



An investigation of the effects of the common cold on simulated driving performance and detection of collisions: A laboratory study

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2012-001047
Article Type:	Research
Date Submitted by the Author:	21-Feb-2012
Complete List of Authors:	Smith, Andrew; Cardiff University, School of Psychology Jamson, Samantha
Primary Subject Heading:	Infectious diseases
Secondary Subject Heading:	Public health
Keywords:	Public health < INFECTIOUS DISEASES, Respiratory infections < THORACIC MEDICINE, RESPIRATORY MEDICINE (see Thoracic Medicine)

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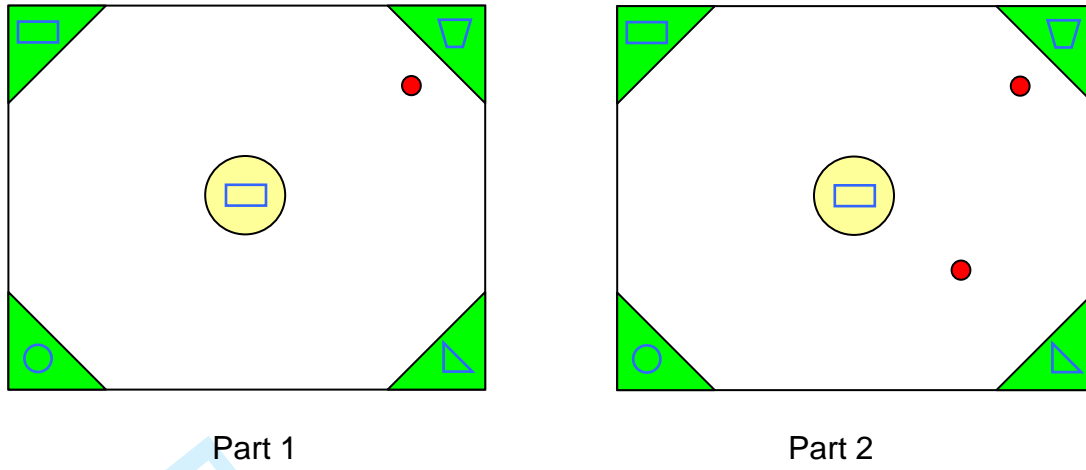


Figure 1: OMEDA computer screen

Data collected are target speed, size of the occlusion circle, time under the occlusion circle, actual time to contact (TTC), estimated TTC and TTC error, errors in shape detection.

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4 **An investigation of the effects of the common cold on simulated driving**
5 **performance and detection of collisions: A laboratory study**
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Abstract

Objective The aim of the present research was to investigate whether individuals with a common cold showed impaired ability on a simulated driving task and the ability to detect potential collisions between moving objects.

Design The study involved comparison of a healthy group with a group with colds. These scores were adjusted for individual differences by collecting further data when both groups were healthy and using these scores as covariates. On both occasions volunteers rated their symptoms, carried out a laboratory task measuring collision detection and also a simulated driving session.

Setting University of Leeds Institute for Transport Studies

Sample Twenty five students from the University of Leeds. 10 volunteers were healthy on both occasions and 15 had a cold on the first session and were healthy on the second.

Main outcome measures In the collision detection task the main outcomes were correct detections and response to a secondary identification task. In the simulated driving task the outcomes were: speed; lateral control; gap acceptance; overtaking behaviour; car following; vigilance and traffic light violations.

Results Those with a cold detected fewer collisions and had a higher divided attention error than those who were healthy. Many basic driving skills were unimpaired by the illness. However, those with a cold were slower at responding to unexpected events and drove closer to the car in front.

Conclusions The finding that having a common cold reduces the ability to detect collisions and respond quickly to unexpected events is of practical importance. Further research is now required to examine the efficacy of information campaigns and countermeasures such as caffeine.

Summary

Article focus:

. The study investigated effects of the common cold on simulated driving and collision detection.

Key messages:

. Drivers with a common cold respond more slowly to unexpected events and drive too close to the car in front.

. Collision detection is impaired when a person has a cold.

Strengths and limitations of this study:

. The study used established methodologies to investigate the topic.

. This small scale study requires replication and extension to provide a more detailed profile of potential effects of the common cold on driving.

Introduction

Studies of simulated driving have played a major role in transport policy and practice. One of the early studies¹, published in the British Medical Journal, demonstrated an increase in driving error following ingestion of alcohol. Changes in state due to drugs like alcohol can be countered by appropriate legislation. Other factors, such as driver fatigue, are more difficult to legislate against – there's no breathalyser for fatigue! In the case of professional drivers some causes of fatigue, such as time spent driving, can be controlled. This is more difficult when one considers driving outside of work or when one has to deal with fatigue produced by other factors (low levels of circadian alertness). In these situations, information campaigns² have to be used to prevent and manage driver fatigue, although legislation relating to being in a fit state to drive could be applied.

Minor illnesses such as the common cold produce a state of reduced alertness which is associated with impaired psychomotor function and cognitive abilities^{3, 4, 5, 6}. These impairments manifest themselves as slower reaction times to unexpected events and a reduced ability to sustain attention. These are important skills involved in driving and one might, therefore, expect that individuals with such illnesses will be involved in more road traffic accidents. Anecdotal evidence, largely consisting of case reports, suggests that this is the case⁷. This has been confirmed in a survey⁸ and extrapolation of this to the whole driving population suggests that 125,000 people in the UK

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3 have a road traffic accident while suffering from a cold or influenza. Results
4 from a driving hazard perception task⁸ confirmed laboratory findings that
5 reaction times are 10% slower when the person has a cold. Again, if one
6 applies this to a real-life driving situation it would mean that it would add 1m
7 (3.3ft) to stopping distance if travelling at 30mph (48km/h) - on top of a normal
8 distance of 12m (40ft) and it would add 2.3m (7.5ft) onto the normal stopping
9 distance of 96m (315ft) if travelling at 70mph (113km/h).
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16 Research using a simple driving simulator⁹ (resembling a computer game)
17 has shown the people with an upper respiratory tract illness responded more
18 slowly to unexpected events and were more likely to steer inaccurately.
19 Another study¹⁰ using a very realistic driving simulator found that basic driving
20 skills were not impaired but that situational awareness was reduced when the
21 person had a cold. The present study continued to examine this topic in detail,
22 using a sophisticated simulation that incorporates the skills necessary for safe
23 driving. In addition, the study also included a laboratory task which evaluated
24 participants' ability to detect potential collisions¹¹ which is a key skill in driving
25 but also something that cannot be repeatedly examined in a simulator.
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34 **Method**

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3 The study was carried out with the approval of the ethics committee, School of
4 Psychology, Cardiff University, and the informed consent of the volunteers.
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8 *Experimental design*

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11 A mixed design was employed whereby two groups of participants (Sample 1
12 and Sample 2) were tested on two occasions (Session 1 and Session 2).
13 Those participants in Sample 1 were healthy on both occasions, whilst those
14 in Sample 2 reported symptoms of minor respiratory illnesses in Session 1,
15 but were symptom free in Session 2.
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20 *Procedure*

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Volunteers were students from the University of Leeds recruited by posting advertisements in the Student Medical Practice and by placing posters in the School of Psychology. On arrival at the first session, they were asked to read the experimental procedure and sign the consent form if they agreed to take part. They then completed a symptom checklist, a self report questionnaire designed to evaluate the severity of their symptoms. If volunteers scored above 8 on symptoms typical of a cold they were included in the cold group. They were excluded if they scored 3 or more on symptoms not associated with a cold.

The laboratory task was then completed, followed by a familiarisation period on the driving simulator. Volunteers were asked to drive as naturally as possible through the road network. The secondary (choice reaction) task was also explained to them. On completion of the drive, volunteers were asked to contact the experimenter after seven symptom free days in order to confirm a second session. When they returned for this session, they completed the same symptom checklist and driving simulator task. After completion, they were debriefed, and their expenses paid.

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3 *OMEDA (Object Movement Estimation under Divided Attention)*
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6 OMEDA¹¹ is a computerised dual-task with two parts. Part 1 of OMEDA
7 allows experimenters to obtain an individual's error in Time-To-Collision (TTC)
8 estimation. Different target speeds can be simulated, as can various degrees
9 of occlusion. A secondary task is also incorporated in the form of a visual
10 divided attention task. This requires the identification of peripheral duplication
11 of stimuli presented centrally (in this case geometrical shapes).
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17 Part 2 of OMEDA provides a quantified estimate of collision detection error
18 under various degrees of occlusion and for a series of target speeds, with the
19 same secondary task as for Part 1. Participants do not need to be computer
20 literate in order to be able to do this task, as the response keys are a foot
21 pedal (for the primary task) and a hand button (for the secondary task).
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28 In Part 1 the participant is presented with a computer screen where the
29 corners are covered by green triangles and in the centre of the screen is a
30 yellow circle. The yellow circle varies in size between two and 250 pixels.
31 From one of the four corners (randomly allocated), a red target, in the form of
32 a circle travels towards the middle of the screen. Once it reaches the edge of
33 the yellow circle, it travels underneath it and it is not visible. Therefore, the
34 larger the circle, the more difficult is the task, due to a longer occlusion time.
35 The participant is asked to estimate exactly when the target reaches the
36 middle of the computer screen. They are instructed to press a foot pedal at
37 the exact point the target reaches the middle.
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46 To order to simulate divided attention, whilst participants are estimating when
47 the target reaches the middle of the screen, they are required to complete a
48 pattern matching task. When the target is moving, five shapes appear on the
49 screen (one overlaid on the yellow circle and one in each of the four corners).
50 Participants are instructed to press a hand button immediately if the shape in
51 the middle matches any of those in the four corners of the screen.
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3 In Part 2, the participants are presented with the same screen as in Part 1.
4 However, the primary task now involves two targets moving towards the
5 centre of the screen, emerging at different times and travelling at different
6 speeds. The targets reach the centre of the screen either at the same time (a
7 hit), almost at the same time (a near miss) or at a noticeable time difference
8 (a miss). The participant is required to press the foot pedal only if and when
9 the targets reach the centre of the screen at the same time (i.e. only for hits).
10 The secondary task is the same as for Part 1. The data collected includes the
11 error in estimating TTC and the error in shape estimation, under different
12 occlusions and target speeds
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20 *Driving Simulator*

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22 The experiments were carried out on a fixed based driving simulator at the
23 University of Leeds presenting a 120° forward view and 50° rear view. The
24 system features a fully interactive Silicon Graphics (Onyx RE²) driving
25 simulator with a six degree of freedom vehicle model. A servo motor linked to
26 the steering mechanism provides control over handling torque and speed and
27 digitised samples of engine, wind, road noise and other vehicles are provided.
28 Photo-realistic scene texturing allows presentation of various road types and
29 features.
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38 Studies¹² have evaluated the behavioural validity of the simulator. The results
39 showed that overall there was a broad correspondence between driving in the
40 simulator and the behaviour of real-world traffic. With regard to speed, the
41 effects of road width, curvature, direction of curve and sequence between
42 road sections were reproduced on the simulator, and there were very high
43 correlations between speed along the real road and speeds in the simulator.
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49 The experimental route was approximately 22 miles in length and comprised
50 of urban, rural and motorway environments, providing a range of speed limits
51 between 30 and 70 mph. Other cars in the scenario provided the opportunity
52 of simulating overtaking scenarios, gap acceptance tasks and car-following
53 situations. The road environment also featured traffic lights and pelican
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3 crossings in order to instigate possible violation scenarios; and sub-standard
4 curves were included in both the urban and rural sections.
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8 Speed measurements were taken every 10 metres throughout the whole
9 journey. In addition, indices of safety critical behaviour such as minimum time
10 to collision in following tasks and the incidence of overtaking manoeuvres
11 were recorded. Traffic light violations, speed violations and curve negotiation
12 behaviour were also noted.
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18 Three car following situations were engineered requiring drivers to maintain
19 their desired headway over a section of road. They were unable to pass the
20 slow moving car in front due to oncoming traffic. These situations allowed
21 measurement of minimum time to collision and variation in headway. In
22 addition, two overtaking scenarios were created: here oncoming traffic was
23 present, but it had sufficient gaps to allow the driver to pass. Propensity to
24 overtake and proximity to the oncoming car were measured. An additional
25 overtaking scenario was created, again using a slow moving vehicle in front.
26 Here drivers were constrained by double white lines; if they chose to overtake,
27 a violation was recorded.
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36 Four sets of traffic lights were placed in the road network. One was
37 programmed to change from green to red as the driver approached. This
38 required the driver to make a stop/go decision, and a violation was recorded if
39 the driver passed through on the red light. Two gap acceptance tasks were
40 incorporated into the road network. The first required the driver to merge from
41 the minor road onto the major road, making a left turn. Traffic on the major
42 road was approaching from the right with varying gaps. The second required
43 the driver to make a right turn across oncoming traffic from a major to a minor
44 road. Again the cars were separated with varying gaps.
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53 Attention to surprise events was measured in terms of performance on a
54 choice reaction task incorporated into the road network. Drivers were
55 required to respond to red and green squares that appeared in front of them.
56 If the square was green, they were asked to ignore it and continue driving. If
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the square was red, they were asked to continue driving, and to flash the headlights once, in response. Throughout the whole drive there appeared three red and three green squares in a random sequence. In subsequent drives the positioning of the squares was changed, in order to prevent associative learning effects. Their response to the stimuli was recorded in terms of reaction time, false/correct hits and missing responses.

Participants

Previous research suggests that the effects of the common cold on behavioural measures are large. A sample size calculation suggested that 24 participants should be tested. Twenty five participants were recruited for this study. Ten were assigned to Sample 1 and 15 to Sample 2. All participants had a full driving licence and a roughly equal number proportion of males and females were recruited. All volunteers were paid for their participation.

	<i>Sample 1</i>	<i>Sample 2</i>
<i>Males/females</i>	<i>4/6</i>	<i>10/5</i>
<i>Mean age (males)</i>	<i>20 years</i>	<i>20 years</i>
<i>Mean age (females)</i>	<i>22 years</i>	<i>21 years</i>

Results

Symptom checklist

The symptom checklist showed significant differences in self-reported health. In the first test session, volunteers with a cold scored on average 19.8 (out of a maximum of 52), whilst on their return, this average score fell to 2, which was similar to the scores for those who were healthy on both occasions.

