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Exploring the sustained and divided attention of novice versus experienced drivers

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ABSTRACT

Purpose of the research: Driving is a complex task that requires appropriate engagement in, and regulation of, sustained attention and divided attention. This study explored the sustained- and divided-attention function of novice young adult drivers and experienced adult drivers.
Methods: Fifteen novice young adult drivers (mean age = 20.07) and 18 experienced adult drivers (mean age = 41.33) participated in the study. The participants' sustained and divided attention were assessed using a computerised fixed Sustained Attention-to-Response Task (SART) and a modified version with low cognitive-load and high cognitive-load conditions. Their attention was also assessed using the Color Trails Test (CTT) and Digit Span Test (DST). The participants' cognitive resources that were available during the assessments were monitored using the Rating Scale Mental Effort (RSME).
Results: The main results of this study showed that the experienced drivers had significantly higher performance in terms of accuracy in both sustained attention ($p = 0.011$) and divided attention ($p = 0.008$ and 0.006 in low and high cognitive-load conditions, respectively) components of the SART. No significant differences in the CTT and DST were found between the two groups. The results of the RSME also indicated that both groups had comparable cognitive resources available throughout the assessments.
Conclusions: This study suggests that experienced adult drivers have a higher developed ability to engage in and maintain sustained and divided attention appropriately. These results provide insight related to attention function, which might affect novice young adult drivers compared with experienced drivers.

Introduction

Driving is a complex task that requires continuous information processing in a constantly changing environment. The dynamic nature of driving necessitates a high level of attention, accuracy and vigilance for safe performance. Therefore, appropriate engagement, maintenance and regulation of sustained attention is critical to driving safety (Gresham et al., 2021; Wickens et al., 2008). In addition, driving at times requires the simultaneous information processing of multiple tasks and, therefore, appropriate engagement in, and regulation of, divided attention is also necessary for safe driving (Lengenfelder et al., 2002).

Sustained attention is the ability to maintain concentration for a prolonged period of time. To achieve this, there must be intrinsic maintenance of an individual's alert state, where there is no external input (Dockree et al., 2005). This ability to sustain attention and redeploy this attention flexibly in response to relevant environmental factors is necessary to avoid adverse driving events. Unfortunately, the ability for individuals to maintain a high sustained attention performance in repetitive and monotonous tasks such as driving is limited (Bonnefond et al., 2010). Cheyne et al. (2006) have suggested that boredom plays a significant role in the inability of individuals to sustain alertness given that poor motivation can lead to decreased attention maintenance, which then results in deficits in sustained attention. The significance of this is paramount because the failure to appropriately sustain and

Abbreviations: CTT, Color Trails Test; DST, Digit Span test; HL, High-load condition; LL, Low-load condition; MVAs, Motor vehicle accidents; NL, Negligible-load condition; RSME, Rating Scale Mental Effort; SART, Sustained Attention-to-Response Task.

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regulate attention can result in attention lapses (absent-minded behaviours resulting from transient reductions in the sustained attention of the driver; (Dockree et al., 2005; Parker et al., 1995); driving errors (inadvertent and inadequate actions resulting from observational failures due to lapses in sustained attention; (Cheyne et al., 2006; Twisk et al., 2010) and consequently accidents.

While driving is considered to be a highly complex task (following learning to drive), it can be perceived as second nature and an automatic process (van Merriënboer et al., 2002). Due to this perception and the repetitive and monotonous nature of driving, many drivers feel it is acceptable perform a secondary task while driving, which may affect driving competence and safety (Bock et al., 2021; Larue et al., 2011). This is known as distracted driving, and it requires the utilisation of divided attention.

Divided attention involves processing and responding to specific information while at the same time engaging in multiple tasks (Lengenfelder et al., 2002). Driving under distracting conditions greatly relies on an individual's executive attentional resources (Thompson et al., 2012). The Yerkes-Dodson law (Yerkes and Dodson, 1908) states that performance and arousal have an inverted-U shaped relationship. As arousal increases, performance will improve up to a certain threshold and then deteriorate (Anderson, 1994; Johnston et al., 2012). Secondary tasks or distractors may increase arousal and performance initially, but the performance may not be sustained. Additional distractors can further compete for the neural resources required for safety in driving. Although initially heightened arousal can improve performance, the added cognitive load may result in performance deterioration, which increases the risk of motor vehicle accidents (MVAs; (Thompson et al., 2012).

