus important to consider, as safely as possible, whether the findings for the presumed cognitively more taxing video-based studies - due to their stated difficulty and complexity by the older participants - could also be found on actual roadways.

1.1. Approach

In order to evaluate any relative difficulty further and as accurately as possible, a participant preference was given to those who had volunteered for the studies reported in Key et al. (2016). A comparative assessment could then be made between their SA (Density) scores, and their perceptions of relative task difficulty.

1.2. Objectives and hypotheses

The principal objective was to capture an appropriate commentary from each participant, sufficient for his/her SA to be assessed for the route.

SA-related network proficiency scores, and the relevance and prominence of the concepts and links that comprised them, could then be determined by computer software.

It was hypothesised that due to age-related perceptual declines, that the Situation Awareness network scores, and the relevance of the concepts within each group's network, would be more deficient for the older, than younger, participants during the drive.

2. Method

2.1. Design

The study once again adopted a 'Think aloud' (or Verbal Protocol Analysis) approach to data capture (Bainbridge, 1990). As with Key et al. (2016), the aim was to have participants drive their own cars around a pre-defined course for around 30 minutes, and whilst doing so, to provide a continual verbal commentary of what information was viewed as relevant from each driving environment encountered, and how it impacted on their driving actions. These commentaries were recorded via an audio capture device, and later transcribed verbatim. They were then run through computer software capable of extracting and depicting visually an individual's, or group's, concept network, and furthermore, numerically calculating how proficiently it was formed.

2.2. Participants

21 participants undertook the trial (12 male/9 female). Of the older participants (7 male/3 female; average age: 77.2 years), all had undertaken the previous study in this series. The younger participants (5 male/6 female; average age: 28.2 years) included 6 who had undertaken the previous study.

2.2.1. Inclusion criteria

Potential participants had to have a full UK driving licence with no recent major endorsements, and have good clarity in spoken English.

2.3. Materials

The vehicle used to drive the route was provided by the participant. His/her commentary was recorded by an (unobtrusive) digital device, and latterly assessed through a PC capable of running the chosen software packages.

2.3.1 Route

The route to be driven was 11.9 miles in length (following a short warm-up phase of 0.5 miles) running through Leicestershire, UK, to Swithand reservoir (see Figure 1). It comprised of 2.5 miles along dual carriageway (A6); 2.25 miles along a major 'A' class road (A6004); 3.2 miles through towns (Quorn: 1.5 miles; Mountsorrel 1.7 miles); and 4 miles of countryside driving (including 2.66 miles along single car width roads).

From pre-testing for safety, difficulty, and potential delay from roadworks, the route was found to take around 30 minutes to drive (with 45 minutes then being allocated for each journey), and was to start and end at Loughborough University, UK. However, no data was captured once a driver had exited the roundabout off of the A6 and back onto the A6004 (see red symbol/Figure 1).

Figure 1: Route map

All trials took place in good visibility and at pre-defined times (11.40 am, 1.40 pm, or 3.30pm). This allowed a driver to avoid peak traffic conditions - thus facilitating better commentary; and enabled more control over traffic density – which was found to be very similar for each trial. For participant safety, no driving would be undertaken in dangerous conditions (none were evident), and care was taken not to overly distract a driver with instructions and directions.

The route chosen presented a participant with more challenges than in a previous driving-based study in the series, though within reason for safety. Table A, below, gives some comparative data.

Table A: Study route difficulty comparisons

Route comparisons	Key et al. (2016)	This Study
Roadway artefact		
Traffic/pedestrian lights	16	17
Roundabouts	6	12
Totals	**22**	**29**
Cornering/turning		
Left turns	1	2
Left bends (sharp & blind)	1	13
Left bends (sharp)	0	2
(Of which were 90 degrees)	(0)	(3)
'T' Junction Left turn	3	1
Right turns	4	2
Right bends (sharp and blind)	1	12
Right bends (sharp)	0	3
(Of which were 90 degrees)	(0)	(3)
'T' Junction Right turn	1	2 (1 blind)
Totals	**11**	**37**

The difference between the two routes was particularly evident during the 4 miles of countryside driving, as this presented a driver with progressively more difficult tight corners that were either blind or had restricted views. This element also included roadways, not utilised in the previous study, where there was only enough space for one car to pass (see top left image: Figure 2). In addition, drivers were exposed to a right turn from a 'T' junction with no visibility from the right (Figure 2: top right image). Restricted road widths through towns with oncoming vehicles (Figure 2: bottom left image), a small angled bridge with room for only one car and no view of oncoming traffic (Figure 2: bottom right image), and an entrance onto a dual carriageway with a limited slip lane, making acceleration and lane entry difficult.

Figure 2: Examples of blind turns and narrow roads encountered on the route

Despite these added aspects, all participants later confirmed that they felt the drive and task did not expose them to undue risk – thus validating the pre-testing of the route.