OMEDA

Performance data on both parts of the OMEDA task are presented. Part 1 of the task provides indication of accuracy in terms of time-to-collision estimates of a moving target. Absolute error (in seconds) was computed for both the

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3 healthy and unhealthy groups. Performance on the secondary task was also
4 recorded, using the number of errors made in identifying the presence of a
5 matching shape in the periphery of the screen. Part 2 of OMEDA provides
6 data relating to the ability to detect a collision between two moving targets.
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8 The results are shown in Table 1.
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15 In Part 1, there were no significant differences between the groups. This is
16 likely due to a ceiling effect, whereby the volunteers found the task easy to
17 complete. Overall, they were able to estimate accurately the TTC, with 50% of
18 the total sample estimating to within 0.3 seconds of the actual TTC. In
19 addition, they found the primary task easy enough to be able to perform well
20 on the secondary task, with only a total of four identification errors across the
21 whole sample. However, when the task became more difficult in Part 2 of the
22 OMEDA, performance decrements were found for those with colds. Healthy
23 individuals were more likely to identify correctly both collisions and non-
24 collisions. Those with colds appear to be impaired to the extent that they
25 were less likely to be able to identify if the moving targets would or would not
26 collide under various degrees of occlusion. Performance on the secondary
27 task also degraded, such that those who were suffering from a cold made
28 more errors in identifying the matching shape in the periphery of the screen.
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39 *Driving performance*

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41 In order to control for individual differences in driving ability, analyses of co-
42 variance, with the session 2 data as covariates, were carried out on the
43 driving data.
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47 *Speed*

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49 For the purpose of data analysis, the experimental road network was divided
50 into sections according to speed limit. Of these sections, where the driver
51 was in free flowing conditions (i.e. not engaged in a car following task) mean
52 speed and standard deviation speed across the section was derived.
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61 Analyses of covariance showed no effect having a cold on speed.

Lateral control

Edgeline/centre line encroachments were not significantly altered as a function of health status.

Gap acceptance

Two gap acceptance tasks were included in the road network. The first required the drivers to merge left into traffic approaching from the right, whilst the second required drivers to turn right across oncoming traffic. Gaps in the traffic increased by 1 second, with each vehicle, and the size of the gap that drivers accepted as well as a minimum time to collision to the on-coming car was calculated. There were no significant effects of cold status on gap acceptance.

Overtaking behaviour

In addition to the car following tasks detailed above, two scenarios were created to examine overtaking behaviour. Drivers encountered lead cars travelling below the posted speed limit on a straight stretch of road. There was little opposing traffic, providing the opportunity for drivers to overtake. Both overtaking attempts and successful overtakings were recorded. However it was found that these values were identical (thus once committed to an overtaking manoeuvre, drivers tended to complete it). There was no difference in overtaking behaviour between the two sessions.

Car following

The road network allowed the inclusion of several car following tasks. In two of these tasks the driver was unable to overtake the car in front due to oncoming traffic. This created a “boxed-in” situation that allowed the measurement of the time headway distribution. The lead cars in these scenarios were travelling at a speed that was constant and below the speed limit. Thus in the urban situation the lead car was travelling at 25 mph, in the rural area at 40 mph. Therefore, even if speed limited, it was possible for drivers to adopt short headways if they wished to. Table 2 shows the time

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3 headway distribution for both healthy and ill drivers in an urban environment
4 (30mph).
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8 It can be seen that those drivers who reported cold symptoms were more
9 likely to spend a larger proportion of time at a shorter headway (in the safety
10 critical area of less than 2 seconds).
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13 *Vigilance*

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15 A choice reaction task required drivers to differentially respond to randomly
16 appearing targets in the visual scene. It was hypothesised that there may be
17 differences in either response times or error rates depending on the health
18 status of the participants. Such differences may arise as a result of
19 decreases in vigilance associated with cognitive impairment. Probably due to
20 the ease of the task, a floor effect was found with regards to the error rates in
21 that drivers demonstrated a high degree of accuracy. Further analysis of the
22 response times to targets however, revealed a significant difference between
23 response times of the healthy and ill volunteers with those with a cold being
24 significantly slower (see Table 2).
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34 *Collision with a pedestrian*

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36 A critical event was added as an additional measure of vigilance. At a
37 pedestrian crossing a pedestrian stepped into the road and crossed in front of
38 the driver's path. This event was staged such that drivers were able, with
39 severe braking, to avoid collision with the pedestrian, if braking was initiated
40 immediately. The healthy volunteers had no collisions whereas those with a
41 cold had 8.
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50 These types of critical scenarios are inherently difficult to manipulate and test
51 in the simulator environment, not least due to exposure effects. It could be
52 postulated that on the second trial, participants were anticipating an event of
53 this kind to occur again and thus be cautious on approach to pedestrian
54 crossings. However, several precautions ensure this is not the case. First, the
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3 location of the surprise event was different on the two driving sessions. In the
4 first session it was located at the end of the road network and in the second
5 session it was moved to half way along the network. Secondly, as a measure
6 of anticipation, speed measures were recorded within the vicinity of the event.
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8 Thus, speed was measured at 50 metres before the event (50 metres was
9 chosen as drivers could see the pedestrian but had not yet begun to brake). In
10 addition, speed was also measured at the point at which they initially began to
11 brake. There were no significant difference in these values between the first
12 and the second driving session. This indicates that drivers were not
13 anticipating the event in the second session.
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21 These results demonstrate that drivers with reported symptoms of minor
22 respiratory illnesses are impaired to the extent that they have longer response
23 times and thus negative safety effects with regards to critical events in the
24 driving environment.
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28 *Traffic light violations*

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31 A situation was created whereby drivers were forced to make a rapid stop/go
32 decision at one set of traffic lights which turned from green to amber as
33 drivers approached. In concordance with the previous results found on the
34 longer response times and reaction to surprise events, drivers who reported
35 cold symptoms violated the traffic lights twice as often as when they were
36 symptom free (see Table 2).
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42 **Discussion**

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46 The present results confirm the earlier findings that having a cold may impair
47 aspects of simulated driving performance. There appears to be reliable
48 evidence that volunteers presenting with symptoms respond more slowly to
49 unexpected events and drive too closely to the car in front. As described in
50 the introduction, this decrement in driving performance could have
51 implications for road safety. The slowing of reaction times associated with
52 having a cold is comparable to effects of known hazards, such as
53 consumption of a dose of alcohol that would lead to a ban from driving or
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3 having to perform at night. The OMEDA task also demonstrated that those
4 suffering from a cold were less able to detect potential collisions. Comparison
5 with a previous study using elderly participants (over 65 years) shows that the
6 detection performance of young adults with a cold falls to that of elderly
7 drivers. There is now a need for an information campaign to provide accurate
8 information about the potential hazards associated with driving while suffering
9 from an upper respiratory tract illness.
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16 There is also evidence that the direct effects of having a cold are not the only
17 ones that need to be considered. A number of studies have shown that
18 individuals who are ill are more susceptible to the effects of other factors
19 which could influence driving (alcohol¹³; prolonged work¹⁴; and noise¹⁵).
20 Research also shows that impairments associated with the common cold are
21 not restricted to the time the person is symptomatic but may be observed in
22 the incubation period and after symptoms have gone⁶.
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30 One must now ask what underlies the effects here. Previous research has
31 shown that the low alertness state associated with a cold can be reversed by
32 a drug which increases the turnover of central noradrenaline¹⁶. Indeed,
33 ingestion of caffeine, which increases alertness, has been shown to remove
34 the cold induced performance impairments seen in laboratory tasks¹⁷. This
35 suggests that a further study examining whether caffeine can remove the
36 effects found here is required. Similarly, it will be important to determine
37 whether medications aimed at producing symptomatic relief also remove the
38 behavioural problems associated with the common cold.
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47 In summary, the present study has used established methods to examine
48 effects of the common cold on simulated driving and collision detection. The
49 finding that having a cold reduces the ability to detect collisions and respond
50 quickly to unexpected events are of practical importance and can be related to
51 plausible underlying mechanisms. The study was small scale and further
52 research is required to determine whether there are additional smaller effects
53 and whether there are contexts and individuals (e.g. the elderly) in which the
54 impairments may be even greater than those seen here. Similarly, further
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research is required to address the issue of prevention of these effects, both by information campaigns and use of countermeasures such as caffeine.

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Table 1. Performance of healthy and unhealthy drivers on the OMEDA task.

a. Part 1			
	Mean		Significance
	Healthy	Ill	
Absolute error of TTC	0.40	0.44	p> 0.05
Shape identification error	0.01	0.03	p>0.05

b. Part 2			
			Significance
	Healthy	Ill	
Missed collisions	8 %	10%	p > 0.05
Detected collisions	45%	37%	p< 0.05
Correct misses	29%	22%	p<0.001
False hits	22%	26%	p= 0.06
Divided attention error	0.46%	1.38%	p< 0.001

Table 2. Significant effects of health status on outcomes from the driving task

a. Percentage of time spent at a headway of less than 2 seconds			
	Healthy	Ill	
	39.2%	51.7	p <0.05
b. Mean response times (seconds) in choice reaction task			
	Healthy	Ill	
Target 1	1.01	1.33	p <0.05
Target 2	0.95	1.21	p < 0.03
c. Number of collisions with a pedestrian			
	Healthy	Ill	
	0	8	p <0.05
a. Mean number of traffic light violations			
	Healthy	Ill	
	0.2	0.43	p <0.05

Contributors

APS wrote the research proposal, designed the study, wrote the statistical analysis plan, analysed the data and drafted and revised the paper. He is guarantor.

SJ implemented the study, analysed the data and revised the paper.

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Disclosure

"All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: all authors had financial support from the ESRC ROPA Scheme (grant R022250188) for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities that could appear to have influenced the submitted work”.

Data Sharing

There is no additional data available.

Funding

Funded by ESRC, grant number RO22250188



An investigation of the effects of the common cold on simulated driving performance and detection of collisions: A laboratory study

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2012-001047.R1
Article Type:	Research
Date Submitted by the Author:	17-May-2012
Complete List of Authors:	Smith, Andrew; Cardiff University, School of Psychology Jamson, Samantha
Primary Subject Heading:	Infectious diseases
Secondary Subject Heading:	Public health, Infectious diseases, Occupational and environmental medicine, Respiratory medicine
Keywords:	Public health < INFECTIOUS DISEASES, Respiratory infections < THORACIC MEDICINE, RESPIRATORY MEDICINE (see Thoracic Medicine)

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4 **An investigation of the effects of the common cold on simulated driving**
5 **performance and detection of collisions: A laboratory study**
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Abstract

Objective The aim of the present research was to investigate whether individuals with a common cold showed impaired ability on a simulated driving task and the ability to detect potential collisions between moving objects.

Design The study involved comparison of a healthy group with a group with colds. These scores were adjusted for individual differences by collecting further data when both groups were healthy and using these scores as covariates. On both occasions volunteers rated their symptoms and carried out a simulated driving session. On the first occasion volunteers also carried out a collision detection task.

Setting University of Leeds Institute for Transport Studies

Sample Twenty five students from the University of Leeds. 10 volunteers were healthy on both occasions and 15 had a cold on the first session and were healthy on the second.

Main outcome measures In the collision detection task the main outcomes were correct detections and response to a secondary identification task. In the simulated driving task the outcomes were: speed; lateral control; gap acceptance; overtaking behaviour; car following; vigilance and traffic light violations.

Results Those with a cold detected fewer collisions and had a higher divided attention error than those who were healthy. Many basic driving skills were unimpaired by the illness. However, those with a cold were slower at responding to unexpected events and spent a greater percentage of time driving at a headway of less than 2 seconds.

Conclusions The finding that having a common cold reduces the ability to detect collisions and respond quickly to unexpected events is of practical importance. Further research is now required to examine the efficacy of information campaigns and countermeasures such as caffeine.

Introduction

Studies of simulated driving have played a major role in transport policy and practice. One of the early studies¹, published in the British Medical Journal, demonstrated an increase in driving error following ingestion of alcohol. Changes in state due to drugs like alcohol can be countered by appropriate legislation. Other factors, such as driver fatigue, are more difficult to legislate against – there's no breathalyser for fatigue! In the case of professional drivers some causes of fatigue, such as time spent driving, can be controlled. This is more difficult when one considers driving outside of work or when one has to deal with fatigue produced by other factors (low levels of circadian alertness). In these situations, information campaigns² have to be used to prevent and manage driver fatigue, although legislation relating to being in a fit state to drive could be applied. The aim of the present research was to investigate whether individuals with a common cold showed impaired ability on a simulated driving task and the ability to detect potential collisions between moving objects.

Minor illnesses such as the common cold produce a state of reduced alertness which is associated with impaired psychomotor function and cognitive abilities^{3, 4, 5, 6}. These impairments manifest themselves as slower reaction times to unexpected events and a reduced ability to sustain attention. These are important skills involved in driving and one might, therefore, expect that individuals with such illnesses will be involved in more crashes. Anecdotal evidence, largely consisting of case reports, suggests that this is the case⁷. This has been confirmed in a survey⁸ and extrapolation of this to the whole driving population suggests that 125,000 people in the UK have a crash while suffering from a cold or influenza. Results from a driving hazard perception task⁸ confirmed laboratory findings that reaction times are 10% slower when the person has a cold. Again, if one applies this to a real-life driving situation it would mean that it would add 1m (3.3ft) to stopping distance if travelling at 30mph (48km/h) - on top of a normal distance of 12m (40ft) and it would add

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3 2.3m (7.5ft) onto the normal stopping distance of 96m (315ft) if travelling at
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5 70mph (113km/h).
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8 Research using a simple driving simulator⁹ (resembling a computer game)
9
10 has shown that people with an upper respiratory tract illness responded more
11 slowly to unexpected events and were more likely to steer inaccurately.
12 Another study¹⁰ using a very realistic driving simulator found that basic driving
13 skills were not impaired but that situational awareness was reduced when the
14 person had a cold. The present study continued to examine this topic in detail,
15 using a sophisticated simulation that incorporates the skills necessary for safe
16 driving. In addition, the study also included a laboratory task which evaluated
17 participants' ability to detect potential collisions¹¹ which is a key skill in driving
18 but also something that cannot be repeatedly examined in a simulator.
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26 **Method**

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29 The study was carried out with the approval of the ethics committee, School of
30 Psychology, Cardiff University, and the informed consent of the volunteers.
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34 *Experimental design*

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37 A mixed design was employed whereby two groups of participants (Sample 1
38 and Sample 2) were tested on two occasions (Session 1 and Session 2).
39 Those participants in Sample 1 were healthy on both occasions, whilst those
40 in Sample 2 reported symptoms of minor respiratory illnesses in Session 1,
41 but were symptom free in Session 2. Participants carried out the driving
42 simulation task on both occasions but only carried out the collision detection
43 task on the first session.
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50 *Procedure*