Statistics have shown that MVAs can be committed by individuals from a wide variety of ages, which indicates that both novice young adult drivers and experienced adult drivers commit MVAs. Research has found that novice young adult drivers have a higher motor vehicle crash rate in motorised countries than for any other age category, which is an alarming statistic (De Craen et al., 2011). For example, in Australia, the road mortality rates in 2019 for 18- to 20-year-olds was 9 in every 100,000 persons compared to an average of 4.7 for the entire population (Organisation for Economic Co-operation and Development Road Safety Report, 2020). Furthermore, the literature has reported that a substantial number of major MVAs are the result of momentary distractions or lapses in sustained attention (Dockree et al., 2005). Distracted driving – for example, using a mobile phone while driving – contributes to a significant percentage of drivers' behaviours causing road safety issues (Organisation for Economic Co-operation and Development Road Safety Report, 2020).

Distracted driving occurs in motorists of all ages. Increased task complexity is shown to delay appropriate responses and affect driving performance risks, and such influence would decrease with more experience (Svetina, 2016). As such, a greater number of years of driving experience has been shown to correlate with better driving performance, where there are fewer errors and attention lapses (Wickens et al., 2008; Xie and Parker, 2002). Selective attention is found to improve with age and is significantly associated with fewer driving risks (Cassarino and Murphy, 2018; McManus et al., 2015). Increased cognitive control could potentially reduce risk driving behaviour in novice drivers (Ross et al., 2015). The higher rate of MVAs in young novice drivers could be related to less skilled use of sustained and divided attention that is necessary to avoid accidents arising from attention lapses and errors due to distracted driving or other reasons. A review of the literature revealed that research had been done on the factors affecting driving performance in novice young and experienced drivers, but less research reports a comparison of the sustained- and divided-attention function of novice young adult drivers with that of experienced adult drivers. Thus, it is apparent that there is a critical need for research on this topic to address this knowledge gap and to provide insight into driver education.

The aims of this research were to explore the sustained and divided attention of novice young adult drivers compared to that of experienced adult drivers. The Sustained Attention-to-Response Task (SART) (Robertson et al., 1997) was used as the main tool for assessing attention, with the addition of a secondary task with low and high levels of cognitive workload being introduced into SART for assessing divided attention. Participant attention function was also assessed by the Color Trails Test (CTT) and Digit Span test (DST). It was hypothesised that the sustained- and divided-attention performance of novice young adult drivers would be significantly lower than that of the experienced adult drivers. It was further hypothesised that the low-load condition would result in a higher SART performance compared to the negligible-load condition. The high-load condition would produce performance deterioration due to a too-high arousal level in both groups.

Methods

Participants

Two groups of drivers – a novice young adult cohort and an experienced adult cohort – were recruited using a snowball sampling technique through recruitment posters and flyers advertised at a local university in New South Wales, Australia. All the novice driver group participants possessed a provisional red (P1) or provisional green (P2) driver's licence, having up to three years of post-on-road driving test experience after passing the written and practical driving test. All the experienced driver group participants possessed a full (unrestricted) licence, having a minimum of 10 years of post-on-road driving test experience. All the participants were literate and possessed normal or corrected-to-normal eyesight. Prospective participants were excluded from the study if they had a neurological disorder or mental illness.

Fifteen novice young adult drivers (12 males and 3 females) between 19 and 21 years of age (mean = 20.07, *SD* = 1.03 years) and 18 experienced adult drivers (2 males and 16 females) between 27 and 60 years of age (mean = 41.33, *SD* = 9.41 years) participated in the study. Ethics approval was provided by the Human Research Ethics Committee, University of Western Sydney (approval number H9770). Informed consent was obtained following institutional human research ethics guidelines.

Aside from the participants' ages and total driving experience, the

Table 1
Demographic Data, Color Trail Test Scores, Digit Span Test Scores and Rating Scale Mental Effort Scores for Novice versus Experienced Drivers.