2.4. Procedure

2.4.1. Pre-run phase

Firstly, informed (ethical) consent was obtained from all participants before the route was driven. At this time, it was also emphasised that control of the vehicle, and the safety of other road users, remained their responsibility at all times, and therefore that they should drive as they normally would do on each roadway. Participants were then given the option to re-read the instruction sheet they had been sent the previous day on how to provide a commentary.

2.4.2. Warm-up phase

Prior to commencing the route, the participant drove a short (0.5 mile) journey through the University's campus. This enabled the (5) new participants to practice their commentaries, and where appropriate, additional input was suggested. For the (16) participants who had driven and provided a commentary for previous studies in the series, this stage was optional.

2.4.3. Data collection phase

During this (11.9 mile) phase, the participant's commentary was recorded as s/he drove around the route. Directions were given, whenever possible, during commentary pauses, as was the prompting for more 'thoughts' – though this was very rare.

2.4.4. Debriefing stage

A debriefing session, in the participant's car, took place on return to the university, at which point his/her views on the route were taken, and additionally for the participants who had undertaken Study 2, one standard question - whether commenting on this drive was a more difficult task (than doing so for the videos of car journeys in Study 2) and to give their reasoning.

2.5. Data analysis

The commentaries that were captured were transcribed verbatim post-trial, and then subjected to analysis by Leximancer software (Smith, 2003). Leximancer uses text representations of natural language to interrogate verbal transcripts and identify particular themes, main concepts, and the relationships between them. It does this by using algorithms linked to an in-built thesaurus and by focussing on particular features within a transcript, such as word proximity, quantity, and salience (Walker et al., 2011). A visual representation of the semantic network found is then produced. This can contain any number of prescribed concepts derived from a transcript, and can reflect the strength of the relationships between them (reflected within the text). As such, a researcher can quickly identify a network's key or main SA concepts, i.e. those that act as hubs, and have shorter and more linkages to other concepts within the network.

Leximancer can also identify those concepts that are similarly found within any number of individual or group networks, as well as those that are unique. This can be revealed both through a qualitative assessment of a network map by the researcher, or from the quantitative 'Prominence' scores that the software generates that reflects the 'uniqueness' a main concept has for each individual or group.

The raw quantitative data sets that Leximancer provides in parallel to its visual network data, can then be entered into a mathematical program (Agna) for further structural analysis comparison. Two of the measures that Agna can produce are of particular relevance for Situation Awareness: *Density* - the level of interconnectivity within a network, in the sense of how proficient the linkages are between its concepts; and *Diameter* - the efficiency of the paths across a network in terms of the number of concept nodes needing to be traversed. The denser a network, and the shorter its diameter, the better the individuals' Situation Awareness is said to be, as this facilitates faster access to relevant information.

3. Results

3.1. Quantitative data

3.1.1. Group SA metric scores and other comparative data

As is generally found in the literature (e.g. Bolstad, 2001; Zhang et al., 2009), the younger drivers exhibited the better SA-related scores, and unlike previous studies in this series (see Key et al., 2016), this was found to be the case whether their commentaries were collated and assessed as two groups, or from a comparison by their (averaged) individual scores (see Table B).

Table B: Group SA metric score comparisons and significance

SA assessments						Statistical significance			
Group	Ppts.	By Group score		By Individual score		T	Ppts.	df.	Sig.
		Dia.	Density	Dia.	Density				
Older	10	2	0.7247	2.7	0.4321	-2.454	21	19	0.024
Younger	11	2	0.8895	2.55	0.5333				

*Lower Diameter scores and higher Density scores equate to better SA

Furthermore, the individual SA Density scores were found to be significantly in favour of the younger group ($p<0.024$) from an independent sample t-test. Note: the Diameter scores could not be likewise assessed as they do not allow for sufficient differentiation.