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54 Volunteers were students from the University of Leeds recruited by posting
55 advertisements in the Student Medical Practice and by placing posters in the
56 School of Psychology. On arrival at the first session, they were asked to read
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3 the experimental procedure and sign the consent form if they agreed to take
4 part. They then completed a symptom checklist, a self report questionnaire
5 designed to evaluate the severity of their symptoms using a 5 point rating
6 scale (0=not all to 4= very severe). If volunteers scored above 8 on symptoms
7 typical of a cold (pain in chest, sore throat, headache, sneezing, runny nose,
8 blocked nose, hoarseness, cough, hot/cold, sweating, shivering, fever, and
9 phlegm) they were included in the cold group. Healthy volunteers were only
10 included if they had a symptom score of 3 or less (based on the upper
11 respiratory tract symptoms and other symptoms of minor illnesses such as
12 digestive problems). Volunteers were excluded if they were taking medication
13 for their colds. All volunteers were tested when their illness had been present
14 for at least 24 hours and no longer than 96 hours.
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24 The laboratory task was then completed, followed by a familiarisation period
25 on the driving simulator. Volunteers were asked to drive as naturally as
26 possible through the road network. The secondary (choice reaction) task was
27 also explained to them. On completion of the drive, volunteers were asked to
28 contact the experimenter after seven symptom free days in order to confirm a
29 second session. Those who were healthy at session 1 returned for their
30 second session approximately a week later. When they returned for this
31 session, they completed the same symptom checklist and driving simulator
32 task. After completion, they were debriefed, and their expenses paid.
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41 *OMEDA (Object Movement Estimation under Divided Attention)*

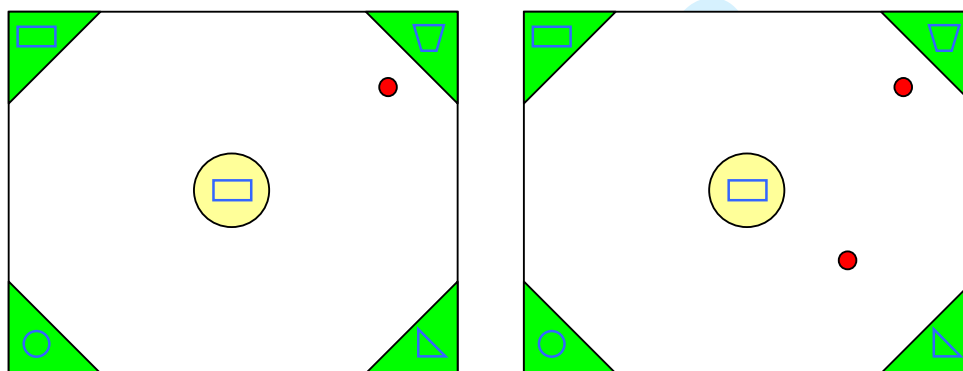
42
43 OMEDA¹¹ is a computerised dual-task with two parts. Part 1 of OMEDA
44 allows experimenters to obtain an individual's error in Time-To-Collision (TTC)
45 estimation. Different target speeds can be simulated, as can various degrees
46 of occlusion. A secondary task is also incorporated in the form of a visual
47 divided attention task. This requires the identification of peripheral duplication
48 of stimuli presented centrally (in this case geometrical shapes).
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55 Part 2 of OMEDA provides a quantified estimate of collision detection error
56 under various degrees of occlusion and for a series of target speeds, with the
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3 same secondary task as for Part 1. Participants do not need to be computer
4 literate in order to be able to do this task, as the response keys are a foot
5 pedal (for the primary task) and a hand button (for the secondary task).
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10 In Part 1 the participant is presented with a computer screen where the
11 corners are covered by green triangles and in the centre of the screen is a
12 yellow circle. The yellow circle varies in size between two and 250 pixels.
13 From one of the four corners (randomly allocated), a red target, in the form
14 of a circle travels towards the middle of the screen. Once it reaches the edge
15 of the yellow circle, it travels underneath it and it is not visible. Therefore,
16 the larger the circle, the more difficult is the task, due to a longer occlusion
17 time. The participant is asked to estimate exactly when the target reaches the
18 middle of the computer screen. They are instructed to press a foot pedal at
19 the exact point the target reaches the middle.
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28 In order to simulate divided attention, whilst participants are estimating when
29 the target reaches the middle of the screen, they are required to complete a
30 pattern matching task. When the target is moving, five shapes appear on the
31 screen (one overlaid on the yellow circle and one in each of the four corners).
32 Participants are instructed to press a hand button immediately if the shape in
33 the middle matches any of those in the four corners of the screen.
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Part 1

Part 2

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6 Figure 1: OMEDA computer screen
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8 Data collected are target speed, size of the occlusion circle, time under the
9 occlusion circle, actual time to contact (TTC), estimated TTC and TTC error,
10 errors in shape detection.
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14 In Part 2, the participants are presented with the same screen as in Part 1.
15 However, the primary task now involves two targets moving towards the
16 centre of the screen, emerging at different times and travelling at different
17 speeds. The targets reach the centre of the screen either at the same time (a
18 hit), almost at the same time (a near miss) or at a noticeable time difference
19 (a miss). The participant is required to press the foot pedal only if and when
20 the targets reach the centre of the screen at the same time (i.e. only for hits).
21 The secondary task is the same as for Part 1. The data collected includes the
22 error in estimating TTC and the error in shape estimation, under different
23 occlusions and target speeds
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32 *Driving Simulator*
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35 The experiments were carried out on a fixed based driving simulator at the
36 University of Leeds presenting a 120° forward view and 50° rear view. The
37 system features a fully interactive Silicon Graphics (Onyx RE²) driving
38 simulator with a six degree of freedom vehicle model. A servo motor linked to
39 the steering mechanism provides control over handling torque and speed and
40 digitised samples of engine, wind, road noise and other vehicles are provided.
41 Photo-realistic scene texturing allows presentation of various road types and
42 features.
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49 Studies¹² have evaluated the behavioural validity of the simulator. The results
50 showed that overall there was a broad correspondence between driving in the
51 simulator and the behaviour of real-world traffic. With regard to speed, the
52 effects of road width, curvature, direction of curve and sequence between
53 road sections were reproduced on the simulator, and there were very high
54 correlations between speed along the real road and speeds in the simulator.
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3 Prior to the experimental drive, participants completed a fifteen minute
4 familiarisation drive. The drive comprised urban, rural and motorway sections,
5 similar to the experimental drive, but contained none of the scenarios under
6 investigation. Once the familiarisation drive was completed, drivers were
7 deemed ready to proceed to the next stage. The experimental route was
8 approximately 22 miles in length and comprised of urban, rural and motorway
9 environments, providing a range of speed limits between 30 and 70 mph.
10 Other cars in the scenario provided the opportunity of simulating overtaking
11 scenarios, gap acceptance tasks and car-following situations. The road
12 environment also featured traffic lights and pelican crossings in order to
13 instigate possible violation scenarios; and sub-standard curves were included
14 in both the urban and rural sections.
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24 Speed measurements were taken every 10 metres throughout the whole
25 journey. In addition, indices of safety critical behaviour such as minimum time
26 to collision in following tasks and the incidence of overtaking manoeuvres
27 were recorded. Traffic light violations, speed violations and curve negotiation
28 behaviour were also noted.
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34 Three car following situations were engineered requiring drivers to maintain
35 their desired headway over a section of road. They were unable to pass the
36 slow moving car in front due to oncoming traffic. These situations allowed
37 measurement of minimum time to collision and variation in headway. In
38 addition, two overtaking scenarios were created: here oncoming traffic was
39 present, but it had sufficient gaps to allow the driver to pass. Propensity to
40 overtake and proximity to the oncoming car were measured. An additional
41 overtaking scenario was created, again using a slow moving vehicle in front.
42 Here drivers were constrained by double white lines; if they chose to overtake,
43 a violation was recorded.
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53 Four sets of traffic lights were placed in the road network. One was
54 programmed to change from green to red as the driver approached. This
55 required the driver to make a stop/go decision, and a violation was recorded if
56 the driver passed through on the red light. Two gap acceptance tasks were
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3 incorporated into the road network. The first required the driver to merge from
4 the minor road onto the major road, making a left turn. Traffic on the major
5 road was approaching from the right with varying gaps. The second required
6 the driver to make a right turn across oncoming traffic from a major to a minor
7 road. Again the cars were separated with varying gaps.
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12 Attention to surprise events was measured in terms of performance on a
13 choice reaction task incorporated into the road network. Drivers were
14 required to respond to red and green squares that appeared in front of them.
15 If the square was green, they were asked to ignore it and continue driving. If
16 the square was red, they were asked to continue driving, and to flash the
17 headlights once, in response. Throughout the whole drive there appeared
18 three red and three green squares in a random sequence. In subsequent
19 drives the positioning of the squares was changed, in order to prevent
20 associative learning effects. Their response to the stimuli was recorded in
21 terms of reaction time, false/correct hits and missing responses.
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30 *Participants*

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32 Previous research suggests that the effects of the common cold on
33 behavioural measures are large. A sample size calculation suggested that 20
34 participants should be tested (minimum group size=9). Twenty five
35 participants were recruited for this study. Ten were assigned to Sample 1 and
36 15 to Sample 2. All participants had a full driving licence and had been driving
37 for less than 5 years. A roughly equal number proportion of males and
38 females were recruited and all 11 volunteers were paid for their participation.
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	<i>Sample 1 (Healthy)</i>	<i>Sample 2 (Colds)</i>
<i>Males/females</i>	<i>4/6</i>	<i>10/5</i>
<i>Mean age (males)</i>	<i>20 years (range: 18-21)</i>	<i>20 years (range: 18-25)</i>
<i>Mean age (females)</i>	<i>22 years (range: 20-24)</i>	<i>21 years (range: 19-24)</i>

Results

Symptom checklist

The symptom checklist showed significant differences in self-reported health. In the first test session, volunteers with a cold scored on average 19.8 (out of a maximum of 52), whilst on their return, this average score fell to 2, which was similar to the scores for those who were healthy on both occasions. Symptom scores for all of the upper respiratory tract symptom scales are shown in Table 1. All of the individual symptoms showed significant differences between the groups except for fever and shivering. This suggests that the participants had colds rather than influenza.

OMEDA

Performance data on both parts of the OMEDA task are presented. Part 1 of the task provides indication of accuracy in terms of time-to-collision estimates of a moving target. Absolute error (in seconds) was computed for both the healthy and unhealthy groups. Performance on the secondary task was also recorded, using the number of errors made in identifying the presence of a matching shape in the periphery of the screen. Part 2 of OMEDA provides data relating to the ability to detect a collision between two moving targets. The results are shown in Table 2.

In Part 1, there were no significant differences between the groups. This is likely due to a ceiling effect, whereby the volunteers found the task easy to complete. Overall, they were able to estimate accurately the TTC, with 50% of the total sample estimating to within 0.3 seconds of the actual TTC (Absolute

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3 error of TTC: Healthy group: 0.40; Ill group: 0.44). In addition, they found the
4 primary task easy enough to be able to perform well on the secondary task,
5 with only a total of four identification errors across the whole sample (Shape
6 identification error: Healthy group: 0.01; Ill group: 0.03). However, when the
7 task became more difficult in Part 2 of the OMEDA, performance decrements
8 were found for those with colds. Healthy individuals were more likely to
9 identify correctly both collisions and non-collisions. Those with colds appear
10 to be impaired to the extent that they were less likely to be able to identify if
11 the moving targets would or would not collide under various degrees of
12 occlusion. Performance on the secondary task was also degraded, such that
13 those who were suffering from a cold made more errors in identifying the
14 matching shape in the periphery of the screen.
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24 *Driving performance*

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26 In order to control for individual differences in driving ability, analyses of co-
27 variance, with the session 2 data as covariates, were carried out on the
28 driving data. Preliminary analyses showed that the two groups were not
29 significantly different at session 2 (when both groups were healthy).
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34 *Speed*

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36 For the purpose of data analysis, the experimental road network was divided
37 into sections according to speed limit. Of these sections, where the driver
38 was in free flowing conditions (i.e. not engaged in a car following task)
39 standard deviation of speed across the section was derived. Analyses of
40 covariance showed no effect of having a cold on standard of speed (Healthy
41 group: mean=4.76 m/s, s.e.= 0.36; Ill group: mean=4.82 m/s, s.e.= 0.30, F
42 <1).
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49 *Lateral control*

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51 Edgeline/centre line encroachments were not significantly altered as a
52 function of health status nor was the standard deviation of lane position (s.d.
53 lane position: healthy group: mean=0.19 m, s.e. 0.3; ill group: mean =0.18m,
54 s.e. = 0.3, F < 1).
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Gap acceptance

Two gap acceptance tasks were included in the road network. The first required the drivers to merge left into traffic approaching from the right, whilst the second required drivers to turn right across oncoming traffic. Gaps in the traffic increased by 1 second, with each vehicle, and the size of the gap that drivers accepted as well as a minimum time to collision to the on-coming car was calculated. There were no significant effects of cold status on gap acceptance.

Overtaking behaviour

In addition to the car following tasks detailed above, two scenarios were created to examine overtaking behaviour. Drivers encountered lead cars travelling below the posted speed limit on a straight stretch of road. There was little opposing traffic, providing the opportunity for drivers to overtake. Both overtaking attempts and successful overtakings were recorded. However it was found that these values were identical (thus once committed to an overtaking manoeuvre, drivers tended to complete it). There was no difference in overtaking behaviour between the two groups.

Car following

The road network allowed the inclusion of several car following tasks. In two of these tasks the driver was unable to overtake the car in front due to oncoming traffic. This created a “boxed-in” situation that allowed the measurement of the time headway distribution. The lead cars in these scenarios were travelling at a speed that was constant and below the speed limit. Thus in the urban situation the lead car was travelling at 25 mph, in the rural area at 40 mph. Therefore, even if speed limited, it was possible for drivers to adopt short headways if they wished to. Table 3 shows the time headway distribution for both healthy and ill drivers in an urban environment (30mph).