Variable	Novice driver mean (*SD*)	Experienced driver mean (*SD*)	*p*-values
Age (years)	20.07 (1.03)	41.33 (9.41)	<0.001**
Total driving experience (months)	25.87 (8.23)	260.78 (95.95)	<0.001**
Driving frequency (days per week)	5.88 (2.32)	6.28 (1.71)	0.578
Kilometres driven (per month)	1195.80 (784.62)	762.56 (651.92)	0.093
CTT1 (seconds)	33.13 (10.11)	29.94 (8.50)	0.332
CTT2 (seconds)	68.00 (13.56)	68.44 (16.19)	0.933
Digits Span forward (number of correct strings)	5.00 (0.85)	5.06 (1.00)	0.866
Digits Span backward (number of correct strings)	4.20 (1.37)	4.17 (1.72)	0.952
RSME prior to SART Block 1	81.20 (16.43)	69.67 (22.90)	0.113
RSME prior to SART Block 2	55.20 (28.72)	59.33 (16.36)	0.608
RSME after SART Block 2	60.60 (34.97)	64.50 (21.97)	0.699

Note. CTT1 = Color Trails Test 1; CTT2 = Color Trails Test 2; RSME = Rating Scale Mental Effort; SART = Sustained Attention-to-Response Task.
** $p \leq 0.001$.

two groups did not differ significantly between driving frequency and the number of average kilometres driven per month (see Table 1).

Design and procedure

The participants were requested to have seven hours of sleep the night before the assessments to ensure they were fatigue free. The data collection process was conducted in a quiet private room that provided minimal distraction. The participants' demographic and driving history information was collected, followed by the administration of the CTT and the DST.

The RSME was then administered, followed by the first block of the SART and the second RSME administration. A second SART block was then conducted, followed by the final RSME administration. The total time required was 60 to 90 min per participant. Each participant received an AUD$40 gift voucher as compensation for their time and travel expenses.

Task/Assessments

Sustained Attention-to-Response task

The SART is a task used frequently to examine sustained attention (Robertson et al., 1997). For this study, the conventional fixed SART design was adopted in order to examining sustained attention in terms of being a "negligible-load" (NL) condition (Dockree et al., 2005; Righi et al., 2009). The fixed SART design was modified to include two secondary tasks – the "low-load" (LL) and "high-load" (HL) conditions. This modification allowed for the divided attention of participants to be examined.

A single block of trials consisted of 648 trials, allowing for 71 trials per digit. Each block consisted of the conventional SART with NL demand and a modified SART with the LL and HL conditions. The participants were required to complete two blocks each, which resulted in 1296 single digits. Blocks were randomly selected from a pool of six blocks by rolling a six-sided dice. Each block lasted 20 min and there was a short rest break as required mid-block. A break of five to 10 min was allocated between blocks. The participants were instructed to respond as fast as possible in both blocks. They were given time to familiarise themselves with the assessment before it commenced by completing a two-minute practice test.

A laptop was used and the STIM2 program from Compumedics Neuroscan specified the tasks and provided the stimuli. The participants were seated with the laptop positioned in front of them. The following section describes the task details.

The conventional SART to assess sustained attention. Having adopted the conventional fixed SART design, the digits one to nine appeared centrally on the laptop screen, one at a time, in ascending order. Each digit was presented for a period of 150 ms. The participants were instructed to click the left mouse button using their right forefinger for digits one to nine for go trials, excluding digit three. The participants were requested to inhibit a response when digit three appeared as these were no-go trials. This formed the NL condition.

To prevent the participants from developing a habitual rhythmic response pattern and succumbing to a speed accuracy trade-off, each digit was followed by an inter-stimulus interval that randomly varied between 1000 ms and 1500 ms. Five random digit sizes were presented: 100, 120, 140, 160 and 180 in Arial font. This was done to increase the processing demands and decrease the likelihood of the participants developing a personal search template for target trials.

The modified SART to assess divided attention. The modified SART with the addition of secondary tasks was designed to study the participants' divided attention.

The block components of the modified SART were separated into sub-blocks, the length of which was randomly selected from 27, 36 and 45 trials. Two cases of sub-blocks – the LL and the HL conditions – were included to study the participants' divided attention. The LL and HL conditions represented the two levels of cognitive workload. The LL condition posed a low cognitive workload, which required memorising a five-digit number composed of the same five digits – for example, 77777. The HL condition posed a high cognitive workload, which required memorising a five-digit number consisting of random and unrepeated digits – for example, 31489.

For both LL and HL conditions, the five-digit number was presented in the screen centre at the start of each sub-block. The participants were required to memorise and rehearse the number presented during the sub-block. At the end of the sub-block, another five-digit number was presented, and the participants were required to indicate if this number was the same as the number previously presented. The participants were required to respond with a left mouse click if the number was the same and a right mouse click if the number was different.