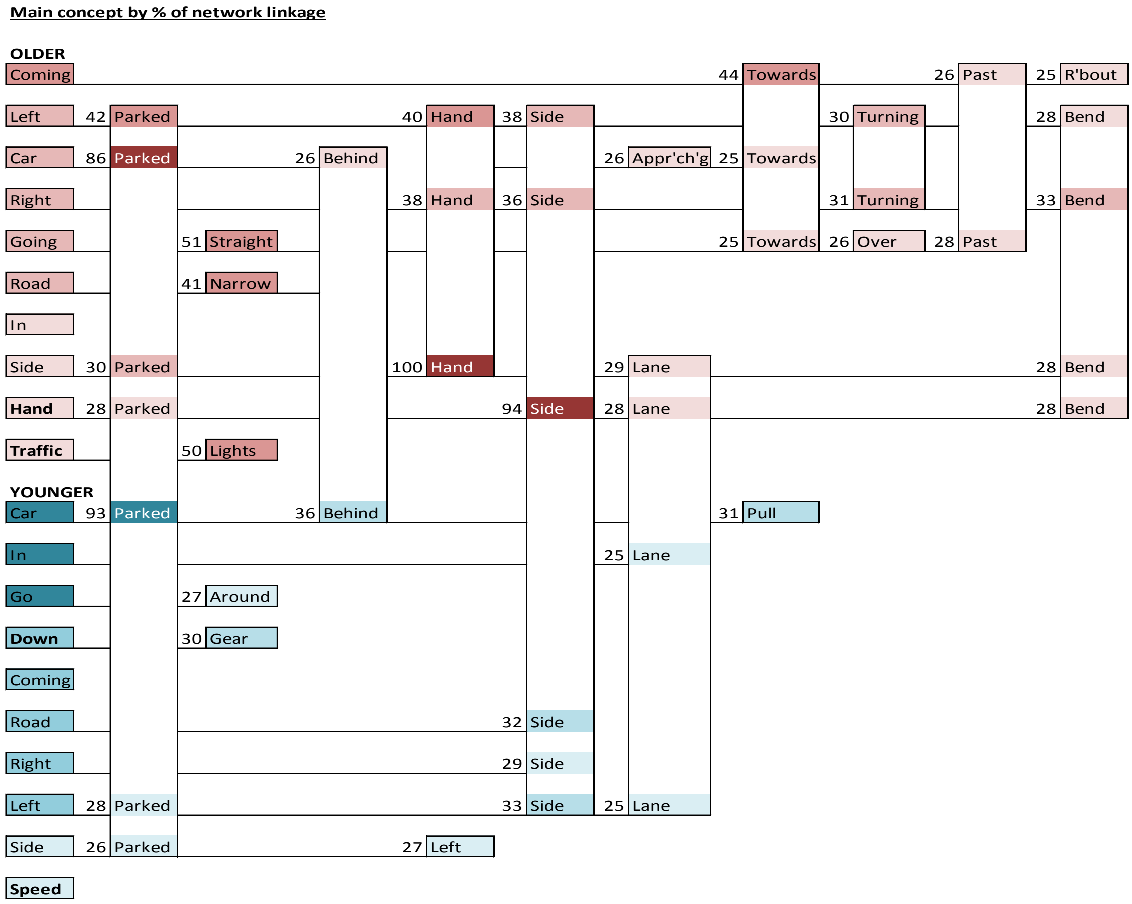
This result is in contrast to that found in Key et al. (2016), where video journey narratives, combined to measure SA, produced far better Density scores for this same older grouping ($p<0.062$).

In terms of individual rankings, the younger participants were found to occupy six of the top seven placings, whereas the older drivers occupied the last five placings. It was also evident that the (9) female participants performed particularly well, occupying five of the top six positions.

3.2. Qualitative data

3.2.1. Group comparison data

Figure 5: Major concepts for the Older and Younger Groups



**major concepts are those above a 50% relevance for the network and with a 200 and above word count.*

In Figure 5 (above), the key or main concepts for each group are given on the left. Those that are in bold text being unique to a particular group (e.g. 'Hand' or 'Speed'), with the background shading indicative of three levels of concept count (399, 299, or 199 hits and above). The Figure also shows the percentage of occurrence with other concepts in the text (again, the darker the background colour the stronger the connection) and where linkages are particular or similar to or for each group.

The older driving group demonstrated a particular tendency to focus on what was 'Coming' or 'Going' 'Towards' or 'Past' the 'Car', and additionally, to 'Turning' the vehicle in response to the many 'Left' and 'Right' 'Hand' 'Bend(s)' along the route. Two main concepts were found as being unique for the group: 'Hand' – as in 'Side' and 'Lane'; and 'Traffic' – related mainly to 'Lights'.

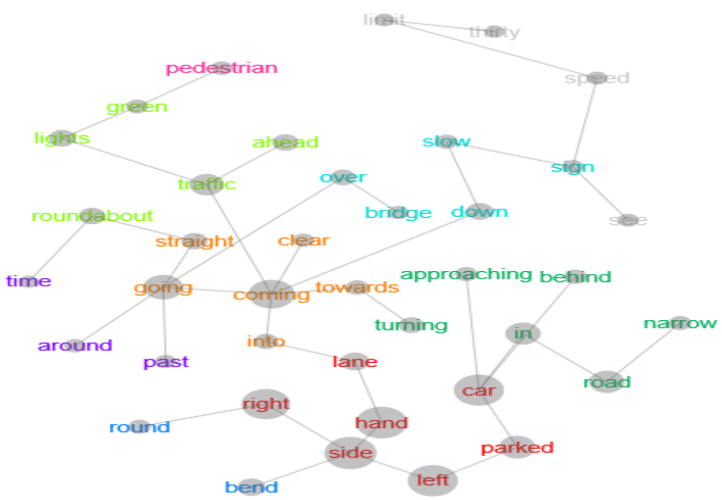
The Younger driver group also showed two unique main concepts: 'Down' - as in going down 'Gear'; and 'Speed'. The latter, unlike the other main concepts in Figure 5, had no concepts linkages of note (the best given by the software being with 'Checking' (at 9%)).