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3 It can be seen that those drivers who reported cold symptoms spent a larger
4 proportion of time at a shorter headway (in the safety critical area of less than
5 2 seconds).
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8 9 *Vigilance*

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11 A choice reaction task required drivers to differentially respond to randomly
12 appearing targets in the visual scene. It was hypothesised that there may be
13 differences in either response times or error rates depending on the health
14 status of the participants. Such differences may arise as a result of
15 decreases in vigilance associated with cognitive impairment. Probably due to
16 the ease of the task, a floor effect was found with regards to the error rates in
17 that drivers demonstrated a high degree of accuracy. Further analysis of the
18 response times to targets however, revealed a significant difference between
19 response times of the healthy and ill volunteers with those with a cold being
20 significantly slower (see Table 3).
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29 30 *Collision with a pedestrian*

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32 A critical event was added as an additional measure of vigilance. At a
33 pedestrian crossing a pedestrian stepped into the road and crossed in front of
34 the driver's path. This event was staged such that drivers were able, with
35 severe braking, to avoid collision with the pedestrian, if braking was initiated
36 immediately. In the first session, the healthy volunteers had no collisions
37 whereas those with a cold had 8 (chi-square = 7.06, $p < 0.01$). In the second
38 session both groups had zero collisions.
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47 These types of critical scenarios are inherently difficult to manipulate and test
48 in the simulator environment, not least due to exposure effects. It could be
49 postulated that on the second trial, participants were anticipating an event of
50 this kind to occur again and thus be cautious on approach to pedestrian
51 crossings. However, several precautions ensure this is not the case. First, the
52 location of the surprise event was different on the two driving sessions. In the
53 first session it was located at the end of the road network and in the second
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3 session it was moved to half way along the network. Secondly, as a measure
4 of anticipation, speed measures were recorded within the vicinity of the event.
5 Thus, speed was measured at 50 metres before the event (50 metres was
6 chosen as drivers could see the pedestrian but had not yet begun to brake). In
7 addition, speed was also measured at the point at which they initially began to
8 brake. There were no significant difference in these values between the first
9 and the second driving session. This indicates that drivers were not
10 anticipating the event in the second session.
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18 These results demonstrate that drivers with reported symptoms of minor
19 respiratory illnesses are impaired to the extent that they have longer response
20 times and thus negative safety effects with regards to critical events in the
21 driving environment.
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24 *Traffic light violations*

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28 A situation was created whereby drivers were forced to make a rapid stop/go
29 decision at one set of traffic lights which turned from green to amber as
30 drivers approached. In concordance with the previous results found on the
31 longer response times and reaction to surprise events, drivers who reported
32 cold symptoms violated the traffic lights twice as often as drivers who were
33 symptom free. However, due to the small number of violations this effect was
34 not significant.
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40 **Discussion**

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45 The present results confirm the earlier findings that having a cold may impair
46 aspects of simulated driving performance. There appears to be reliable
47 evidence that volunteers presenting with symptoms respond more slowly to
48 unexpected events and spent a greater percentage of time driving too close to
49 the car in front compared with healthy volunteers. As described in the
50 introduction, this decrement in driving performance could have implications for
51 road safety. The slowing of reaction times associated with having a cold is
52 comparable to effects of known hazards, such as consumption of a dose of
53 alcohol that would lead to a ban from driving (80mg alcohol/100ml blood) or
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3 having to perform at night. The OMEDA task also demonstrated that those
4 suffering from a cold were less able to detect potential collisions. Comparison
5 with a previous study¹¹ using elderly participants (over 65 years) shows that
6 the detection performance of young adults with a cold falls to that of elderly
7 drivers. There is now a need for an information campaign to provide accurate
8 information about the potential hazards associated with driving while suffering
9 from an upper respiratory tract illness.
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16 There is also evidence that the direct effects of having a cold are not the only
17 ones that need to be considered. A number of studies have shown that
18 individuals who are ill are more susceptible to the effects of other factors
19 which could influence driving (alcohol¹³; prolonged work¹⁴; and noise¹⁵).
20 Research also shows that impairments associated with the common cold are
21 not restricted to the time the person is symptomatic but may be observed in
22 the incubation period and a few days after symptoms have gone⁶.
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30 One must now ask what underlies the effects here. Previous research has
31 shown that the low alertness state associated with a cold can be reversed by
32 a drug which increases the turnover of central noradrenaline¹⁶. Indeed,
33 ingestion of caffeine, which increases alertness, has been shown to remove
34 the cold induced performance impairments seen in laboratory tasks¹⁷. This
35 suggests that a further study examining whether caffeine can remove the
36 effects found here is required. Similarly, it will be important to determine
37 whether medications aimed at producing symptomatic relief also remove the
38 behavioural problems associated with the common cold.
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47 In summary, the present study has used established methods to examine
48 effects of the common cold on simulated driving and collision detection. The
49 findings that having a cold reduces the ability to detect collisions and respond
50 quickly to unexpected events are of practical importance and can be related to
51 plausible underlying mechanisms. The study was small scale using relatively
52 inexperienced drivers and further research is required to determine whether
53 there are additional smaller effects and whether there are contexts and
54 individuals (e.g. the elderly) in which the impairments may be even greater
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3 than those seen here. Similarly, further research is required to address the
4 issue of awareness of these effects by using information campaigns and
5 prevention by using countermeasures that increase alertness.
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Table 1: Upper respiratory tract symptoms reported by colds and healthy groups on first testing session (scores are the means, s.e.s in parentheses. Significance tested by a Mann-Whitney test)

Symptom	Colds Group	Healthy Group	Significance
Pain in chest	0.93 (0.23)	0.0 (0.0)	p < 0.05
Sore Throat	1.80 (0.24)	0.2 (0.13)	p < 0.001
Headache	1.27 (0.267)	0.0 (0.0)	p < 0.005
Sneezing	1.47 (0.29)	0.10 (0.10)	p < 0.005
Runny nose	2.47 (0.19)	0.40 (0.16)	p < 0.001
Blocked nose	1.93 (0.21)	0.10 (0.10)	p < 0.001
Hoarseness	1.33 (0.30)	0.0 (0.0)	p < 0.005
Cough	2.13 (0.26)	0.20 (0.13)	p < 0.001
Feeling hot/cold	1.47 (0.24)	0.10 (0.10)	p < 0.001
Sweating	1.20 (0.31)	0.10 (0.10)	p < 0.05
Shivering	0.67 (0.21)	0.00 (0.00)	p=0.06
Fever	0.80 (0.30)	0.00 (0.00)	p=0.10
Phlegm	2.33 (0.30)	0.20 (0.13)	p < 0.001
Total URTI score	19.80 (1.96)	1.40 (0.27)	p < 0.001

Table 2. Performance of healthy and unhealthy drivers on the divided attention part of the OMEDA task.

	Healthy	Cold	Chi-square	Significance
Missed collisions	6%	5%	.122	p = 0.727
Detected collisions	27%	22%	3.67	p = 0.012
Correct misses	35%	27%	5.32	p = 0.002
False hits	31%	27%	.971	p = 0.325
Divided attention error	0.34%	1.68%	2.87	p = 0.014

Table 3. Significant effects of health status on outcomes from the driving task

a. Mean percentage of time spent at a headway of less than 2 seconds (s.e.s in parentheses)

	Healthy	Ill	
	39.2%	51.7	F = 4.80,
	(5.4)	(4.3)	p < 0.05

b. Mean response times (seconds) in choice reaction task (s.e.s in parentheses)

	Healthy	Ill	
Target 1	1.01	1.33	F= 4.35,
	(0.10)	(0.11)	p < 0.05
Target 2	0.95	1.21	F = 6.09,
	(0.0.6)	(0.06)	p < 0.05

Contributors

APS wrote the research proposal, designed the study, wrote the statistical analysis plan, analysed the data and drafted and revised the paper. He is guarantor.

SJ implemented the study, analysed the data and revised the paper.

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Disclosure

"All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: all authors had financial support from the ESRC ROPA Scheme (grant R022250188) for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities that could appear to have influenced the submitted work".

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7 **An investigation of the effects of the common cold on simulated driving**
8 **performance and detection of collisions: A laboratory study**
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12 Andrew P. Smith *professor of psychology*¹, Samantha L. Jamson *principal*
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Abstract

Objective ~~The aim of the present research was to investigate whether individuals with a common cold showed impaired ability on a simulated driving task and the ability to detect potential collisions between moving objects.~~
The aim of the present research was to investigate whether individuals with a common cold showed impaired ability on a simulated driving task and the ability to detect potential collisions between moving objects.

Design The study involved comparison of a healthy group with a group with colds. These scores were adjusted for individual differences by collecting further data when both groups were healthy and using these scores as covariates. On both occasions volunteers rated their symptoms and, carried out a ~~laboratory task measuring collision detection and also a~~ simulated driving session. On the first occasion volunteers also carried out a collision detection task.

Setting University of Leeds Institute for Transport Studies

Sample Twenty five students from the University of Leeds. 10 volunteers were healthy on both occasions and 15 had a cold on the first session and were healthy on the second.

Main outcome measures In the collision detection task the main outcomes were correct detections and response to a secondary identification task. In the simulated driving task the outcomes were: speed; lateral control; gap acceptance; overtaking behaviour; car following; vigilance and traffic light violations.

Results Those with a cold detected fewer collisions and had a higher divided attention error than those who were healthy. Many basic driving skills were unimpaired by the illness. However, those with a cold were slower at responding to unexpected events and ~~drove closer to the car in front.~~ spent a greater percentage of time driving at a headway of less than 2 seconds.

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6 **Conclusions** The finding that having a common cold reduces the ability to
7 detect collisions and respond quickly to unexpected events is of practical
8 importance. Further research is now required to examine the efficacy of
9 information campaigns and countermeasures such as caffeine.
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For peer review only

Introduction

Studies of simulated driving have played a major role in transport policy and practice. One of the early studies¹, published in the British Medical Journal, demonstrated an increase in driving error following ingestion of alcohol. Changes in state due to drugs like alcohol can be countered by appropriate legislation. Other factors, such as driver fatigue, are more difficult to legislate against – there's no breathalyser for fatigue! In the case of professional drivers some causes of fatigue, such as time spent driving, can be controlled. This is more difficult when one considers driving outside of work or when one has to deal with fatigue produced by other factors (low levels of circadian alertness). In these situations, information campaigns² have to be used to prevent and manage driver fatigue, although legislation relating to being in a fit state to drive could be applied. The aim of the present research was to investigate whether individuals with a common cold showed impaired ability on a simulated driving task and the ability to detect potential collisions between moving objects.

Minor illnesses such as the common cold produce a state of reduced alertness which is associated with impaired psychomotor function and cognitive abilities^{3, 4, 5, 6}. These impairments manifest themselves as slower reaction times to unexpected events and a reduced ability to sustain attention. These are important skills involved in driving and one might, therefore, expect that individuals with such illnesses will be involved in more ~~road traffic accidents~~ crashes. Anecdotal evidence, largely consisting of case reports, suggests that this is the case⁷. This has been confirmed in a survey⁸ and extrapolation of this to the whole driving population suggests that 125,000 people in the UK have a ~~road traffic accident~~ crash while suffering from a cold or influenza. Results from a driving hazard perception task⁸ confirmed laboratory findings that reaction times are 10% slower when the person has a cold. Again, if one applies this to a real-life driving situation it would mean that it would add 1m (3.3ft) to stopping distance if travelling at 30mph (48km/h) -

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6 on top of a normal distance of 12m (40ft) and it would add 2.3m (7.5ft) onto
7 the normal stopping distance of 96m (315ft) if travelling at 70mph (113km/h).
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10 Research using a simple driving simulator⁹ (resembling a computer game)
11 has shown thate people with an upper respiratory tract illness responded
12 more slowly to unexpected events and were more likely to steer inaccurately.
13 Another study¹⁰ using a very realistic driving simulator found that basic driving
14 skills were not impaired but that situational awareness was reduced when the
15 person had a cold. The present study continued to examine this topic in detail,
16 using a sophisticated simulation that incorporates the skills necessary for safe
17 driving. In addition, the study also included a laboratory task which evaluated
18 participants' ability to detect potential collisions¹¹ which is a key skill in driving
19 but also something that cannot be repeatedly examined in a simulator.
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26 **Method**

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28 The study was carried out with the approval of the ethics committee, School of
29 Psychology, Cardiff University, and the informed consent of the volunteers.
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33 *Experimental design*

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35 A mixed design was employed whereby two groups of participants (Sample 1
36 and Sample 2) were tested on two occasions (Session 1 and Session 2).
37 Those participants in Sample 1 were healthy on both occasions, whilst those
38 in Sample 2 reported symptoms of minor respiratory illnesses in Session 1,
39 but were symptom free in Session 2. Participants carried out the driving
40 simulation task on both occasions but only carried out the collision detection
41 task on the first session.
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49 *Procedure*

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51 Volunteers were students from the University of Leeds recruited by posting
52 advertisements in the Student Medical Practice and by placing posters in the
53 School of Psychology. On arrival at the first session, they were asked to read
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6 the experimental procedure and sign the consent form if they agreed to take
7 part. They then completed a symptom checklist, a self report questionnaire
8 designed to evaluate the severity of their symptoms using a 5 point rating
9 scale (0=not all to 4= very severe). If volunteers scored above 8 on symptoms
10 typical of a cold (pain in chest, sore throat, headache, sneezing, runny nose,
11 blocked nose, hoarseness, cough, hot/cold, sweating, shivering, fever, and
12 phlegm) they were included in the cold group. Healthy volunteers were only
13 included if they had a symptom score of 3 or less (based on the upper
14 respiratory tract symptoms and other symptoms of minor illnesses such as
15 digestive problems).~~They were excluded if they scored 3 or more on~~
16 ~~symptoms not associated with a cold.~~Volunteers were excluded if they were
17 taking medication for their colds. All volunteers were tested when their illness
18 had been present for at least 24 hours and no longer than 96 hours.
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27 The laboratory task was then completed, followed by a familiarisation period
28 on the driving simulator. Volunteers were asked to drive as naturally as
29 possible through the road network. The secondary (choice reaction) task was
30 also explained to them. On completion of the drive, volunteers were asked to
31 contact the experimenter after seven symptom free days in order to confirm a
32 second session. Those who were healthy at session 1 returned for their
33 second session approximately a week later. When they returned for this
34 session, they completed the same symptom checklist and driving simulator
35 task. After completion, they were debriefed, and their expenses paid.
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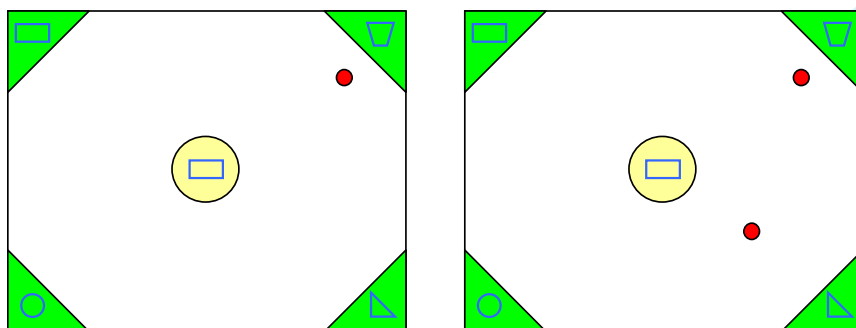
41 *OMEDA (Object Movement Estimation under Divided Attention)*

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43 OMEDA¹¹ is a computerised dual-task with two parts. Part 1 of OMEDA
44 allows experimenters to obtain an individual's error in Time-To-Collision (TTC)
45 estimation. Different target speeds can be simulated, as can various degrees
46 of occlusion. A secondary task is also incorporated in the form of a visual
47 divided attention task. This requires the identification of peripheral duplication
48 of stimuli presented centrally (in this case geometrical shapes).
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6 Part 2 of OMEDA provides a quantified estimate of collision detection error
7 under various degrees of occlusion and for a series of target speeds, with the
8 same secondary task as for Part 1. Participants do not need to be computer
9 literate in order to be able to do this task, as the response keys are a foot
10 pedal (for the primary task) and a hand button (for the secondary task).
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15 In Part 1 the participant is presented with a computer screen where the
16 corners are covered by green triangles and in the centre of the screen is a
17 yellow circle. The yellow circle varies in size between two and 250 pixels.
18 From one of the four corners (randomly allocated), a red target, in the form
19 of a circle travels towards the middle of the screen. Once it reaches the edge
20 of the yellow circle, it travels underneath it and it is not visible. Therefore,
21 the larger the circle, the more difficult is the task, due to a longer occlusion
22 time. The participant is asked to estimate exactly when the target reaches the
23 middle of the computer screen. They are instructed to press a foot pedal at
24 the exact point the target reaches the middle.
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31 In order to simulate divided attention, whilst participants are estimating
32 when the target reaches the middle of the screen, they are required to
33 complete a pattern matching task. When the target is moving, five shapes
34 appear on the screen (one overlaid on the yellow circle and one in each of the
35 four corners). Participants are instructed to press a hand button immediately if
36 the shape in the middle matches any of those in the four corners of the
37 screen.
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Part 1

Part 2

Figure 1: OMEDA computer screen

Data collected are target speed, size of the occlusion circle, time under the occlusion circle, actual time to contact (TTC), estimated TTC and TTC error, errors in shape detection.