Color Trails test

The CTT was used to assess the participants' attention (D'Elia et al., 1996). This test has two modalities: the Color Trails Trial 1 (CTT1), which primarily focuses on sustained attention; and the Color Trails Trial 2 (CTT2), which is focused on divided attention (Strauss et al., 2006).

In CTT1, the participants were requested to rapidly connect the coloured circles numbered one to 25 in sequence order with a pencil. The CTT2 consisted of two sets of numbered circles, one through to 25; one set was coloured pink and the other yellow. The participants were requested to rapidly connect the circles one through 25 with a pencil in sequence order, alternating between the pink and yellow circles. The time taken to correctly complete each trial was recorded.

Previous studies have demonstrated the use of the Trail Making Test in discriminating drivers and non-drivers (Cullen et al., 2014) and a strong correlation between the Trail Making Test and driving or driving simulator performance (Szlyk et al., 2002). The CTT has been reported as a cultural-fair test and the best alternative to Trail Making Test for non-native English speakers as the participants in this study (Dugbartey et al., 2000). This study has, therefore, adopted the CTT to assess the participants' attention.

Digit Span test

The DST captured both the participants' attention and immediate verbal recall (Wechsler, 1981). This test takes two forms: the Digits Forward and the Digits Backward. The assessor read out strings of digits at a rate of one per second, which the participants were required to orally repeat in the correct sequence, either forward or backward (Ostrosky-Solís and Lozano, 2006). The total strings of digits each participant repeated correctly resulted in the total score.

The same as the Trail Making Test, the DST has been widely report and associated with driving performance (Cullen et al., 2014; Szlyk et al., 2002).

Rating Scale mental Effort

The RSME is a commonly used measure of mental workload and indicates the difference between the resource demands posed by the task and an individual's available cognitive resources (Gopher et al., 1986; Widyanti et al., 2013; Zijlstra, 1993). In this study, the RSME was used to assess the participants' mental workload and cognitive resources during the assessments.

The RSME comprises a 150 mm long vertical line marked with 10 mm intervals, containing scale points from zero to 150. In addition, the scale has nine anchor points which denote the descriptions of mental workload that range from *absolutely no effort*, which is near zero, to *extreme effort*. The participants were required to indicate on the axis the level of effort that it had taken them to complete the task or tasks they had completed just before the RSME.

Data analysis

The SART data was extracted and computed separately for the NL, LL and HL conditions. It included (1) go-trial accuracy rates; (2) go-trial reaction times (RT) for correct responses; (3) commission errors (failure to inhibit response to digit three); and (4) commission error reaction times. In addition, accuracy and reaction times for correct responses for LL and HL secondary tasks were computed. Go-trial accuracy scores, commission error scores and secondary-task accuracy scores were converted to percentage scores for clarity. The relationships between the participants' demographic characteristics and their performance in the assessments were analysed using Pearson's correlation. The *t*-test was used to generate between-group comparisons for demographic and assessment data. Using paired sample t-tests, performances under the SART NL, LL and HL conditions were compared separately to determine the performance differences that had been experienced by each group under different cognitive loads. The eta-squared was used to report the effect size of the differences between the two groups, with 0.01 regarded as a small effect size, 0.06 as a medium, and 0.14 as a large effect (Cohen, 1988).

Results

Color Trails test and digit Span test

No significant differences were found between the novice and experienced driver groups in the CTT or DST ($p = 0.332$ and 0.933 for CTT1 and CTT2, respectively; $p = 0.866$ and 0.952 for Digits Forward and Digits Backward, respectively; see Table 1).

Mental workload

No significant differences were found for the three RSME administrations that were conducted between the groups ($p = 0.113$, 0.608 and 0.699, respectively), which indicates that both groups had similar cognitive resources during the assessment phase (see Table 1).

Go-Trial accuracy

The experienced drivers had a significantly higher go-trial accuracy percentage than the novice drivers in all three load conditions ($p =$ 0.011, 0.008 and 0.006 for NL, LL and HL, respectively; see Table 2). Large effect sizes were found.

A moderate positive correlation was found between age and NL go-trial accuracy ($r = 0.354$, $p = 0.044$); LL go-trial accuracy ($r = 0.369$, $p = 0.034$); and HL go-trial accuracy ($r = 0.388$, $p = 0.025$), with increased age being associated with higher NL, LL and HL go-trial accuracy. A moderate positive correlation was found between the scores from the Digits Forward test and NL go-trial accuracy ($r = 0.394$, $p = 0.023$) and HL go-trial accuracy ($r = 0.361$, $p = 0.039$); a strong positive correlation was also found between the scores from the Digits Forward test and LL go-trial accuracy ($r = 0.402$, $p = 0.020$), with higher digit span forward scores being associated with higher NL, LL and HL go-trial accuracy.