It therefore would seem that speed regulation was an important differentiating factor for this, as with previous younger groups in this series.

Overall, the younger drivers produced less major linkages from their main (to related) concepts in Figure 5, despite producing more narrative text (7%), and a higher concept-related total word count (5077 to 4519).

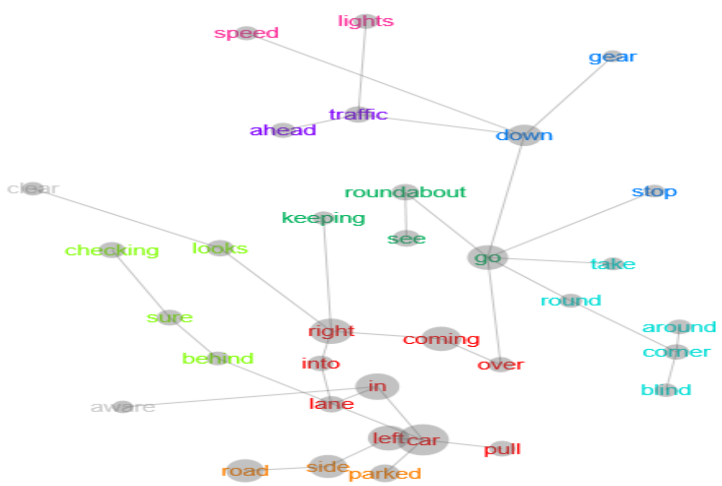
How the concept linkages were made for both groups is also shown in the networks reproduced in Figures 6 & 7 below.

Figure 6: Concept network for the Older Group



In Figure 6, the centrality and importance of the 'Coming' concept is clearly revealed for the older group, as it was in Key et al. (2016), with a closeness and interrelation with 'Going' and 'Towards'. The 'Right', 'Hand', Side' and 'Left' concepts also appear to be an important interrelated cluster, 'Traffic', less so, but it is linked to the 'Coming' concept.

Figure 7: Concept network for the Younger Group



For the younger drivers in Figure 7, there are arguably three important concept clusters that are more spread out in the network. The closely related cluster centring around 'Car' and 'Left', and two others that have a focus at the 'Go' and 'Down' concepts.

3.3. Combined Group data

The Leximancer software also has the capability of combining texts from within (two or more) groups, and then assessing them to reveal the most (comparatively) distinguishing concepts for each. This is reflected through the production of a Prominence score, derived from how frequently and uniquely a particular concept was for each group (see Table C, below). The authors have additionally included each concept's individual group ranking.

Table C: Concept Prominences for the Older and Younger Groups

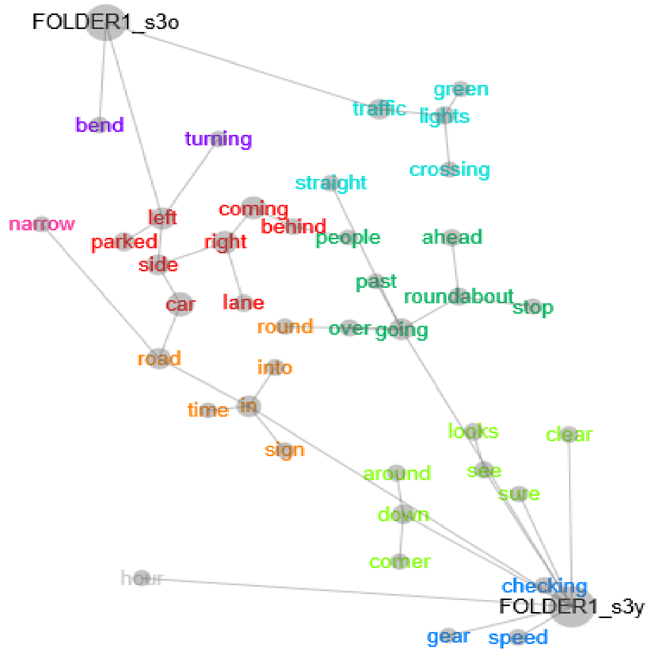
Relative Prominence of main concepts for both groups								
	Older Group				Younger Group			
Concept	**Rk.**	**Freq. ↓**	**Strength ↓**	**Prom. ↓**	**Rk.**	**Freq. ↑**	**Strength ↑**	**Prom. ↑**
Parked	11	4	58	1.2	23			
Traffic	10	6	58	1.2	17			
Left	2	8	55	1.2	8	6	44	0.8
Coming	1	9	53	1.1	5	7	46	0.9
Right	4	8	50	1.1	7	7	49	0.9
Side	8	5	49	1.1	9	5	50	0.9
Road	6	7	47	1.0	6	7	52	1.0
Going	5	7	45	1.0	3	8	54	1.0
Car	3	8	44	0.9	1	9	55	1.1
In	7	7	42	0.9	2	8	57	1.1
Down	16				4	7	71	1.3
Checking	270				12	4	96	1.8

It was found that the older group showed little uniqueness in its concepts, with 'Parked' and 'Traffic' appearing to be the most differentiating in this regard with a 58% strength score. However, when frequency in the text is taken into account, the 'Left' concept is also seen to match these concepts in Prominence score.

