Driving Without Awareness and the Tandem Model of Driving

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Driving without attention mode (DWAM)
(Kerr, 1991)

Driving without awareness (DWA)
(Brown, 1994)

A familiar subjective experience for many drivers…

No active attention for the driving task, performing on 'autopilot';
a sudden realisation that you have no recollection of the past several minutes of driving, and that you have arrived at this point in the journey with little or no conscious attention to the surrounding traffic

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It is a general principle in Psychology that consciousness deserts all processes where it can no longer be of use... We grow unconscious of every feeling which is useless as a sign to lead us to our ends, and where one sign will suffice others drop out, and that one remains, to work alone.
Wm James (1890) (p. 496)

Highly practised tasks become automatic

Individual thoughts and actions repeated together
often enough become combined into a single unit
an ***open-loop*** (ballistic) program or script

The notion of automaticity is nearly as old as experimental psychology itself

Driving is an oft-cited example of automatic performance

but automaticity is usually studied with tasks like Stroop and priming

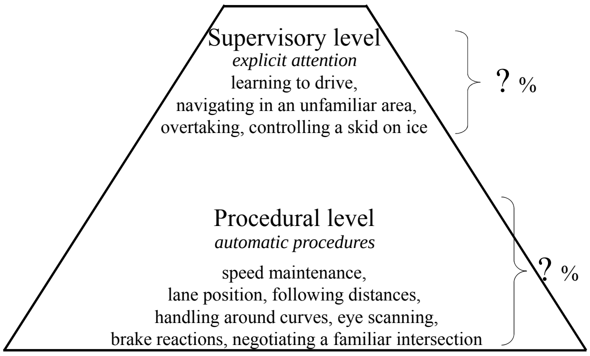
Bryan & Harter, 1897
James, 1890
Shiffrin & Schneider, 1977
Norman, 1981
Reason, 1984
Logan, 1988
Rasmussen, 1993
Bargh & Chartrand, 1999

Automaticity often defined in contrast to non-automatic performance

closed-loop	open-loop
conscious	unconscious
controlled	uncontrolled
knowledge-based	skill-based
effortful	effortless
goal-driven	stimulus-driven
intentional	unintentional
top-down	bottom-up

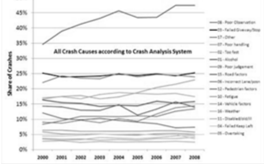
Two modes of driving

Much of our driving behaviour is governed implicitly
esp. lane keeping & speed maintenance



Driving without awareness appears to be associated with many of the most common crash types

The most commonly coded cause on TCRs is "poor observation".
In New Zealand, almost half of all injury crashes were coded as "poor observation" in 2008



"There is, however, good reason to suspect that inattention, either through distraction, fatigue, or a combination of the two, is the leading cause of injury crashes." (NZAA, 2010)

There have been few actual studies of automaticity in driving

There have been cross-sectional comparisons of novice and expert drivers

Experienced drivers show poorer scanning and braking, experts superior in car control skills (Duncan, Williams & Brown, 1991)

Manual gear shifting impairs sign detection for novices but not for experts (Shinar, Meir, & Ben-Shoham, 1998)

Experienced drivers identified signs better than inexperienced drivers when signs were at expected location, worse than inexperienced drivers at unexpected locations (Borowsky. Shinar, & Parmet, 2008)

Some have questioned whether these sorts of studies show anything like automaticity in the strict sense of the term
(e.g., Groeger & Clegg, 1997)

Most studies of driver behaviour generally involve short sessions, unfamiliar cars or simulators where the participants know their driving is under scrutiny

Is it possible to see proceduralised driving in these situations?

Exceptions:

Naturalistic driving studies

Documenting the precursors to crashes, and near crashes and the occurrence of driver distractions

(Stutts et al., 2005) (Dingus et al., 2006) (Salmon et al., 2010)

Longitudinal driving studies

Martens & Fox (2007) -- Practice on a desk-top simulator over 5 days. Found increased speeds and decreased glance duration – esp. on the first day. More practice led to better recollection of traffic signs but poorer driving performance and post-drive recognition when a target sign was changed.
Concluded that effects of practice were to establish top-down control over visual scanning patterns, resulting in failure to detect changes to road environment.