In Part 2, the participants are presented with the same screen as in Part 1. However, the primary task now involves two targets moving towards the centre of the screen, emerging at different times and travelling at different speeds. The targets reach the centre of the screen either at the same time (a hit), almost at the same time (a near miss) or at a noticeable time difference (a miss). The participant is required to press the foot pedal only if and when the targets reach the centre of the screen at the same time (i.e. only for hits). The secondary task is the same as for Part 1. The data collected includes the error in estimating TTC and the error in shape estimation, under different occlusions and target speeds

Driving Simulator

The experiments were carried out on a fixed based driving simulator at the University of Leeds presenting a 120° forward view and 50° rear view. The system features a fully interactive Silicon Graphics (Onyx RE²) driving simulator with a six degree of freedom vehicle model. A servo motor linked to the steering mechanism provides control over handling torque and speed and digitised samples of engine, wind, road noise and other vehicles are provided. Photo-realistic scene texturing allows presentation of various road types and features.

Studies¹² have evaluated the behavioural validity of the simulator. The results showed that overall there was a broad correspondence between driving in the

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6 simulator and the behaviour of real-world traffic. With regard to speed, the
7 effects of road width, curvature, direction of curve and sequence between
8 road sections were reproduced on the simulator, and there were very high
9 correlations between speed along the real road and speeds in the simulator.
10 Prior to the experimental drive, participants completed a fifteen minute
11 familiarisation drive. The drive comprised urban, rural and motorway sections,
12 similar to the experimental drive, but contained none of the scenarios under
13 investigation. Once the familiarisation drive was completed, drivers were
14 deemed ready to proceed to the next stage. The experimental route was
15 approximately 22 miles in length and comprised of urban, rural and motorway
16 environments, providing a range of speed limits between 30 and 70 mph.
17 Other cars in the scenario provided the opportunity of simulating overtaking
18 scenarios, gap acceptance tasks and car-following situations. The road
19 environment also featured traffic lights and pelican crossings in order to
20 instigate possible violation scenarios; and sub-standard curves were included
21 in both the urban and rural sections.

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31 Speed measurements were taken every 10 metres throughout the whole
32 journey. In addition, indices of safety critical behaviour such as minimum time
33 to collision in following tasks and the incidence of overtaking manoeuvres
34 were recorded. Traffic light violations, speed violations and curve negotiation
35 behaviour were also noted.

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40 Three car following situations were engineered requiring drivers to maintain
41 their desired headway over a section of road. They were unable to pass the
42 slow moving car in front due to oncoming traffic. These situations allowed
43 measurement of minimum time to collision and variation in headway. In
44 addition, two overtaking scenarios were created: here oncoming traffic was
45 present, but it had sufficient gaps to allow the driver to pass. Propensity to
46 overtake and proximity to the oncoming car were measured. An additional
47 overtaking scenario was created, again using a slow moving vehicle in front.
48 Here drivers were constrained by double white lines; if they chose to overtake,
49 a violation was recorded.
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6 Four sets of traffic lights were placed in the road network. One was
7 programmed to change from green to red as the driver approached. This
8 required the driver to make a stop/go decision, and a violation was recorded if
9 the driver passed through on the red light. Two gap acceptance tasks were
10 incorporated into the road network. The first required the driver to merge from
11 the minor road onto the major road, making a left turn. Traffic on the major
12 road was approaching from the right with varying gaps. The second required
13 the driver to make a right turn across oncoming traffic from a major to a minor
14 road. Again the cars were separated with varying gaps.
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21 Attention to surprise events was measured in terms of performance on a
22 choice reaction task incorporated into the road network. Drivers were
23 required to respond to red and green squares that appeared in front of them.
24 If the square was green, they were asked to ignore it and continue driving. If
25 the square was red, they were asked to continue driving, and to flash the
26 headlights once, in response. Throughout the whole drive there appeared
27 three red and three green squares in a random sequence. In subsequent
28 drives the positioning of the squares was changed, in order to prevent
29 associative learning effects. Their response to the stimuli was recorded in
30 terms of reaction time, false/correct hits and missing responses.
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36 *Participants*

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38 Previous research suggests that the effects of the common cold on
39 behavioural measures are large. A sample size calculation suggested that
40 204 participants should be tested (minimum group size=9). Twenty five
41 participants were recruited for this study. Ten were assigned to Sample 1 and
42 15 to Sample 2. All participants had a full driving licence and had been driving
43 for less than 5 years. and Aa roughly equal number proportion of males and
44 females were recruited and all. All volunteers were paid for their participation.
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	Sample 1 (<i>Healthy</i>)	Sample 2 (<i>Colds</i>)
Males/females	4/6	10/5
Mean age (males)	20 years (<i>range: 18-21</i>)	20 years (<i>range: 18-25</i>)
Mean age (females)	22 years (<i>range: 20-24</i>)	21 years (<i>range: 19-24</i>)

Results

Symptom checklist

The symptom checklist showed significant differences in self-reported health. In the first test session, volunteers with a cold scored on average 19.8 (out of a maximum of 52), whilst on their return, this average score fell to 2, which was similar to the scores for those who were healthy on both occasions. Symptom scores for all of the upper respiratory tract symptom scales are shown in Table 1. All of the individual symptoms showed significant differences between the groups except for fever and shivering. This suggests that the participants had colds rather than influenza.

OMEDA

Performance data on both parts of the OMEDA task are presented. Part 1 of the task provides indication of accuracy in terms of time-to-collision estimates of a moving target. Absolute error (in seconds) was computed for both the healthy and unhealthy groups. Performance on the secondary task was also recorded, using the number of errors made in identifying the presence of a matching shape in the periphery of the screen. Part 2 of OMEDA provides data relating to the ability to detect a collision between two moving targets.

The results are shown in Table 24.

In Part 1, there were no significant differences between the groups. This is likely due to a ceiling effect, whereby the volunteers found the task easy to complete. Overall, they were able to estimate accurately the TTC, with 50% of

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6 the total sample estimating to within 0.3 seconds of the actual TTC (Absolute
7 error of TTC: Healthy group: 0.40; Ill group: 0.44). In addition, they found the
8 primary task easy enough to be able to perform well on the secondary task,
9 with only a total of four identification errors across the whole sample (Shape
10 identification error: Healthy group: 0.01; Ill group: 0.03). However, when the
11 task became more difficult in Part 2 of the OMEDA, performance decrements
12 were found for those with colds. Healthy individuals were more likely to
13 identify correctly both collisions and non-collisions. Those with colds appear
14 to be impaired to the extent that they were less likely to be able to identify if
15 the moving targets would or would not collide under various degrees of
16 occlusion. Performance on the secondary task was also degraded, such that
17 those who were suffering from a cold made more errors in identifying the
18 matching shape in the periphery of the screen.
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25 *Driving performance*

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28 In order to control for individual differences in driving ability, analyses of co-
29 variance, with the session 2 data as covariates, were carried out on the
30 driving data. Preliminary analyses showed that the two groups were not
31 significantly different at session 2 (when both groups were healthy).
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35 *Speed*

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37 For the purpose of data analysis, the experimental road network was divided
38 into sections according to speed limit. Of these sections, where the driver
39 was in free flowing conditions (i.e. not engaged in a car following task) ~~mean~~
40 ~~speed and~~ standard deviation of speed across the section was derived.
41 Analyses of covariance showed no effect of having a cold on standard of
42 speed (Healthy group: mean=4.76 m/s, s.e.= 0.36; Ill group: mean=4.82 m/s,
43 s.e.= 0.30, F <1).
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49 *Lateral control*

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51 Edgeline/centre line encroachments were not significantly altered as a
52 function of health status nor was the standard deviation of lane position (s.d.
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lane position: healthy group: mean=0.19 m, s.e. 0.3; ill group: mean =0.18m, s.e. = 0.3, $F < 1$).

Gap acceptance

Two gap acceptance tasks were included in the road network. The first required the drivers to merge left into traffic approaching from the right, whilst the second required drivers to turn right across oncoming traffic. Gaps in the traffic increased by 1 second, with each vehicle, and the size of the gap that drivers accepted as well as a minimum time to collision to the on-coming car was calculated. There were no significant effects of cold status on gap acceptance.

Overtaking behaviour

In addition to the car following tasks detailed above, two scenarios were created to examine overtaking behaviour. Drivers encountered lead cars travelling below the posted speed limit on a straight stretch of road. There was little opposing traffic, providing the opportunity for drivers to overtake. Both overtaking attempts and successful overtakings were recorded. However it was found that these values were identical (thus once committed to an overtaking manoeuvre, drivers tended to complete it). There was no difference in overtaking behaviour between the two groupsessions.

Car following

The road network allowed the inclusion of several car following tasks. In two of these tasks the driver was unable to overtake the car in front due to oncoming traffic. This created a "boxed-in" situation that allowed the measurement of the time headway distribution. The lead cars in these scenarios were travelling at a speed that was constant and below the speed limit. Thus in the urban situation the lead car was travelling at 25 mph, in the rural area at 40 mph. Therefore, even if speed limited, it was possible for drivers to adopt short headways if they wished to. Table 32 shows the time headway distribution for both healthy and ill drivers in an urban environment (30mph).

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It can be seen that those drivers who reported cold symptoms ~~were more likely to spend~~ a larger proportion of time at a shorter headway (in the safety critical area of less than 2 seconds).

Vigilance

A choice reaction task required drivers to differentially respond to randomly appearing targets in the visual scene. It was hypothesised that there may be differences in either response times or error rates depending on the health status of the participants. Such differences may arise as a result of decreases in vigilance associated with cognitive impairment. Probably due to the ease of the task, a floor effect was found with regards to the error rates in that drivers demonstrated a high degree of accuracy. Further analysis of the response times to targets however, revealed a significant difference between response times of the healthy and ill volunteers with those with a cold being significantly slower (see Table [32](#)).

Collision with a pedestrian

A critical event was added as an additional measure of vigilance. At a pedestrian crossing a pedestrian stepped into the road and crossed in front of the driver's path. This event was staged such that drivers were able, with severe braking, to avoid collision with the pedestrian, if braking was initiated immediately. In the first session, the healthy volunteers had no collisions whereas those with a cold had 8 (chi-square = 7.06, p < 0.01). In the second session both groups had zero collisions.

These types of critical scenarios are inherently difficult to manipulate and test in the simulator environment, not least due to exposure effects. It could be postulated that on the second trial, participants were anticipating an event of this kind to occur again and thus be cautious on approach to pedestrian crossings. However, several precautions ensure this is not the case. First, the location of the surprise event was different on the two driving sessions. In the

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6 first session it was located at the end of the road network and in the second
7 session it was moved to half way along the network. Secondly, as a measure
8 of anticipation, speed measures were recorded within the vicinity of the event.
9 Thus, speed was measured at 50 metres before the event (50 metres was
10 chosen as drivers could see the pedestrian but had not yet begun to brake). In
11 addition, speed was also measured at the point at which they initially began to
12 brake. There were no significant difference in these values between the first
13 and the second driving session. This indicates that drivers were not
14 anticipating the event in the second session.
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21 These results demonstrate that drivers with reported symptoms of minor
22 respiratory illnesses are impaired to the extent that they have longer response
23 times and thus negative safety effects with regards to critical events in the
24 driving environment.
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27 *Traffic light violations*

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29 A situation was created whereby drivers were forced to make a rapid stop/go
30 decision at one set of traffic lights which turned from green to amber as
31 drivers approached. In concordance with the previous results found on the
32 longer response times and reaction to surprise events, drivers who reported
33 cold symptoms violated the traffic lights twice as often as drivers who
34 when they were symptom free. However, due to the small number of violations this
35 effect was not significant. (see Table 2).
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41 **Discussion**

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43 The present results confirm the earlier findings that having a cold may impair
44 aspects of simulated driving performance. There appears to be reliable
45 evidence that volunteers presenting with symptoms respond more slowly to
46 unexpected events and spent a greater percentage of time driving too close to
47 the car in front compared with healthy volunteers drive too closely to the car in
48 front. As described in the introduction, this decrement in driving performance
49 could have implications for road safety. The slowing of reaction times
50 associated with having a cold is comparable to effects of known hazards,
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6 such as consumption of a dose of alcohol that would lead to a ban from
7 driving ([80mg alcohol/100ml blood](#)) or having to perform at night. The OMEDA
8 task also demonstrated that those suffering from a cold were less able to
9 detect potential collisions. Comparison with a previous study¹¹ using elderly
10 participants (over 65 years) shows that the detection performance of young
11 adults with a cold falls to that of elderly drivers. There is now a need for an
12 information campaign to provide accurate information about the potential
13 hazards associated with driving while suffering from an upper respiratory tract
14 illness.
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21 There is also evidence that the direct effects of having a cold are not the only
22 ones that need to be considered. A number of studies have shown that
23 individuals who are ill are more susceptible to the effects of other factors
24 which could influence driving (alcohol¹³; prolonged work¹⁴; and noise¹⁵).
25 Research also shows that impairments associated with the common cold are
26 not restricted to the time the person is symptomatic but may be observed in
27 the incubation period and [a few days](#) after symptoms have gone⁶.
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33 One must now ask what underlies the effects here. Previous research has
34 shown that the low alertness state associated with a cold can be reversed by
35 a drug which increases the turnover of central noradrenaline¹⁶. Indeed,
36 ingestion of caffeine, which increases alertness, has been shown to remove
37 the cold induced performance impairments seen in laboratory tasks¹⁷. This
38 suggests that a further study examining whether caffeine can remove the
39 effects found here is required. Similarly, it will be important to determine
40 whether medications aimed at producing symptomatic relief also remove the
41 behavioural problems associated with the common cold.
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48 In summary, the present study has used established methods to examine
49 effects of the common cold on simulated driving and collision detection. The
50 findings that having a cold reduces the ability to detect collisions and respond
51 quickly to unexpected events are of practical importance and can be related to
52 plausible underlying mechanisms. The study was small scale [using relatively](#)
53 [inexperienced drivers](#) and further research is required to determine whether
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there are additional smaller effects and whether there are contexts and individuals (e.g. the elderly) in which the impairments may be even greater than those seen here. Similarly, further research is required to address the issue of ~~prevention awareness~~ of these effects, ~~both~~ by using information campaigns and ~~prevention by using of~~ countermeasures ~~such as caffeine that increase alertness~~.