For the younger group, in contrast, the need for 'Checking' was found as being particularly unique. Its Prominence score of 1.8 being considerably higher than the 1.3 rating given to another distinguishing concept for the group, 'Down' – as in going 'Down' 'Gear' (see also, Figure 5).

Finally, any further differences between the two group's perspectives in this regard could be revealed through a combined network (see Figure 8, below). This reflects the relevance that the forty most commonly cited concepts had for each group from their proximity to either the 's3o' 'folder' node for the older group, or the 's3y' variant for the younger group.

Figure 8: Relative relevance of a concept for each group (from 'folder' proximity)



This network again highlights the importance of the 'Checking' concept for the younger group, and additionally two other concepts: 'Speed' and 'Gear'(s) - that also appeared distinguishing in Figure 5. Again, as in that Figure, these three concepts did not appear to be interrelated.

For the older group, 'Traffic' once again appeared to be a distinguishing concept, and seemed to be particularly related to 'Lights'. 'Bend' was also prominent, but was not found here to have linkages to other concepts, as it did to many main ones in Figure 5. In addition, the 'Left' concept, that also, like 'Traffic' and 'Bend', had a direct linkage to the older group's folder node, appears here to be particularly related to a third distinguishing concept, 'Turning'. This did not register in Table C, but it was evident for the older group in Figure 5.

3.4. Was this study, or the video-based study reported in Key et al (2016), the harder to undertake?

Relevant participants were asked on completing the route whether they had found the drive, or the video-based tasks of the previous study, the easier to undertake. All of the older drivers said the drive was the easier task to provide a commentary for (see Table D). In contrast, for a majority of the younger participants, it was the video-based study.

Table D: Perceived task difficulty and main reasons

Which Study was the easier to undertake?				
Group	Previous (video)	Present (driving)	Neither	Main Reasons
Older	0	10	0	Preferred speed/vehicle familiarity and control/unrestricted view/ directional knowledge.
Younger	3	2	1	Unfamiliar route/need to drive and comment.

Table E below additionally summarises the performance patterns of those participants who undertook both this (driving) study and the previous video-based study within Key et al. (2016).

Table E: SA Density score changes from the video-based study within Key et al. (2016).

SA Density score uplifts		
Group	Improving from video-based study	Worsening from video-based study
Older	1	9
Younger	5	1

These findings, taken together, suggest that rather than a (perceived) easier task bringing higher SA proficiency, it is more likely that a harder (perceived) task would have that effect.

3.5. Additional findings relating to rearward and safety-relevant concepts

As Key et al. (2016) argued that older drivers showed indications of having an undue focus to the front, and front/left of their vehicles, at the expense of what was occurring behind, a directional concept comparison was again made to assess this (see Table F).

Table F: Rearward-related concept comparisons

Concept	Older Group	Younger Group
	Word Count	Word Count
Behind	105	86
Mirror	3	97
Rearview	0	35
Wing (mirror)	1	14
Totals	**108**	**232**

These summations provide support for this contention, particularly as they showed a similar 2:1 ratio to that found in Key et al. (2016).

A second aspect of interest from those studies was a potentially sub-optimal amount of relevant information generally being processed by the older drivers. It is conceded that this is not possible to substantiate from the narratives alone. However, it does seem worthy to note that the younger group mentioned what were considered as safety-related concepts, about three times more often than the older group (see Table G, below). Again, a similar ratio to what was found for a less cognitively taxing driven route undertaken for Key et al. (2016).

Table G: Group comparison of concepts considered to be safety-related

Concept	Older Group	Younger Group
	Word Count	Word count
Checking	6	183
Check		
Indicating	76	71
Indicate(d)		
Blind	20	81
Clear	55	121
Sure	23	124
Gap	5	12
Safe	12	20
Looking	64	175
Look		
Aware	3	79
Warning	8	2
(having)Time	7	23
(enough)Space	9	28
(enough)Room	27	14
Totals	**315**	**933**

4. Discussion

4.1. SA scoring and concept comparisons

4.1.1. Quantitative data

In terms of measures indicative of Situation Awareness, it was found that the younger group out-performed that of an older group as is generally found in the literature (e.g. Bolstad, 2001; Zhang et al., 2009; Kaber et al., 2012). This was the case whether the narratives of the two groups were considered as a whole, or from an averaging of their individual scores (see Table B). In the latter case, which allows for a statistical evaluation, the Group differences by SA Density score were found to be significant ($p<0.024$).