Go-Trial reaction time – For correct responses

The novice drivers had a significantly faster go-trial RT than the experienced drivers in all three load conditions, with large effect sizes ($p = 0.021$, 0.033, 0.010 for NL, LL and HL, respectively; see Table 2).

A moderate positive correlation was found between age and NL go-trial RT ($r = 0.351$, $p = 0.045$), and HL go trial RT ($r = 0.354$, $p = 0.044$), with increased age being associated with slower NL and HL go-trial RT.

A strong positive correlation was found between NL go-trial RT and NL go-trial accuracy ($r = 0.632$, $p = 0.000$); between LL go-trial RT and LL go-trial accuracy ($r = 0.630$, $p = 0.000$); and between HL go-trial RT and HL go-trial accuracy ($r = 0.635$, $p = 0.000$), with slower NL, LL and HL go-trial RT being associated with higher NL, LL and HL go-trial accuracy, respectively.

Table 2
Negligible-Load, Low-Load and High-Load Go-Trial Accuracy, Reaction Time and Commission Errors, and Between-Group Difference for Novice versus Experienced Drivers.

Variable	Novice drivers mean (SD)	Experienced drivers, mean (SD)	p-value	Eta-squared
NL go-trial accuracy (percentage)	79.55 (16.71)	91.84 (8.99)	0.011*	0.19
LL go-trial accuracy (percentage)	77.60 (16.50)	90.68 (9.85)	0.008*	0.20
HL go-trial accuracy (percentage)	76.15 (18.17)	90.74 (9.45)	0.006*	0.22
NL go-trial RT (ms)	226.67 (42.98)	263.39 (43.40)	0.021*	0.16
LL go-trial RT (ms)	221.60 (52.30)	258.86 (43.60)	0.033*	0.14
HL go-trial RT (ms)	220.77 (42.93)	265.69 (49.77)	0.010*	0.20
NL commission errors (percentage)	10.56 (6.32)	6.37 (4.37)	0.032*	0.14
LL commission errors (percentage)	9.58 (7.33)	4.98 (3.36)	0.023*	0.16
HL commission errors (percentage)	6.53 (4.78)	5.44 (3.72)	0.468	0.02

Note. NL = negligible load; LL = low load; HL = high load; RT = reaction time; ms = milliseconds.
* $p \leq 0.05$.

Commission errors – Failure to inhibit response to digit three

The novice drivers had a higher commission error percentage than the experienced drivers in all three load conditions ($p = 0.032$, 0.023, 0.468 for NL, LL and HL, respectively; see Table 2). Large effect sizes were found in NL and LL conditions, and a small effect size in HL condition.

A strong negative correlation was found between age and NL commission errors ($r = -0.410$, $p = 0.018$), and LL commission errors ($r = -0.425$, $p = 0.014$), with increased age being associated with less NL and LL commission errors. A strong negative correlation was found between driving experience and NL commission errors ($r = -0.460$, $p = 0.007$), and LL commission errors ($r = -0.428$, $p = 0.013$), with increased driving experience being associated with fewer NL and LL commission errors. A moderate negative correlation was found between scores from the Digits Forward test and HL commission errors ($r = -0.386$, $p = 0.027$), with higher Digits Forward scores being associated with fewer HL commission errors.

Commission errors reaction time

No reliable RT for commission errors was generated due to the lower number of commission errors and the high variability between the participants (some of the participants made no or very few commission errors).

Novice group – Within-Group differences between load conditions

No significant difference was found in go-trial accuracy and RT among NL, LL and HL conditions ($p = \geq 0.100$; see Table 3).

Commission errors were significantly different between NL and HL ($p = 0.025$), and LL and HL ($p = 0.044$); however, they were not

Table 3
Between-Load Differences for Go-Trial Accuracy, Reaction Time and Commission Errors for Novice and Experienced Drivers.