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Table 1: Upper respiratory tract symptoms reported by colds and healthy groups on first testing session (scores are the means, s.e.s in parentheses. Significance tested by a Mann-Whitney test)

Symptom	Colds Group	Healthy Group	Significance
Pain in chest	0.93 (0.23)	0.0 (0.0)	p < 0.0542
Sore Throat	1.80 (0.24)	0.2 (0.13)	p < 0.001
Headache	1.27 (0.267)	0.0 (0.0)	p < 0.005
Sneezing	1.47 (0.29)	0.10 (0.10)	p < 0.005
Runny nose	2.47 (0.19)	0.40 (0.16)	p < 0.001
Blocked nose	1.93 (0.21)	0.10 (0.10)	p < 0.001
Hoarseness	1.33 (0.30)	0.0 (0.0)	p < 0.005
Cough	2.13 (0.26)	0.20 (0.13)	p < 0.001
Feeling hot/cold	1.47 (0.24)	0.10 (0.10)	p < 0.001
Sweating	1.20 (0.31)	0.10 (0.10)	p < 0.05
Shivering	0.67 (0.21)	0.00 (0.00)	p=0.06
Fever	0.80 (0.30)	0.00 (0.00)	p=0.10
Phlegm	2.33 (0.30)	0.20 (0.13)	p < 0.001
Total URTI score	19.80 (1.96)	1.40 (0.27)	p < 0.001

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Table 42. Performance of healthy and unhealthy drivers on the divided attention part of the OMEDA task.

a. Part 1

	Mean		Significance
	Healthy	III	
Absolute error of TTC	0.40	0.44	p>0.05
Shape identification error	0.04	0.03	p>0.05

b. Part 2

	Healthy	III	Significance
Missed collisions	8%	40%	p>0.05
Detected collisions	45%	37%	p<0.05
Correct misses	29%	22%	p<0.001
False hits	22%	26%	p=0.06
Divided attention error	0.46%	1.38%	p<0.001

	Healthy	Cold	Chi-square	Significance
Missed collisions	6%	5%	.122	p = 0.727
Detected collisions	27%	22%	3.67	p = 0.012
Correct misses	35%	27%	5.32	p = 0.002
False hits	31%	27%	.971	p = 0.325
Divided attention error	0.34%	1.68%	2.87	p = 0.014

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Table 32. Significant effects of health status on outcomes from the driving task

a. Mean pPercentage of time spent at a headway of less than 2 seconds (s.e.s in parentheses)

	Healthy	III	
	39.2%	51.7	<u>F = 4.80,</u>
	<u>(5.4)</u>	<u>(4.3)</u>	p < 0.05

b. Mean response times (seconds) in choice reaction task (s.e.s in parentheses)

	Healthy	III	
Target 1	1.01	1.33	<u>F = 4.35,</u>
	<u>(0.10)</u>	<u>(0.11)</u>	p < 0.05p
			<0.05
Target 2	0.95	1.21	<u>F = 6.09,</u>
	<u>(0.0.6)</u>	<u>(0.06)</u>	p < 0.05p<
			0.03

c. Number of collisions with a pedestrian

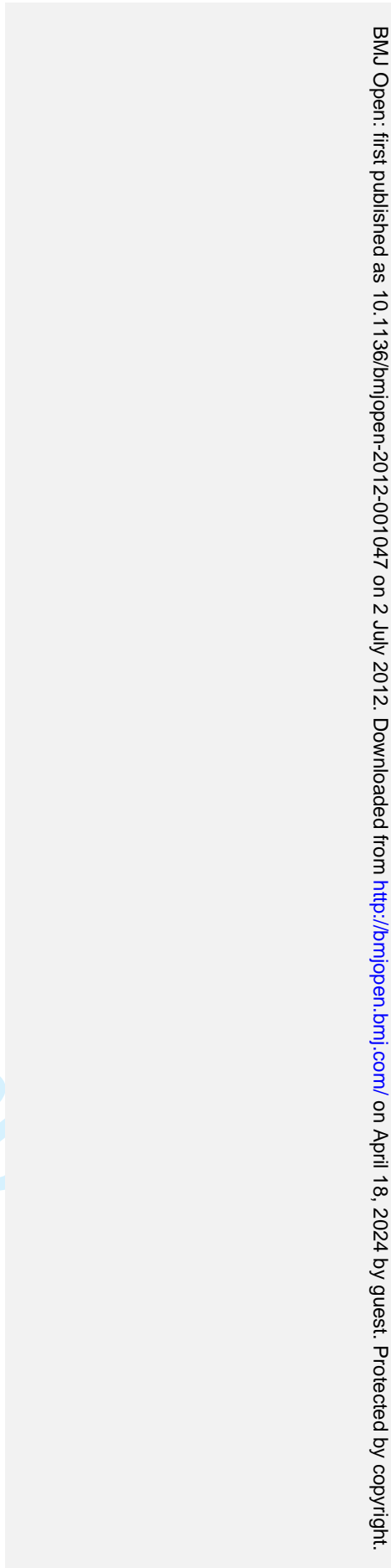
	Healthy	III	
	0	8	p < 0.05

a. Mean number of traffic light violations

	Healthy	III	
	0.2	0.43	p < 0.05

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Contributors

APS wrote the research proposal, designed the study, wrote the statistical analysis plan, analysed the data and drafted and revised the paper. He is guarantor.

SJ implemented the study, analysed the data and revised the paper.

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Disclosure

"All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: all authors had financial support from the ESRC ROPA Scheme (grant R022250188) for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities that could appear to have influenced the submitted work".



An investigation of the effects of the common cold on simulated driving performance and detection of collisions: A laboratory study

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2012-001047.R2
Article Type:	Research
Date Submitted by the Author:	24-May-2012
Complete List of Authors:	Smith, Andrew; Cardiff University, School of Psychology Jamson, Samantha
Primary Subject Heading:	Infectious diseases
Secondary Subject Heading:	Public health, Infectious diseases, Occupational and environmental medicine, Respiratory medicine
Keywords:	Public health < INFECTIOUS DISEASES, Respiratory infections < THORACIC MEDICINE, RESPIRATORY MEDICINE (see Thoracic Medicine)

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4 **An investigation of the effects of the common cold on simulated driving**
5 **performance and detection of collisions: A laboratory study**
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Abstract

Objective The aim of the present research was to investigate whether individuals with a common cold showed impaired ability on a simulated driving task and the ability to detect potential collisions between moving objects.

Design The study involved comparison of a healthy group with a group with colds. These scores were adjusted for individual differences by collecting further data when both groups were healthy and using these scores as covariates. On both occasions volunteers rated their symptoms and carried out a simulated driving session. On the first occasion volunteers also carried out a collision detection task.

Setting University of Leeds Institute for Transport Studies

Sample Twenty five students from the University of Leeds. 10 volunteers were healthy on both occasions and 15 had a cold on the first session and were healthy on the second.

Main outcome measures In the collision detection task the main outcomes were correct detections and response to a secondary identification task. In the simulated driving task the outcomes were: speed; lateral control; gap acceptance; overtaking behaviour; car following; vigilance and traffic light violations.

Results Those with a cold detected fewer collisions and had a higher divided attention error than those who were healthy. Many basic driving skills were unimpaired by the illness. However, those with a cold were slower at responding to unexpected events and spent a greater percentage of time driving at a headway of less than 2 seconds.

Conclusions The finding that having a common cold is associated with reduced ability to detect collisions and respond quickly to unexpected events is of practical importance. Further research is now required to examine the efficacy of information campaigns and countermeasures such as caffeine.

Introduction

Studies of simulated driving have played a major role in transport policy and practice. One of the early studies¹, published in the British Medical Journal, demonstrated an increase in driving error following ingestion of alcohol. Changes in state due to drugs like alcohol can be countered by appropriate legislation. Other factors, such as driver fatigue, are more difficult to legislate against – there's no breathalyser for fatigue! In the case of professional drivers some causes of fatigue, such as time spent driving, can be controlled. This is more difficult when one considers driving outside of work or when one has to deal with fatigue produced by other factors (low levels of circadian alertness). In these situations, information campaigns² have to be used to prevent and manage driver fatigue, although legislation relating to being in a fit state to drive could be applied. The aim of the present research was to investigate whether individuals with a common cold showed impaired ability on a simulated driving task and the ability to detect potential collisions between moving objects.

Minor illnesses such as the common cold produce a state of reduced alertness which is associated with impaired psychomotor function and cognitive abilities^{3, 4, 5, 6}. These impairments manifest themselves as slower reaction times to unexpected events and a reduced ability to sustain attention. These are important skills involved in driving and one might, therefore, expect that individuals with such illnesses will be involved in more crashes. Anecdotal evidence, largely consisting of case reports, suggests that this is the case⁷. This has been confirmed in a survey⁸ and extrapolation of this to the whole driving population suggests that 125,000 people in the UK have a crash while suffering from a cold or influenza. Results from a driving hazard perception task⁸ confirmed laboratory findings that reaction times are 10% slower when the person has a cold. Again, if one applies this to a real-life driving situation it would mean that it would add 1m (3.3ft) to stopping distance if travelling at 30mph (48km/h) - on top of a normal distance of 12m (40ft) and it would add

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3 2.3m (7.5ft) onto the normal stopping distance of 96m (315ft) if travelling at
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5 70mph (113km/h).
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8 Research using a simple driving simulator⁹ (resembling a computer game)
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10 has shown that people with an upper respiratory tract illness responded more
11 slowly to unexpected events and were more likely to steer inaccurately.
12 Another study¹⁰ using a very realistic driving simulator found that basic driving
13 skills were not impaired but that situational awareness was reduced when the
14 person had a cold. The present study continued to examine this topic in detail,
15 using a sophisticated simulation that incorporates the skills necessary for safe
16 driving. In addition, the study also included a laboratory task which evaluated
17 participants' ability to detect potential collisions¹¹ which is a key skill in driving
18 but also something that cannot be repeatedly examined in a simulator.
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26 **Method**

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29 The study was carried out with the approval of the ethics committee, School of
30 Psychology, Cardiff University, and the informed consent of the volunteers.
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33 *Experimental design*

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38 A mixed design was employed whereby two groups of participants (Sample 1
39 and Sample 2) were tested on two occasions (Session 1 and Session 2).
40 Those participants in Sample 1 were healthy on both occasions, whilst those
41 in Sample 2 reported symptoms of minor respiratory illnesses in Session 1,
42 but were symptom free in Session 2. Participants carried out the driving
43 simulation task on both occasions but only carried out the collision detection
44 task on the first session.
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50 *Procedure*

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Volunteers were students from the University of Leeds recruited by posting
advertisements in the Student Medical Practice and by placing posters in the
School of Psychology. On arrival at the first session, they were asked to read

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3 the experimental procedure and sign the consent form if they agreed to take
4 part. They then completed a symptom checklist, a self report questionnaire
5 designed to evaluate the severity of their symptoms using a 5 point rating
6 scale (0=not all to 4= very severe). If volunteers scored above 8 on symptoms
7 typical of a cold (pain in chest, sore throat, headache, sneezing, runny nose,
8 blocked nose, hoarseness, cough, hot/cold, sweating, shivering, fever, and
9 phlegm) they were included in the cold group. Healthy volunteers were only
10 included if they had a symptom score of 3 or less (based on the upper
11 respiratory tract symptoms and other symptoms of minor illnesses such as
12 digestive problems). Volunteers were excluded if they were taking medication
13 for their colds. All volunteers were tested when their illness had been present
14 for at least 24 hours and no longer than 96 hours.
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24 The laboratory task was then completed, followed by a familiarisation period
25 on the driving simulator. Volunteers were asked to drive as naturally as
26 possible through the road network. The secondary (choice reaction) task was
27 also explained to them. On completion of the drive, volunteers were asked to
28 contact the experimenter after seven symptom free days in order to confirm a
29 second session. Those who were healthy at session 1 returned for their
30 second session approximately a week later. When they returned for this
31 session, they completed the same symptom checklist and driving simulator
32 task. After completion, they were debriefed, and their expenses paid.
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41 *OMEDA (Object Movement Estimation under Divided Attention)*