Unlike the driving route in Key et al. (2016), where care was taken not to challenge drivers with difficult roadways, this study, in contrast, actually sought out road environments that would require extra cognitive taxation, and often for long time periods. Rather than degrade SA-related scoring, however, overall, for both groups, the route produced improvements and more consistency in their scores. There was, though, more evidence of an age to SA relationship at the extreme scoring rankings, with younger drivers occupying the top four positions and older drivers the bottom five positions. This perhaps was indicative of a more complex drive providing a context for a relative magnification amongst those younger drivers who had the best awareness, and those older drivers who had the worst?

4.1.2. Qualitative data

The older drivers tended to perceive and evaluate more concepts to the front of their vehicles. This was reflected by the importance of the 'Coming' concept in Figure 5 (where it had the highest concept count) and its high 'centrality' within Figure 6. The importance of the 'Going' concept is also reflective of this preference, as was its linkage (also found for the 'Coming' concept) to 'Towards'. Other distinguishing concepts for the group were 'Hand', which appeared to be merely a product of more precision in speech than better awareness per se, and also, a general 'Traffic' concept - simply denoting more of an interest with road signalling. The older drivers also gave indications of being more aware of driving movement and roadway artefacts than they had been in the less cognitively taxing route driven in Key et al. (2016). Examples from Figure 5 are the, unique to the group, 'Bends', and a related 'Turning' concept.

For the younger group, concepts indicative of speed regulation were again evident. This is highlighted in Figure 5 through the group's interest in gear changes relating to slowing 'Down'. However, the 'Down' concept had considerably less importance for this study than for the easier drive undertaken for Key et al. (2016). For example, there were no tangible links between 'Speed' and 'Down', and 'Coming' to a 'Stop' in this study. The younger group also appeared to have undertaken more strategic, broader, processing here. For example, in regards to the older group's awareness of a need for 'Turning' around 'Bend'(s), they tended to use 'Go' 'Around' for this action. Figure 5 also showed less distinguishing and less concept relationships for this group than was found previously.

The network maps (in Figures 6 & 7) reflect the information given in Figure 5 in a visual form. It was evident here that the older group's concepts emanated principally from the important 'Coming' concept. As such, certain concept clusters, such as those related to signage ('Speed', 'Limit' and 'Thirty'), appear somewhat detached in the network. However, other more specific concepts, such as 'Bridge', 'Pedestrian', 'Roundabout', 'Sign', and 'Lights' are more evident in the group's network, than were found in Key et al. (2016).

The younger group, in contrast, shows the main concepts within its network slightly more spread out e.g. 'Go', 'Down', and 'Car', giving the impression of a better overall linkage. There are also more indications of hazard anticipation here, from concepts such as 'Checking', that a 'Corner' maybe 'Blind', and that a roadway 'Looks' - 'Clear'. The older group did also have 'Clear' in their network, but it was related to the 'Coming' concept that had a focus more on what was being seen out of the front windscreen.

4.1.3. Combined Group data

In Table C, it becomes evident that for the older group there were few, if any, main concepts that showed a particular uniqueness. The software calculates 'Parked' and 'Traffic' in this category each with a 58% relevance in the text, with the 'Left' concept at 55% but also with a Prominence score of 1.2. It could be argued from this data that the older drivers were more aware of cars that were parked on the left hand side of a roadway - a relationship also reflected in other data forms (e.g. a 42% linkage in Figure 5, and conceptual proximities within the group's networks).

The younger group, however, did exhibit particular concept uniqueness here, from its high, 96%, strength score for 'Checking' (a 181-6 concept comparison count). This relates to, and possibly reflects, better awareness of potential roadway dangers by the group? To a lesser degree, the 'Down' concept also showed some differentiation with a 71% strength score (from a 373-121 concept comparison count). As with the previous driving study in the series, this appears indicative of more relative awareness by the younger drivers of speed regulation.

A network map of concepts (in Figure 8) that was produced from the combined data, shows visually how relevant a (top 40) concept was for a particular group from its proximity to a relevant 'Folder' node. As might be anticipated, the ones that stand out here reflect what was found in the standalone networks considered earlier (in Figures 6 and 7).

For the older group, the more distinguishing concepts were found to be 'Turning' (with an 88-43 concept count comparison) and 'Bend' (123-54) which were also shown to be particularly relevant for this group in Figure 5, but were too low in relative frequency/strength combination to be included in Table C.

For the younger group, three related concepts showed particular relevance: 'Checking', 'Speed' and 'Gear'. The 'Checking' concept was unsurprising given the data provided in Table C above. 'Speed' was a main and distinguishing concept (like 'Gear') in Figure 5, with both concepts linked to the important 'Down' concept in Figure 7.