Three research questions for the present study

(1) can proceduralised (automatic) driving be produced and detected in a driving simulator?

(2) how is automaticity reflected in drivers' behaviour?

(3) do existing conclusions about driver behaviour generalise to proceduralised driving?

Participants asked to repeatedly drive the same road in a driving simulator over a period of 3 months

Participants: 2 groups

Expert group – 9 participants recruited to drive twice a week for approx 12 weeks
Mean age = 31.25 years (ranged 20 to 50 years)
6 participants completed 20 sessions
2 participants completed 15 sessions
1 completed 6 sessions

Casual group – 12 participants recruited to drive for one session only
Mean age = 25.83 years (ranged 20 to 50 years)

Apparatus: University of Waikato driving simulator

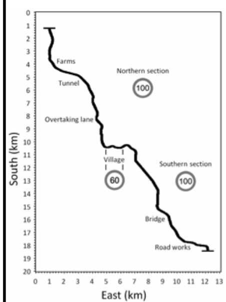
BMW 314i, vehicle dynamics model configured as 3 litre engine (making 170 kW power) with power steering, feedback, sound etc.

175° horizontal field-of-view + 2 rear-view mirrors

images and vehicle model updated at 100 frames per sec

Procedure:

24 km-long section of rural road
Divided into northern & southern sections



Participants drove 2 sections each session separated by a short rest

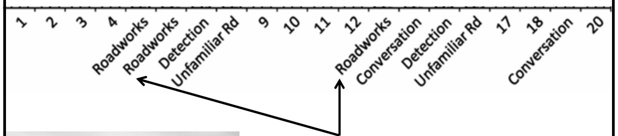
Each section contained prominent landmarks to promote familiarity (e.g., tunnel)

Driving difficulty rating collected at end of each session

$10 gift voucher for every session completed

Simulation scenarios:

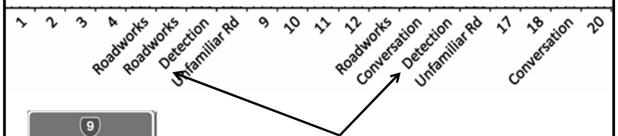
Detection tasks: VW beetle & anything unusual, interesting or hazardous



Road works scenarios:
road warnings,
30 km/h speed, cones,
construction equip

Simulation scenarios:

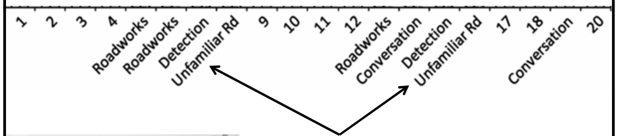
Detection tasks: VW beetle & anything unusual, interesting or hazardous



Detection scenarios: changes to road markings, road signs & removal of road markings for 200 m

Simulation scenarios:

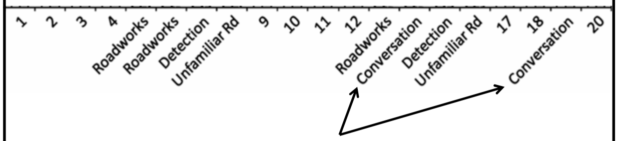
Detection tasks: VW beetle & anything unusual, interesting or hazardous



Unfamiliar road scenario: identical road geometry, different landscape, landmarks removed

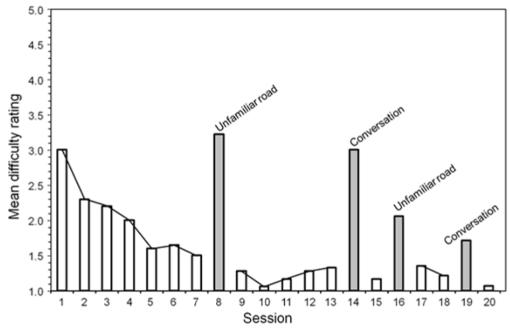
Simulation scenarios:

Detection tasks: VW beetle & anything unusual, interesting or hazardous



Conversation scenario: hands-free cell phone conversation with experimenter

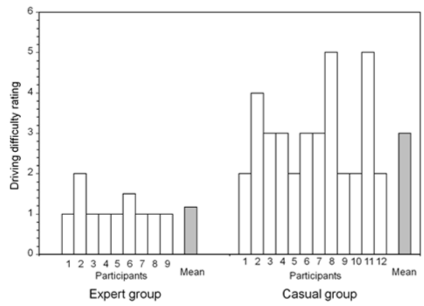
Results – Driving difficulty ratings:



Progressively lower ratings of driving difficulty

Exception of Unfamiliar road scenario (changed visual appearance of the road) and Conversation sessions (hands-free cell phone conversation)

Results – Driving difficulty ratings:

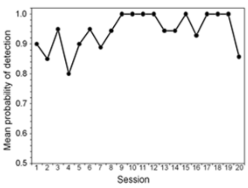


Significantly lower driving difficulty ratings for Expert group as compared to Casual group

(yoked comparison on Session 15 scenario)

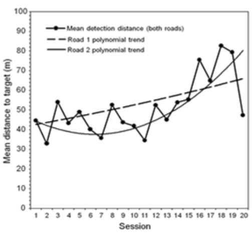
$F_{(1, 18)} = 18.96$, $p < 0.001$, $\acute{\eta}_p^2$ (Partial eta squared) = .513

Results – Detection tasks:



Volkswagen detection

Average probability of detection generally increased across the 20 sessions



Detection distances generally increased across the 20 sessions

Different rates for 1st and 2nd scenarios presented

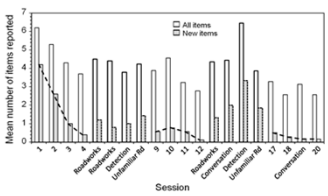
Significant scenario x session interaction

$F_{(4, 4)} = 14.53$, $p < 0.01$, $\acute{\eta}_p^2 = .936$

and significant session effect

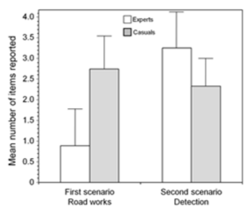
$F_{(4, 4)} = 14.09$, $p < 0.01$, $\acute{\eta}_p^2 = .934$

Results – Detection tasks:



Detection of interesting, unusual, or hazardous items

Number of items reported by Expert group generally decreased across sessions (total items & new items)



Fewer items detected by the Expert group in 1st scenario, more items detected during 2nd scenario (Detection scenario)

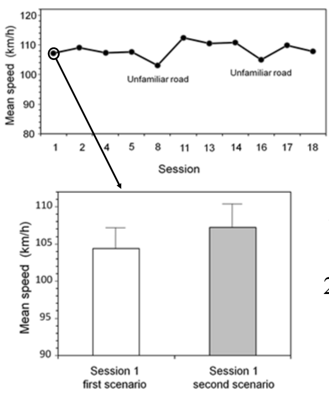
Significant group x scenario interaction

$F_{(1, 18)} = 11.21$, $p < 0.01$, $\acute{\eta}_p^2 = .384$

and significant scenario effect

$F_{(1, 18)} = 5.06$, $p < 0.05$, $\acute{\eta}_p^2 = .220$

Results – Vehicle speed and lane position:



Mean speeds for the southern scenarios

No significant change in speed

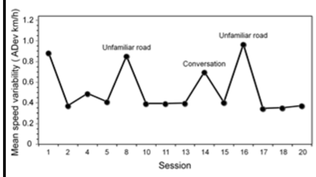
$F_{(1, 7)} = 2.13$, $p > 0.10$, $\acute{\eta}_p^2 = .233$

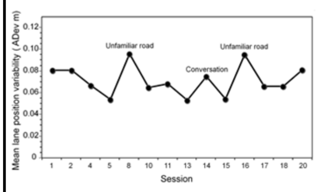
Mean speeds for the 1st scenario of Session 1 compared to the 2nd scenario of Session 1

Significant increase in speeds during Session 1

$F_{(1, 8)} = 6.30$, $p < 0.05$, $\acute{\eta}_p^2 = .441$

Results – Vehicle speed and lane position:





Mean speed variability for the southern scenarios

With 1 participant removed

Decrease in speed and lane position variability

Session 1 compared to Session 15

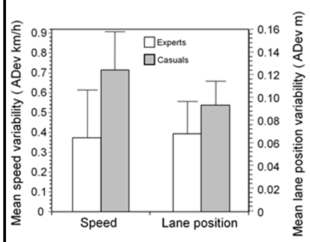
MANOVA: Wilks' Lambda = .317, $F_{(2, 5)} = 5.39$, $p < 0.056$, $\acute{\eta}_p^2 = .683$

mostly due to speed var measure: univariate $F_{(1, 6)} = 4.26$, $p < 0.08$, $\acute{\eta}_p^2 = .415$

not lane position var measure

Mean lane position variability for the southern scenarios

Results – Vehicle speed and lane position:



Mean speed and lane position variability

(yoked comparison Session 13)

Expert group displayed lower speed and lane position variability than the Casual group

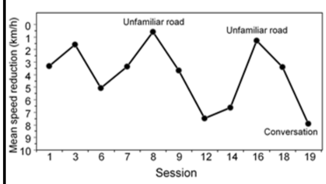
Significant difference between Expert and Casual participants

MANOVA: Wilks' Lambda = .666, $F_{(2, 17)} = 4.27$, $p < 0.05$, $\acute{\eta}_p^2 = .334$

mostly due to speed var measure: univariate $F_{(1, 17)} = 5.25$, $p < 0.05$, $\acute{\eta}_p^2 = .226$

not lane position var measure

Results – Perceptual speed regulation:



Speed reduction increased with experience

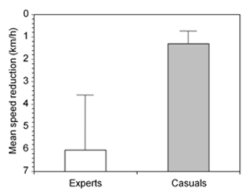
(largest during conversation)

Mean speed change for the 400m tunnel

(tunnel entry vs mid-point)

Session 14 significantly larger speed decrease than Session 1

$F_{(1, 7)} = 33.19$, $p < 0.001$, $\acute{\eta}_p^2 = .826$

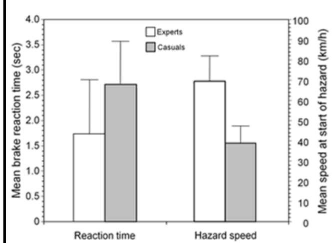


Participants in the Expert group displayed greater perceptual speed regulation than the Casual group

(yoked comparison Session 15)

$F_{(1, 18)} = 9.826$, $p < 0.01$, $\acute{\eta}_p^2 = .353$

Results – Reactions to a road hazard:



Brake reaction times for the road works hazard (measured from 1st warning sign) and vehicle speeds at start of hazard (1st road cone)

Experts were faster to hit brakes but did not reduce their speeds to appropriate levels (posted 30 km/h)

Significant difference between the Expert and Casual groups

MANOVA: Wilks' Lambda = .505, $F_{(2, 17)} = 8.35$, $p < 0.01$, $\acute{\eta}_p^2 = .495$

mostly due to speed measure: univariate $F_{(1, 18)} = 14.79$, $p < 0.001$, $\acute{\eta}_p^2 = .451$

not BRT measure

Results – Summary:

Progressively lower ratings of driving difficulty
(except Unfamiliar road and Conversation sessions

Higher probability of detection and faster detection
(except for road signs and roadside objects)

No significant change in mean speed
(except during 1st session)

Decreases in speed variability and
lane position variability

Perceptual speed regulation increased
(speed reductions in tunnel)
greatest during conversation scenarios

Faster hazard detection but poorer speed change
at road works scenario

Research questions revisited

(1) can proceduralised (automatic) driving be produced and detected in a driving simulator?

Ratings of driving difficulty suggest that the answer is yes

Reinforced by participants' comments

"*I found myself going into auto, not paying attention to what I was doing*" (Participant 2, Session 5)
"*Feels very normal, just like the drive home; thinking mostly about food*" (Participant 3, Session 6)
"*Was daydreaming, a lot on my mind*" (Participant 8, Session 7)

Not just improved vehicle control skill, as demonstrated by high difficulty ratings for Unfamiliar road scenario

Research questions revisited

(2) how is automaticity reflected in drivers' behaviour?