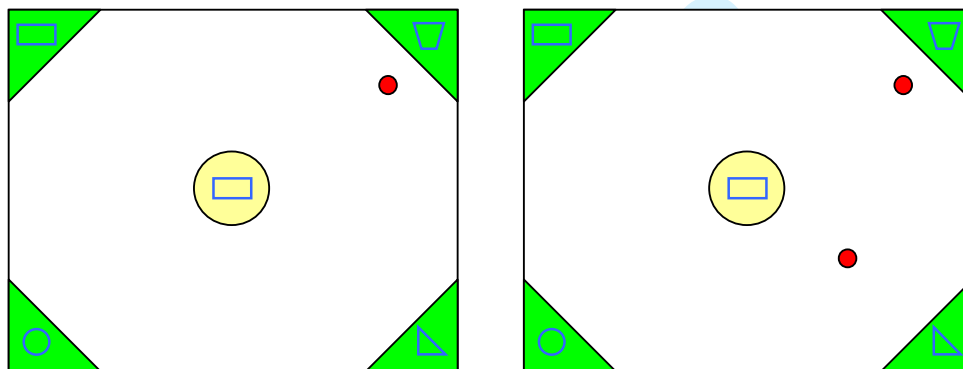
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43 OMEDA¹¹ is a computerised dual-task with two parts. Part 1 of OMEDA
44 allows experimenters to obtain an individual's error in Time-To-Collision (TTC)
45 estimation. Different target speeds can be simulated, as can various degrees
46 of occlusion. A secondary task is also incorporated in the form of a visual
47 divided attention task. This requires the identification of peripheral duplication
48 of stimuli presented centrally (in this case geometrical shapes).
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55 Part 2 of OMEDA provides a quantified estimate of collision detection error
56 under various degrees of occlusion and for a series of target speeds, with the
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3 same secondary task as for Part 1. Participants do not need to be computer
4 literate in order to be able to do this task, as the response keys are a foot
5 pedal (for the primary task) and a hand button (for the secondary task).
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10 In Part 1 the participant is presented with a computer screen where the
11 corners are covered by green triangles and in the centre of the screen is a
12 yellow circle. The yellow circle varies in size between two and 250 pixels.
13 From one of the four corners (randomly allocated), a red target, in the form
14 of a circle travels towards the middle of the screen. Once it reaches the edge
15 of the yellow circle, it travels underneath it and it is not visible. Therefore,
16 the larger the circle, the more difficult is the task, due to a longer occlusion
17 time. The participant is asked to estimate exactly when the target reaches the
18 middle of the computer screen. They are instructed to press a foot pedal at
19 the exact point the target reaches the middle.
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28 In order to simulate divided attention, whilst participants are estimating when
29 the target reaches the middle of the screen, they are required to complete a
30 pattern matching task. When the target is moving, five shapes appear on the
31 screen (one overlaid on the yellow circle and one in each of the four corners).
32 Participants are instructed to press a hand button immediately if the shape in
33 the middle matches any of those in the four corners of the screen.
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Part 1

Part 2

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6 Figure 1: OMEDA computer screen
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8 Data collected are target speed, size of the occlusion circle, time under the
9 occlusion circle, actual time to contact (TTC), estimated TTC and TTC error,
10 errors in shape detection.
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14 In Part 2, the participants are presented with the same screen as in Part 1.
15 However, the primary task now involves two targets moving towards the
16 centre of the screen, emerging at different times and travelling at different
17 speeds. The targets reach the centre of the screen either at the same time (a
18 hit), almost at the same time (a near miss) or at a noticeable time difference
19 (a miss). The participant is required to press the foot pedal only if and when
20 the targets reach the centre of the screen at the same time (i.e. only for hits).
21 The secondary task is the same as for Part 1. The data collected includes the
22 error in estimating TTC and the error in shape estimation, under different
23 occlusions and target speeds
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32 *Driving Simulator*
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35 The experiments were carried out on a fixed based driving simulator at the
36 University of Leeds presenting a 120° forward view and 50° rear view. The
37 system features a fully interactive Silicon Graphics (Onyx RE²) driving
38 simulator with a six degree of freedom vehicle model. A servo motor linked to
39 the steering mechanism provides control over handling torque and speed and
40 digitised samples of engine, wind, road noise and other vehicles are provided.
41 Photo-realistic scene texturing allows presentation of various road types and
42 features.
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49 Studies¹² have evaluated the behavioural validity of the simulator. The results
50 showed that overall there was a broad correspondence between driving in the
51 simulator and the behaviour of real-world traffic. With regard to speed, the
52 effects of road width, curvature, direction of curve and sequence between
53 road sections were reproduced on the simulator, and there were very high
54 correlations between speed along the real road and speeds in the simulator.
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3 Prior to the experimental drive, participants completed a fifteen minute
4 familiarisation drive. The drive comprised urban, rural and motorway sections,
5 similar to the experimental drive, but contained none of the scenarios under
6 investigation. Once the familiarisation drive was completed, drivers were
7 deemed ready to proceed to the next stage. The experimental route was
8 approximately 22 miles in length and comprised of urban, rural and motorway
9 environments, providing a range of speed limits between 30 and 70 mph.
10 Other cars in the scenario provided the opportunity of simulating overtaking
11 scenarios, gap acceptance tasks and car-following situations. The road
12 environment also featured traffic lights and pelican crossings in order to
13 instigate possible violation scenarios; and sub-standard curves were included
14 in both the urban and rural sections.
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25 Speed measurements were taken every 10 metres throughout the whole
26 journey. In addition, indices of safety critical behaviour such as minimum time
27 to collision in following tasks and the incidence of overtaking manoeuvres
28 were recorded. Traffic light violations, speed violations and curve negotiation
29 behaviour were also noted.
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35 Three car following situations were engineered requiring drivers to maintain
36 their desired headway over a section of road. They were unable to pass the
37 slow moving car in front due to oncoming traffic. These situations allowed
38 measurement of minimum time to collision and variation in headway. In
39 addition, two overtaking scenarios were created: here oncoming traffic was
40 present, but it had sufficient gaps to allow the driver to pass. Propensity to
41 overtake and proximity to the oncoming car were measured. An additional
42 overtaking scenario was created, again using a slow moving vehicle in front.
43 Here drivers were constrained by double white lines; if they chose to overtake,
44 a violation was recorded.
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53 Four sets of traffic lights were placed in the road network. One was
54 programmed to change from green to red as the driver approached. This
55 required the driver to make a stop/go decision, and a violation was recorded if
56 the driver passed through on the red light. Two gap acceptance tasks were
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3 incorporated into the road network. The first required the driver to merge from
4 the minor road onto the major road, making a left turn. Traffic on the major
5 road was approaching from the right with varying gaps. The second required
6 the driver to make a right turn across oncoming traffic from a major to a minor
7 road. Again the cars were separated with varying gaps.
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12 Attention to surprise events was measured in terms of performance on a
13 choice reaction task incorporated into the road network. Drivers were
14 required to respond to red and green squares that appeared in front of them.
15 If the square was green, they were asked to ignore it and continue driving. If
16 the square was red, they were asked to continue driving, and to flash the
17 headlights once, in response. Throughout the whole drive there appeared
18 three red and three green squares in a random sequence. In subsequent
19 drives the positioning of the squares was changed, in order to prevent
20 associative learning effects. Their response to the stimuli was recorded in
21 terms of reaction time, false/correct hits and missing responses.
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30 *Participants*

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32 Previous research suggests that the effects of the common cold on
33 behavioural measures are large. A sample size calculation suggested that 20
34 participants should be tested (minimum group size=9). Twenty five
35 participants were recruited for this study. Ten were assigned to Sample 1 and
36 15 to Sample 2. All participants had a full driving licence and had been driving
37 for less than 5 years. A roughly equal number proportion of males and
38 females were recruited and all 11 volunteers were paid for their participation.
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	<i>Sample 1 (Healthy)</i>	<i>Sample 2 (Colds)</i>
<i>Males/females</i>	<i>4/6</i>	<i>10/5</i>
<i>Mean age (males)</i>	<i>20 years (range: 18-21)</i>	<i>20 years (range: 18-25)</i>
<i>Mean age (females)</i>	<i>22 years (range: 20-24)</i>	<i>21 years (range: 19-24)</i>

Results

Symptom checklist

The symptom checklist showed significant differences in self-reported health. In the first test session, volunteers with a cold scored on average 19.8 (out of a maximum of 52), whilst on their return, this average score fell to 2, which was similar to the scores for those who were healthy on both occasions. Symptom scores for all of the upper respiratory tract symptom scales are shown in Table 1. All of the individual symptoms showed significant differences between the groups except for fever and shivering. This suggests that the participants had colds rather than influenza.

OMEDA

Performance data on both parts of the OMEDA task are presented. Part 1 of the task provides indication of accuracy in terms of time-to-collision estimates of a moving target. Absolute error (in seconds) was computed for both the healthy and unhealthy groups. Performance on the secondary task was also recorded, using the number of errors made in identifying the presence of a matching shape in the periphery of the screen. Part 2 of OMEDA provides data relating to the ability to detect a collision between two moving targets. The results are shown in Table 2.

In Part 1, there were no significant differences between the groups. This is likely due to a ceiling effect, whereby the volunteers found the task easy to complete. Overall, they were able to estimate accurately the TTC, with 50% of the total sample estimating to within 0.3 seconds of the actual TTC (Absolute

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3 error of TTC: Healthy group: 0.40; Ill group: 0.44). In addition, they found the
4 primary task easy enough to be able to perform well on the secondary task,
5 with only a total of four identification errors across the whole sample (Shape
6 identification error: Healthy group: 0.01; Ill group: 0.03). However, when the
7 task became more difficult in Part 2 of the OMEDA, performance decrements
8 were found for those with colds. Healthy individuals were more likely to
9 identify correctly both collisions and non-collisions. Those with colds appear
10 to be impaired to the extent that they were less likely to be able to identify if
11 the moving targets would or would not collide under various degrees of
12 occlusion. Performance on the secondary task was also degraded, such that
13 those who were suffering from a cold made more errors in identifying the
14 matching shape in the periphery of the screen.
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24 *Driving performance*

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26 In order to control for individual differences in driving ability, analyses of co-
27 variance, with the session 2 data as covariates, were carried out on the
28 driving data. Preliminary analyses showed that the two groups were not
29 significantly different at session 2 (when both groups were healthy).
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34 *Speed*

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36 For the purpose of data analysis, the experimental road network was divided
37 into sections according to speed limit. Of these sections, where the driver
38 was in free flowing conditions (i.e. not engaged in a car following task)
39 standard deviation of speed across the section was derived. Analyses of
40 covariance showed no effect of having a cold on standard of speed (Healthy
41 group: mean=4.76 m/s, s.e.= 0.36; Ill group: mean=4.82 m/s, s.e.= 0.30, F
42 <1).
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49 *Lateral control*

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51 Edgeline/centre line encroachments were not significantly altered as a
52 function of health status nor was the standard deviation of lane position (s.d.
53 lane position: healthy group: mean=0.19 m, s.e. 0.3; ill group: mean =0.18m,
54 s.e. = 0.3, $F < 1$).
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Gap acceptance

Two gap acceptance tasks were included in the road network. The first required the drivers to merge left into traffic approaching from the right, whilst the second required drivers to turn right across oncoming traffic. Gaps in the traffic increased by 1 second, with each vehicle, and the size of the gap that drivers accepted as well as a minimum time to collision to the on-coming car was calculated. There were no significant effects of cold status on gap acceptance.

Overtaking behaviour

In addition to the car following tasks detailed above, two scenarios were created to examine overtaking behaviour. Drivers encountered lead cars travelling below the posted speed limit on a straight stretch of road. There was little opposing traffic, providing the opportunity for drivers to overtake. Both overtaking attempts and successful overtakings were recorded. However it was found that these values were identical (thus once committed to an overtaking manoeuvre, drivers tended to complete it). There was no difference in overtaking behaviour between the two groups.

Car following

The road network allowed the inclusion of several car following tasks. In two of these tasks the driver was unable to overtake the car in front due to oncoming traffic. This created a “boxed-in” situation that allowed the measurement of the time headway distribution. The lead cars in these scenarios were travelling at a speed that was constant and below the speed limit. Thus in the urban situation the lead car was travelling at 25 mph, in the rural area at 40 mph. Therefore, even if speed limited, it was possible for drivers to adopt short headways if they wished to. Table 3 shows the time headway distribution for both healthy and ill drivers in an urban environment (30mph).

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3 It can be seen that those drivers who reported cold symptoms spent a larger
4 proportion of time at a shorter headway (in the safety critical area of less than
5 2 seconds).
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8 9 *Vigilance*

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11 A choice reaction task required drivers to differentially respond to randomly
12 appearing targets in the visual scene. It was hypothesised that there may be
13 differences in either response times or error rates depending on the health
14 status of the participants. Such differences may arise as a result of
15 decreases in vigilance associated with cognitive impairment. Probably due to
16 the ease of the task, a floor effect was found with regards to the error rates in
17 that drivers demonstrated a high degree of accuracy. Further analysis of the
18 response times to targets however, revealed a significant difference between
19 response times of the healthy and ill volunteers with those with a cold being
20 significantly slower (see Table 3).
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29 30 *Collision with a pedestrian*

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32 A critical event was added as an additional measure of vigilance. At a
33 pedestrian crossing a pedestrian stepped into the road and crossed in front of
34 the driver's path. This event was staged such that drivers were able, with
35 severe braking, to avoid collision with the pedestrian, if braking was initiated
36 immediately. In the first session, the healthy volunteers had no collisions
37 whereas those with a cold had 8 (chi-square = 7.06, $p < 0.01$). In the second
38 session both groups had zero collisions.
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47 These types of critical scenarios are inherently difficult to manipulate and test
48 in the simulator environment, not least due to exposure effects. It could be
49 postulated that on the second trial, participants were anticipating an event of
50 this kind to occur again and thus be cautious on approach to pedestrian
51 crossings. However, several precautions ensure this is not the case. First, the
52 location of the surprise event was different on the two driving sessions. In the
53 first session it was located at the end of the road network and in the second
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3 session it was moved to half way along the network. Secondly, as a measure
4 of anticipation, speed measures were recorded within the vicinity of the event.
5 Thus, speed was measured at 50 metres before the event (50 metres was
6 chosen as drivers could see the pedestrian but had not yet begun to brake). In
7 addition, speed was also measured at the point at which they initially began to
8 brake. There were no significant difference in these values between the first
9 and the second driving session. This indicates that drivers were not
10 anticipating the event in the second session.
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18 These results demonstrate that drivers with reported symptoms of minor
19 respiratory illnesses are impaired to the extent that they have longer response
20 times and thus negative safety effects with regards to critical events in the
21 driving environment.
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24 25 *Traffic light violations* 26

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28 A situation was created whereby drivers were forced to make a rapid stop/go
29 decision at one set of traffic lights which turned from green to amber as
30 drivers approached. In concordance with the previous results found on the
31 longer response times and reaction to surprise events, drivers who reported
32 cold symptoms violated the traffic lights twice as often as drivers who were
33 symptom free. However, due to the small number of violations this effect was
34 not significant.
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40 41 **Discussion** 42