4.2. Comparative task difficulty to the video trials reported in Key et al (2016)

A common theme conveyed by the older drivers in the study was that as they were familiar with their vehicles, they could proceed at a speed that was comfortable for them to make a commentary. In contrast, in the video-based studies of Key et al. (2016), they had felt that the route was being driven too quickly, and believed they were disadvantaged from not knowing the direction the car would be heading. Yet despite, or because of this, their SA scores were actually higher than the younger participants for the video-based tasks, perhaps through a need for greater concentration?

The younger drivers, in contrast, marginally found the video task easier, and when not, it was due to them becoming more familiar and confident with giving a commentary, rather than a reflection of the driving task itself. In general, having (more) familiarity with video footage, they saw advantages in simply commenting than having to both drive and comment. They also felt the driving task became more difficult once the route became unfamiliar, i.e. away from the University's environs, even though the route shown in the video footage was actually less familiar to them.

Notwithstanding the low comparison sample here, particularly for the younger participants, this data further underlines that, firstly, SA could be variable according to the task rather than being, say, uniformly poor for older drivers. And secondly, that the danger for these older drivers might be more related to a lessening of awareness from underestimating the difficulties that a particular driving environment posed. This, together with age-related decrements, could thus be important precursors to driving accidents.

4.3. Additional findings relating to rearward and safety-relevant concepts

As was mentioned in 3.5 above, an older driver group, traversing a less cognitively taxing route for studies reported in Key et al. (2016), had shown indications of having a particular focus to the front and front/left of their vehicles. Furthermore, this predilection was seemingly detrimental to an awareness of what was occurring 'Behind' their vehicles. As such, it was felt that this might result in the older drivers missing important safety-related information.

The initial evidence in this study, from Figure 5 above, appeared to show that the older drivers had taken more of a 360-degree visual perspective, for what was, after all, a more difficult drive. A strong linkage was evident between the (main) 'Car' and 'Behind' concepts, mirroring the younger group, and with that latter concept occupying more of a neutral, central position, within the group comparison network of Figure 8. However, when consideration is given to the number of the times a rearward looking concept or word is mentioned in all of the twenty-one narratives, the results show the younger group to have mentioned them around twice as often (as Table F, above shows). Furthermore, this ratio was also found within the narratives produced from the less onerous drive undertaken for Key et al. (2016).

A second aspect of interest from that research was a potentially sub-optimal amount of safety-relevant information being processed by the older drivers. This is reflected in Table G (above) where it was shown that the younger group mentioned concepts reflective of safety awareness about three times more often than the older group. Once again, these results mirrored the findings found in Key et al. (2016), despite the drive for this study being more difficult.

There were indications whilst traversing the route that the older drivers were more easily distracted from, and therefore had less awareness of, the driving task. This would most likely be reflected by the group's overall (SA metric) scoring, and indeed the younger group showed a better SA proficiency by this measure. It could be, of course, that any lack of focus by the older group may only have been prevalent at times when they perceived a driving environment as being less risky - due to their far greater driving experience. Additionally, it should be borne in mind that the younger group also produced 7% more average text in their commentaries due, perhaps, to them having one additional participant. However, with the drive being a more difficult one to that undertaken in Key et al. (2016), it would be reasonable to expect more group parity in the enunciation of such safety-related concepts.

The findings discussed in this section would no doubt benefit from corroboration by additional research with different methodologies. As if they could be substantiated, they could indicate important precursors for accident involvement amongst older drivers.

4.4. How do the findings relate to what has been found in the literature?

If the age-related decrement assertions in the literature are correct for older drivers (e.g. Laux, 1995; Salthouse, 1985; Smith & Earles, 1996; Damos & Wickens, 1980; Korteling, 1993; Lorsbach & Simpson, 1988; McDowd & Craik, 1988; Schneider & Fisk, 1982; Tun & Wingfield, 1997), then it could fairly be assumed that their SA should be worse for driving trials that are more cognitively taxing.

This was corroborated in this study; however, not so for a more cognitively taxing task viewed on video within Key et al. (2016). Here the SA for the older group was unexpectedly enhanced. This is not, though, such an unusual finding per se. Kaber et al. (2012), for example, found "Young drivers exhibited degraded Level 1 SA in the complex environment after hazard exposure, while older drivers exhibited improved Level 1 SA in the same condition." (p.605). Kaber's complex condition perhaps had the effect of bringing additional attention from his older drivers once they encountered a hazard, but that "higher Levels SA, comprehension and projection, were degraded for older drivers due to hazard exposure" (p.609). The extra perceptual effort seems to have cost them better comprehension, which could have relevance for when they have to correctly identify a driving hazard.