Variable	Novice drivers		Experienced drivers	
	Mean difference (SD)	*p*-value	Mean difference (SD)	*p*-value
NL and LL go-trial accuracy (percentage)	1.94 (5.26)	0.174	1.16 (1.67)	0.009*
NL and HL go-trial accuracy (percentage)	3.40 (8.26)	0.133	1.10 (2.16)	0.045*
LL and HL go-trial accuracy (percentage)	1.45 (3.60)	0.139	−0.06 (2.02)	0.905
NL and LL go-trial RT (ms)	5.07 (18.18)	0.299	4.52 (11.64)	0.117
NL and HL go-trial RT (ms)	5.90 (15.96)	0.174	−2.31 (16.68)	0.565
LL and HL go-trial RT (ms)	0.83 (16.00)	0.843	−6.83 (16.56)	0.098
NL and LL commission errors (percentage)	0.97 (7.09)	0.603	1.39 (3.71)	0.131
NL and HL commission errors (percentage)	4.03 (6.22)	0.025*	0.93 (5.55)	0.488
LL and HL commission errors (percentage)	3.06 (5.33)	0.044*	−0.46 (3.95)	0.625

Note. NL = negligible load; LL = low load; HL = high load; RT = reaction time; ms = milliseconds.
* $p \leq 0.05$.

significant between NL and LL ($p = 0.603$; see Table 3).

Experienced group – Within-Group differences between load conditions

Go-trial accuracy was significantly different between the NL and LL conditions ($p = 0.009$), and the NL and HL conditions ($p = 0.045$); however; it was not significantly different between the LL and HL conditions ($p = 0.905$). No significant difference was found in RT between the NL, LL and HL conditions (see Table 3).

Commission errors were not significantly different between any load conditions ($p = \geq 0.100$; see Table 3).

Secondary task

No significant difference for LL and HL secondary-task accuracy was found between the novice and experienced drivers ($p = 0.924$ for the LL task; 0.260 for the HL task; see Table 4).

For the LL secondary task, the novice drivers had a significantly quicker RT than the experienced drivers with a large effect size ($p = 0.038$). No significant difference in RT was found for the HL secondary task between the two groups ($p = 0.211$).

Table 4
Secondary-Task Performance Accuracy and Reaction Time for Novice versus Experienced Drivers.

Variable	Novice drivers mean (SD)	Experienced drivers mean (SD)	*p*-value	Eta-squared
LL secondary-task accuracy (percentage)	96.11 (6.19)	95.83 (9.59)	0.924	0.00
HL secondary-task accuracy (percentage)	90.00 (11.87)	93.98 (7.99)	0.260	0.04
LL secondary-task RT (ms)	910.70 (181.68)	1081.67 (255.98)	0.038	0.13
HL secondary-task RT (ms)	1297.70 (234.77)	1422.83 (312.24)	0.211	0.05

Note. NL = negligible load; LL = low load; HL = high load; RT = reaction time; ms = milliseconds.

Discussion

To better understand the sustained and divided attention of novice young adult drivers compared to experienced adult drivers, we assessed the sustained attention performance of these drivers using the conventional fixed SART design and a modified one that included a secondary task to reflect the participants' divided attention. The main results of this study indicate that the experienced drivers had significantly higher performance in terms of accuracy in both the sustained- and divided-attention components of the SART than the novice drivers, where the cognitive resources of drivers in both groups were comparable. These results support our hypothesis that the sustained- and divided-attention performance of novice young adult drivers is significantly lower than that of experienced adult drivers.

Our research suggests that when engaging in a task requiring sustained attention, experienced adult drivers perform better than novice young adult drivers, which aligns with the notion that extensive driving experience is associated with fewer lapses in attention (Wickens et al., 2008; Xie et al, 2002). This notion is supported by the significantly higher go-trial accuracy rate ($p = 0.011$) and significantly lower commission error rate ($p = 0.032$) performed by the experienced drivers compared to the novice drivers in the sustained-attention component of the SART (NL condition).

While the experienced drivers had greater accuracy than the novice drivers during sustained attention (NL condition), the novice drivers had a significantly faster reaction time ($p = 0.021$). It could have been possible that the novice drivers, on average, had responded more quickly to stimuli while maintaining attention. However, it is also likely that the faster reaction time paired with the lower accuracy may have resulted from the poorer maintenance of sustained attention to the task and may have created errors with impulsivity. It has been suggested that the SART, which requires frequent responses to go trials and infrequent responses to no-go trials, can produce a habitual rhythmic response pattern (Helton, 2009; McVay and Kane, 2009). In this study, the SART was designed to include varying inter-stimulus intervals between digits to help prevent such response patterns from developing. The poor maintenance of sustained attention and the occurrence of a habitual response pattern in the SART may have led to impulsive responses that had resulted from reacting too quickly to go trials to yield a valid response and increased failure to inhibit responses to no-go trials. The maintenance of sustained attention, the development of a habitual response pattern, and impulsivity may be related or independent of each other; nevertheless, the results suggest that the sustained-attention function of novice drivers might be inferior to that of experienced drivers. Real-life implications for the inadequate maintenance of sustained attention in driving are attention lapses and driving errors, which may increase the risk of MVAs (Dockree et al., 2005).