Slight increase in mean speed in 1st session (not automaticity)

Reductions in speed and lane position variability

Changes in detection performance:
VW detection became proceduralised part of driving and more efficient as a result
Item detection became stereotyped

Not all items equally likely to be detected

No participants noticed road sign changes even changes from English to German!

Attentional neglect for familiar road signs (Charlton, 2006)

Research questions revisited

(3) do existing conclusions about driver behaviour generalise to proceduralised driving?

Practice increased the degree of perceptual speed regulation at the tunnel

Proceduralised driving relies on implicit perceptual speed cues (optic flow)
When attention is drawn away with conversation, effect is magnified

Faster hazard detection, but poor speed choice at road works

Desensitised to hazard or difficulty modifying proceduralised speed?

Two modes of driving revisited

Top-down: conscious deliberation, effortful, resource limited
Early sessions & Unfamiliar road in present experiment

Bottom-up: automatic, unconscious, low cognitive demand
Maintenance of speed & lane position, rapid detection, more susceptible to perceptual influences

Note – our use of the term *Top-down* is not the same as Martens & Fox (2007) who referred to proceduralised scanning patterns as being "top-down"

Perhaps none of the conventional terminology properly reflect the phenomenon

Top-down and *Bottom-up* driving is not a true dichotomy

An alternative conceptualisation
Both processes working in tandem

Operating process: a conscious, intentional search of the environment, requires effort and can be undermined by distractions that also require effortful processing

Monitoring process: an unconscious error monitoring system, requires little cognitive effort, continues until an error is detected or it is terminated by a conscious choice

Reviews input with regard to a stored template for performance or information, and when a stimulus indicative of potential failure is detected, the object receives additional activation until the operating process can be brought to bear on the situation and select an appropriate action

An alternative conceptualisation
Both processes working in tandem

Operating process: deliberate, intentional decision making
required when individual lacks experience or expertise or for unusual & dynamically changing traffic situation

Monitoring process: continuously active, sufficient to maintain many aspects of driving, rapid error detection
When potential failure stimulus is detected, the object receives additional activation until the operating process returns conscious attention to task

Proceduralisation represents a broadening and refinement of the templates (schemata) used by the monitoring process

Theoretical implications

Similar to Wegner's (1994) Ironic processes in self-control of mental states

an effortful, intentional operating process searches for mental contents consistent with an intended state and an unconscious monitoring process tests whether the operating process is needed by searching for mental contents inconsistent with the intended state

Links to the Somatic-Marker Hypothesis of decision-making (Damasio, 1994, 1996)

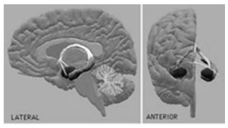
unconscious activation of incoming stimuli previously associated with negative affective states can unconsciously guide performance and produce greater attentional capture

Theoretical implications

Also congruent with the Behavioural Inhibition System developed to describe the neurological basis of anxiety (Gray, 1976; Gray and McNaughton, 1983, 2003)

BIS is believed to be constantly acting in a monitoring capacity, influencing behaviour when conflict, novelty, or threat is detected

Animal research confirms the role of the septo-hippocampal pathway and the hippocampus in detecting mismatches between on-going behaviour and environmental threats or novelty



Given the hippocampus' role in spatial information, ideally suited for hazard detection and redirection of behaviour and attention while driving

Theoretical implications

Tandem processing approach complements & reconciles many existing models of driver behaviour

Summala's Zero-risk Theory
Fuller's Task-Capability Interface Theory
Lewis-Evans & Rothengatter's Threshold model

Monitoring process (unconsciously) detects potentially important stimuli operating process engages when an activation threshold has been reached

Consciously interpreted as feelings of driving difficulty, risk, discomfort, or a time gap

Theoretical implications

Tandem processing approach complements & reconciles many existing models of driver behaviour

Tandem processing approach differs from existing models in that proceduralised driving is seen as the default mode for experienced drivers (monitoring process works continuously to guide behaviour)

Other models view automaticity as an exception to normal driving, either an uncontrollable motor program or impoverished level of performance that remains when driver attention is elsewhere

Acknowledgements

My thanks to Nicola Starkey

Thanks to the volunteer drivers who participated in this project; it would not have been possible without their dedication

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