Additionally, Bolstad (2001), although not finding any increased SA proficiency with her older driver group when encountering complex driving conditions, equally did not find them more affected. Her results showed that whilst "SA for all age groups declined from [a] moderate complexity condition to [a] high complexity condition; [that the] older adults did not experience a greater decrease in performance when compared to the other age groups." (p.276). Thus perhaps SA performance can actually be uplifted, through greater effort, to meet the demands of increased cognitive taxation and a task's unfamiliarity or difficulty? However, this would only seem prevalent when the individual is *aware* of that difficulty. In this study, for example, the older drivers (unlike many younger drivers) did not feel the driving task to be relatively more demanding, and their SA performance fell from when this was the case, perhaps as a result.

In regards to the potential lack of awareness by the older drivers of safety-related cues, as has already been alluded to above, the literature has tended to focus on particular age-related deficits, such as useful field of view (Ball, Owsley, & Beard, 1990; Scialfa, Kline, & Lyman, 1987), and overall attention capacity (Madden, 1986). Studies have also shown, however, that older drivers make less glances towards peripheral, than their central, visual field - where they were found to hold significantly longer mean fixation durations (Maltz & Shinar, 1999). This is reflected in the findings above through the particular importance of the 'Coming' – 'Towards' concept interrelation for the older group, in contrast to the 'Cars' – 'Parked' interrelation for the younger group (see Figure 5). It has been suggested that this predilection for forward viewing leaves older drivers more susceptible to side impacts (e.g. Viano et al., 1990) and an increased risk of fatality from them relative to frontal impacts (e.g. Bédard et al., 2002).

In addition, Ho et al. (2001) have found more search errors by older drivers in relating to observing specific objects. This study adds to such findings by revealing potential conscious decision making deficits to that of a younger group from the latter's higher incidence of concepts such as I'm 'Looking', 'Checking', (making) 'Sure'.

In terms of a lack of rearward focus by the older drivers - specifically, their 2:1 ratio deficit in associated words – such findings support what previous research has been undertaken. Bao & Boyle (2009), for example, found that middle-aged drivers checked their rearview mirror a significantly higher proportion of time than any age-group. However, they also observed differences between older and younger drivers during 'straight across' and 'left turning' manoeuvres, with the younger drivers being found to check their rearview mirror to a higher degree.

4.5. Limitations

The 'Think aloud' methodology or Verbal Protocol Analysis (Bainbridge, 1990), whilst being less obtrusive and easy to understand, does impact on the number of participants that can be assessed within a reasonable time period. This is principally due to the need for commentaries to be accurately transcribed, and then formatted as truly as possible to a participant's enunciation. Thus, in driving contexts, with engine and exogenous noise, this limitation can be of particular relevance.

The need for limited numbers also brings related limits on generalisations - though this issue is not uncommon in SA research (whether or not narratives are utilised).

It should also be noted that whilst it can be said that strong and related connections between knowledge concepts will no doubt aid their recall, and thus, in this context, an individual's SA, it is important to remain aware that the method can only assess what the participant *says* s/he is aware of.

Thus, it would be of benefit to have the important findings of this research confirmed by the use of additional measures. In this regard, eye-tracking would seem the best supporting option within actual roadway research, as this could validate any deficiency in rear view and sideways checking by older drivers. It would also be able to assess for the impact of any decrements to UFOV and peripheral vision by drivers of this age group (70 – 85).

In order to gain an insight into which roadway environments were the more taxing, and which might be impacting on a commentary, the recording of brain activity during a trial would additionally appear useful. If this could be achieved in a non-invasively manner, it would then be possible to direct SA training to relevant cues within these environments, with the aim of reducing potentially dangerous excesses of information processing.

Although the studies in this research advantageously utilised actual roadways to measure SA, as a result, consideration rightly had to be given to a participant's safety. Thus it was never possible to expose the driver to particularly dangerous conditions, which though rare, may be the very ones where we need to find "the few unsafe drivers that may need to be identified" (p.276) (Bolstad, 2001). It is hoped that future research will take up that challenge, given the remarkable improvements in driving simulator technology from the time of Bolstad's study, and indeed Zhang et al. (2009).

5. Conclusion

This study's findings support a general contention in the literature that older drivers exhibit less Situation Awareness (e.g. Bolstad, 2001; Zhang et al., 2009; Kaber et al., 2012). However, much in regards to the measured proficiency of SA may be down to perceptions of task difficulty and motivation. Indeed, these could be important contributors in forming SA for any particular environment, which if not 'set' to appropriate levels, could result in an insufficient and possibly a dangerous lack of awareness. It should further be added that with older drivers, such deficits could additionally be exacerbated by age-related cognitive decrements - particularly if the impact of those decrements are not fully appreciated by the individual.

In general, driving more slowly, and employing in-car automated driver assistance devices, will no doubt help to give the older driver more time to process sufficient and relevant information, and stave-off the inevitable impact of age-related declines. To assist this further, a method for keeping them concentrating and processing at appropriate levels during journeys, particularly those of a longer duration, would seem invaluable for increasing their, and others, road safety.

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