Regarding divided attention, the results suggest that experienced drivers have a greater ability to maintain divided attention than novice drivers when required to perform the secondary task that poses low and high cognitive loads. This was reflected by the significantly higher go-trial accuracy rate ($p = 0.008$ in the LL condition and $p = 0.006$ in the HL condition) and lower commission error rate ($p = 0.023$ in the LL condition but insignificant in the HL condition) performed by the experienced drivers compared to the novice drivers in the divided-attention component of the SART. This suggests that experienced drivers are better able to manage the cognitive load posed by a secondary task and, therefore, might have a greater ability to engage in divided attention than novice drivers. The insignificant difference in HL commission errors may indicate that both the novice and experienced groups had a similar level of attention maintenance to inhibiting a response to no-go trials in the HL condition. This observation, in which the difference between commission errors was not significant while the difference between go-trial accuracy was, can be explained by the reaction time results. The novice drivers, again, had a significantly faster reaction time in both the LL and HL conditions ($p = 0.033$ and 0.01, respectively). The novice drivers' faster reaction times, in the HL condition especially, may have resulted from inadequate attention maintenance and the possible development of the previously discussed habitual response pattern. This possible development may have led to the increased failure to inhibit responses to the no-go trials and the too-quick responses to the go trials, which led to invalid responses being recorded. Nevertheless, these results indicate that when required to engage in divided attention that poses a high cognitive load, the experienced drivers still performed better in the SART task. This suggests that experienced drivers are better able to manage the increased cognitive load posed by the secondary task and, therefore, might have a superior ability to engage in, and maintain, divided attention than novice drivers.

This study also examined how the SART performance between the novice and experienced groups was affected by the different levels of cognitive workload, ranging from the NL condition, which assessed sustained attention without a secondary task, to the LL and HL conditions, which assessed divided attention when a secondary task had been posed. The novice drivers made the fewest commission errors in the HL condition, the second fewest in the LL condition, and the most in the NL condition. Furthermore, the differences were significantly different between the HL and NL conditions ($p = 0.025$) and the LL condition ($p = 0.044$); however, they were not significant between the NL and LL conditions. These results suggest that with the additional cognitive load posed by the HL condition, the novice drivers were more alert and more effectively inhibited their responses to the no-go trials. These results are concurrent with the Yerkes-Dodson law, which states that both arousal and the level of task difficulty contribute to performance efficacy (Anderson, 1994; Yerkes et al, 1908). In the Yerkes-Dodson law, it states that performance and arousal have an inverted-U shaped relationship. As arousal increases, performance will improve up to a certain threshold before deteriorating when too highly aroused (Johnston et al., 2012). It can be posited from the results that novice drivers perform quite similarly in the sustained-attention task and the divided-attention task posing a low cognitive load when required to inhibit a response to digit three; however, with the increased load posed by the HL condition, performance would appear to have improved to an optimal level. While these results support the hypothesis that the novice drivers' performance was lower in the NL condition than the LL condition, the difference was not significant. These results do not support the hypothesis that the HL condition would pose too high a cognitive arousal level that would lead to performance deterioration in novice drivers. The HL condition, in fact, appeared to increase the novice drivers' arousal level and performance, possibly to a more optimal level than the NL or LL conditions. As for go-trial accuracy, the novice drivers' performance was highest in the NL condition, then the LL condition, with the lowest performance in the HL condition; however, performance was not significantly different between load conditions.

The novice drivers' SART performance appeared to improve when a secondary task posed a high cognitive load. The monotonous and repetitive SART task could potentially represent tedious motorway driving. Could potentially engaging in a secondary task while performing monotonous driving create an optimal arousal level that increases novice motorists' driving performance? This study did not examine sustained and divided attention through the real-life driving of motor vehicles or through a simulation of driving. Therefore, any implications for performance in real-life driving based on these SART results would need further investigation. However, the results may provide insight into driver education for the consideration of professional driving educators and parents (Rodwell et al., 2020). Further advice can be sought from professionals such as neuropsychologists or occupational therapists on people's attentional needs and driving performance (Golisz, 2014).

As for the experienced drivers who made the fewest commission errors in the LL condition, followed by the HL condition, they, like the novice drivers, made the most errors in the NL condition, although the between-load differences were not significant. There were, however, significant differences between the experienced drivers' go-trial accuracy for the three loads. The experienced group scored highest in the NL condition, second highest in the HL condition, and lowest in the LL condition. Go-trial accuracy was significantly different between the NL and LL conditions ($p = 0.009$) and the HL condition ($p = 0.045$); however, it was not significant between the LL and HL conditions. The significant difference in the experienced drivers' performance in the sustained-attention task compared to the divided-attention task indicates that the increased arousal posed by the secondary task resulted in performance deterioration, which was also concurrent with the Yerkes-Dodson law. It could be suggested that the increased cognitive load resulted in too-high arousal levels for the experienced drivers, which then led to performance deterioration (Johnston et al., 2012). These results support the hypothesis that the HL condition leads to performance deterioration caused by a too-high arousal level in experienced drivers. Interestingly, the experienced drivers' performance in the LL condition also resulted in performance deterioration, with their performance in the NL condition being significantly higher. This outcome does not support the hypothesis that the LL condition produces a greater SART performance than the NL condition in experienced drivers. As the LL condition was no better than the NL condition, a divided-attention task may not necessarily increase the arousal level of experienced drivers.

Relating these results to real-world driving, driving under distracting conditions relies heavily on an individual's executive attentional resources (Thompson et al., 2012). Additional distracters further compete for the neural resources required for safety in driving (Bock et al., 2021). While heightened arousal can improve performance, the added cognitive load can result in performance deterioration, which then increases the risk of MVAs (Thompson et al., 2012).

Both the novice and experienced drivers had the greatest rate of commission errors in the NL condition, which may have resulted from boredom. Cheyne et al. (2006) have suggested that boredom plays a major role in the inability of individuals to sustain alertness, where poor motivation can lead to decreased attention maintenance that then produces deficits in sustained attention. The sustained-attention task is often quite repetitive and monotonous and, therefore, could be considered to be boring. The monotonous nature of the NL condition, which involves the SART without the addition of a secondary task, may have resulted in the development of boredom, which then led to a decreased ability to maintain sustained attention to inhibiting a response to digit three (Larue et al., 2011).

This study also used the DST and CTT to assess between-group differences in sustained and divided attention. The insignificant between-group differences suggest that the DST and CTT, while designed to examine sustained and divided attention, might not be sufficiently sensitive to detect differences in sustained and divided attention between novice and experienced drivers.

There were several limitations to this study. First, the snowball sampling method that was used, while more practical given the nature of this study, can make research susceptible to greater bias, which then results in internal and external validity limitations (Cohen and Arieli, 2011). Consequently, the results from this study cannot be appropriately generalised to the general population. Second, this study involved a small number of participants located in the geographical regions of Sydney and Western Sydney in Australia. It did not extend beyond these regions for practical reasons. Therefore, the results of this study may only be applicable to a population that has similar characteristics to the participants recruited for this study and who are located in the Sydney or Western Sydney regions of Australia. In addition, there was an unequal number of males and females in each group due to the recruitment process. This could mean that the results of this study are not representative of the general novice and experienced driver population. Finally, as previously mentioned, this study did not assess sustained and divided attention using a simulation of or a real-life driving task. The ecological validity of the tests and the assessment conducted in a non-driving scenario may not reflect the driving-related skills. It was also unclear if the attention assessed by the Sustained Attention-to-Response Task would be of cognitive or perceptual nature (Lavie et al., 1641). The results of the study should be interpreted with caution.

Conclusions

This study has shown that the experienced-driver participants had significantly higher performance in terms of accuracy in both the sustained- and divided-attention components of the SART than the novice–driver participants under the condition that cognitive resources in both driver groups were comparable. These results support our hypothesis that the sustained- and divided-attention performance of novice young adult drivers is significantly lower than that of experienced adult drivers. The implications for real-life driving performance, based on the SART results from this study, need further investigation.

CRediT authorship contribution statement

Louise Kerruish: Writing – original draft, Writing – review & editing. **Andy S.K. Cheng:** Conceptualization, Methodology, Writing – review & editing. **Kin-Hung Ting:** Conceptualization, Methodology, Writing – review & editing. **Karen P.Y. Liu:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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