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44 The present results confirm the earlier findings that having a cold may impair
45 aspects of simulated driving performance. There appears to be reliable
46 evidence that volunteers presenting with symptoms respond more slowly to
47 unexpected events and spent a greater percentage of time driving too close to
48 the car in front compared with healthy volunteers. As described in the
49 introduction, this decrement in driving performance could have implications for
50 road safety. The slowing of reaction times associated with having a cold is
51 comparable to effects of known hazards, such as consumption of a dose of
52 alcohol that would lead to a ban from driving (80mg alcohol/100ml blood) or
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3 having to perform at night. The OMEDA task also demonstrated that those
4 suffering from a cold were less able to detect potential collisions. Comparison
5 with a previous study¹¹ using elderly participants (over 65 years) shows that
6 the detection performance of young adults with a cold falls to that of elderly
7 drivers. There is now a need for an information campaign to provide accurate
8 information about the potential hazards associated with driving while suffering
9 from an upper respiratory tract illness.
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16 There is also evidence that the direct effects of having a cold are not the only
17 ones that need to be considered. A number of studies have shown that
18 individuals who are ill are more susceptible to the effects of other factors
19 which could influence driving (alcohol¹³; prolonged work¹⁴; and noise¹⁵).
20 Research also shows that impairments associated with the common cold are
21 not restricted to the time the person is symptomatic but may be observed in
22 the incubation period and a few days after symptoms have gone⁶.
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31 One must now ask what underlies the effects here. Previous research has
32 shown that the low alertness state associated with a cold can be reversed by
33 a drug which increases the turnover of central noradrenaline¹⁶. Indeed,
34 ingestion of caffeine, which increases alertness, has been shown to remove
35 the cold induced performance impairments seen in laboratory tasks¹⁷. This
36 suggests that a further study examining whether caffeine can remove the
37 effects found here is required. Similarly, it will be important to determine
38 whether medications aimed at producing symptomatic relief also remove the
39 behavioural problems associated with the common cold.
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47 In summary, the present study has used established methods to examine
48 effects of the common cold on simulated driving and collision detection. The
49 findings that having a cold reduces the ability to detect collisions and respond
50 quickly to unexpected events are of practical importance and can be related to
51 plausible underlying mechanisms. The study was small scale using relatively
52 inexperienced drivers and further research is required to determine whether
53 there are additional smaller effects and whether there are contexts and
54 individuals (e.g. the elderly) in which the impairments may be even greater
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3 than those seen here. Similarly, further research is required to address the
4 issue of awareness of these effects by using information campaigns and
5 prevention by using countermeasures that increase alertness.
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Table 1: Upper respiratory tract symptoms reported by colds and healthy groups on first testing session (scores are the means, s.e.s in parentheses. Significance tested by a Mann-Whitney test)

Symptom	Colds Group	Healthy Group	Significance
Pain in chest	0.93 (0.23)	0.0 (0.0)	p < 0.05
Sore Throat	1.80 (0.24)	0.2 (0.13)	p < 0.001
Headache	1.27 (0.267)	0.0 (0.0)	p < 0.005
Sneezing	1.47 (0.29)	0.10 (0.10)	p < 0.005
Runny nose	2.47 (0.19)	0.40 (0.16)	p < 0.001
Blocked nose	1.93 (0.21)	0.10 (0.10)	p < 0.001
Hoarseness	1.33 (0.30)	0.0 (0.0)	p < 0.005
Cough	2.13 (0.26)	0.20 (0.13)	p < 0.001
Feeling hot/cold	1.47 (0.24)	0.10 (0.10)	p < 0.001
Sweating	1.20 (0.31)	0.10 (0.10)	p < 0.05
Shivering	0.67 (0.21)	0.00 (0.00)	p=0.06
Fever	0.80 (0.30)	0.00 (0.00)	p=0.10
Phlegm	2.33 (0.30)	0.20 (0.13)	p < 0.001
Total URTI score	19.80 (1.96)	1.40 (0.27)	p < 0.001

Table 2. Performance of healthy and unhealthy drivers on the divided attention part of the OMEDA task.

	Healthy	Cold	Chi-square	Significance
Missed collisions	6%	5%	.122	p = 0.727
Detected collisions	27%	22%	3.67	p = 0.012
Correct misses	35%	27%	5.32	p = 0.002
False hits	31%	27%	.971	p = 0.325
Divided attention error	0.34%	1.68%	2.87	p = 0.014

Table 3. Significant effects of health status on outcomes from the driving task

- a. Mean percentage of time spent at a headway of less than 2 seconds (s.e.s in parentheses)

	Healthy	Ill	
	39.2%	51.7	F = 4.80,
	(5.4)	(4.3)	p < 0.05

- b. Mean response times (seconds) in choice reaction task (s.e.s in parentheses)

	Healthy	Ill	
Target 1	1.01	1.33	F = 4.35,
	(0.10)	(0.11)	p < 0.05
Target 2	0.95	1.21	F = 6.09,
	(0.06)	(0.06)	p < 0.05

Contributors

APS wrote the research proposal, designed the study, wrote the statistical analysis plan, analysed the data and drafted and revised the paper. He is guarantor.

SJ implemented the study, analysed the data and revised the paper.

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Disclosure

"All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: all authors had financial support from the ESRC ROPA Scheme (grant R022250188) for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities that could appear to have influenced the submitted work".

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4 **An investigation of the effects of the common cold on simulated driving**
5 **performance and detection of collisions: A laboratory study**
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Abstract

Objective The aim of the present research was to investigate whether individuals with a common cold showed impaired ability on a simulated driving task and the ability to detect potential collisions between moving objects.

Design The study involved comparison of a healthy group with a group with colds. These scores were adjusted for individual differences by collecting further data when both groups were healthy and using these scores as covariates. On both occasions volunteers rated their symptoms and carried out a simulated driving session. On the first occasion volunteers also carried out a collision detection task.

Setting University of Leeds Institute for Transport Studies

Sample Twenty five students from the University of Leeds. 10 volunteers were healthy on both occasions and 15 had a cold on the first session and were healthy on the second.

Main outcome measures In the collision detection task the main outcomes were correct detections and response to a secondary identification task. In the simulated driving task the outcomes were: speed; lateral control; gap acceptance; overtaking behaviour; car following; vigilance and traffic light violations.

Results Those with a cold detected fewer collisions and had a higher divided attention error than those who were healthy. Many basic driving skills were unimpaired by the illness. However, those with a cold were slower at responding to unexpected events and spent a greater percentage of time driving at a headway of less than 2 seconds.

Conclusions The finding that having a common cold is associated with reduced ~~the~~ ability to detect collisions and respond quickly to unexpected events is of practical importance. Further research is now required to examine the efficacy of information campaigns and countermeasures such as caffeine.

Introduction

Studies of simulated driving have played a major role in transport policy and practice. One of the early studies¹, published in the British Medical Journal, demonstrated an increase in driving error following ingestion of alcohol. Changes in state due to drugs like alcohol can be countered by appropriate legislation. Other factors, such as driver fatigue, are more difficult to legislate against – there's no breathalyser for fatigue! In the case of professional drivers some causes of fatigue, such as time spent driving, can be controlled. This is more difficult when one considers driving outside of work or when one has to deal with fatigue produced by other factors (low levels of circadian alertness). In these situations, information campaigns² have to be used to prevent and manage driver fatigue, although legislation relating to being in a fit state to drive could be applied. The aim of the present research was to investigate whether individuals with a common cold showed impaired ability on a simulated driving task and the ability to detect potential collisions between moving objects.

Minor illnesses such as the common cold produce a state of reduced alertness which is associated with impaired psychomotor function and cognitive abilities^{3, 4, 5, 6}. These impairments manifest themselves as slower reaction times to unexpected events and a reduced ability to sustain attention. These are important skills involved in driving and one might, therefore, expect that individuals with such illnesses will be involved in more crashes. Anecdotal evidence, largely consisting of case reports, suggests that this is the case⁷. This has been confirmed in a survey⁸ and extrapolation of this to the whole driving population suggests that 125,000 people in the UK have a crash while suffering from a cold or influenza. Results from a driving hazard perception task⁸ confirmed laboratory findings that reaction times are 10% slower when the person has a cold. Again, if one applies this to a real-life driving situation it would mean that it would add 1m (3.3ft) to stopping distance if travelling at 30mph (48km/h) - on top of a normal distance of 12m (40ft) and it would add

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3 2.3m (7.5ft) onto the normal stopping distance of 96m (315ft) if travelling at
4 70mph (113km/h).
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8 Research using a simple driving simulator⁹ (resembling a computer game)
9 has shown that people with an upper respiratory tract illness responded more
10 slowly to unexpected events and were more likely to steer inaccurately.
11 Another study¹⁰ using a very realistic driving simulator found that basic driving
12 skills were not impaired but that situational awareness was reduced when the
13 person had a cold. The present study continued to examine this topic in detail,
14 using a sophisticated simulation that incorporates the skills necessary for safe
15 driving. In addition, the study also included a laboratory task which evaluated
16 participants' ability to detect potential collisions¹¹ which is a key skill in driving
17 but also something that cannot be repeatedly examined in a simulator.
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26 **Method**

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29 The study was carried out with the approval of the ethics committee, School of
30 Psychology, Cardiff University, and the informed consent of the volunteers.
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33 *Experimental design*

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38 A mixed design was employed whereby two groups of participants (Sample 1
39 and Sample 2) were tested on two occasions (Session 1 and Session 2).
40 Those participants in Sample 1 were healthy on both occasions, whilst those
41 in Sample 2 reported symptoms of minor respiratory illnesses in Session 1,
42 but were symptom free in Session 2. Participants carried out the driving
43 simulation task on both occasions but only carried out the collision detection
44 task on the first session.
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50 *Procedure*

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Volunteers were students from the University of Leeds recruited by posting
advertisements in the Student Medical Practice and by placing posters in the
School of Psychology. On arrival at the first session, they were asked to read

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3 the experimental procedure and sign the consent form if they agreed to take
4 part. They then completed a symptom checklist, a self report questionnaire
5 designed to evaluate the severity of their symptoms using a 5 point rating
6 scale (0=not all to 4= very severe). If volunteers scored above 8 on symptoms
7 typical of a cold (pain in chest, sore throat, headache, sneezing, runny nose,
8 blocked nose, hoarseness, cough, hot/cold, sweating, shivering, fever, and
9 phlegm) they were included in the cold group. Healthy volunteers were only
10 included if they had a symptom score of 3 or less (based on the upper
11 respiratory tract symptoms and other symptoms of minor illnesses such as
12 digestive problems). Volunteers were excluded if they were taking medication
13 for their colds. All volunteers were tested when their illness had been present
14 for at least 24 hours and no longer than 96 hours.
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24 The laboratory task was then completed, followed by a familiarisation period
25 on the driving simulator. Volunteers were asked to drive as naturally as
26 possible through the road network. The secondary (choice reaction) task was
27 also explained to them. On completion of the drive, volunteers were asked to
28 contact the experimenter after seven symptom free days in order to confirm a
29 second session. Those who were healthy at session 1 returned for their
30 second session approximately a week later. When they returned for this
31 session, they completed the same symptom checklist and driving simulator
32 task. After completion, they were debriefed, and their expenses paid.
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41 *OMEDA (Object Movement Estimation under Divided Attention)*

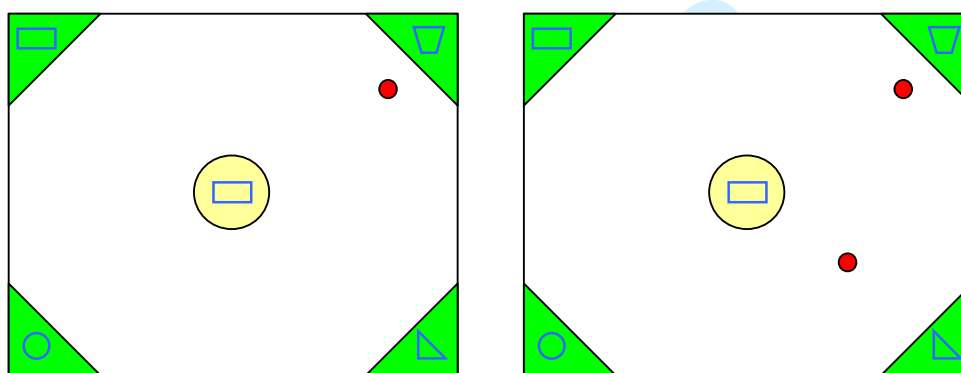
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43 OMEDA¹¹ is a computerised dual-task with two parts. Part 1 of OMEDA
44 allows experimenters to obtain an individual's error in Time-To-Collision (TTC)
45 estimation. Different target speeds can be simulated, as can various degrees
46 of occlusion. A secondary task is also incorporated in the form of a visual
47 divided attention task. This requires the identification of peripheral duplication
48 of stimuli presented centrally (in this case geometrical shapes).
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54 Part 2 of OMEDA provides a quantified estimate of collision detection error
55 under various degrees of occlusion and for a series of target speeds, with the
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3 same secondary task as for Part 1. Participants do not need to be computer
4 literate in order to be able to do this task, as the response keys are a foot
5 pedal (for the primary task) and a hand button (for the secondary task).
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10 In Part 1 the participant is presented with a computer screen where the
11 corners are covered by green triangles and in the centre of the screen is a
12 yellow circle. The yellow circle varies in size between two and 250 pixels.
13 From one of the four corners (randomly allocated), a red target, in the form
14 of a circle travels towards the middle of the screen. Once it reaches the edge
15 of the yellow circle, it travels underneath it and it is not visible. Therefore,
16 the larger the circle, the more difficult is the task, due to a longer occlusion
17 time. The participant is asked to estimate exactly when the target reaches the
18 middle of the computer screen. They are instructed to press a foot pedal at
19 the exact point the target reaches the middle.
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28 In order to simulate divided attention, whilst participants are estimating when
29 the target reaches the middle of the screen, they are required to complete a
30 pattern matching task. When the target is moving, five shapes appear on the
31 screen (one overlaid on the yellow circle and one in each of the four corners).
32 Participants are instructed to press a hand button immediately if the shape in
33 the middle matches any of those in the four corners of the screen.
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Part 1

Part 2

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6 Figure 1: OMEDA computer screen
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8 Data collected are target speed, size of the occlusion circle, time under the
9 occlusion circle, actual time to contact (TTC), estimated TTC and TTC error,
10 errors in shape detection.
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14 In Part 2, the participants are presented with the same screen as in Part 1.
15 However, the primary task now involves two targets moving towards the
16 centre of the screen, emerging at different times and travelling at different
17 speeds. The targets reach the centre of the screen either at the same time (a
18 hit), almost at the same time (a near miss) or at a noticeable time difference
19 (a miss). The participant is required to press the foot pedal only if and when
20 the targets reach the centre of the screen at the same time (i.e. only for hits).
21 The secondary task is the same as for Part 1. The data collected includes the
22 error in estimating TTC and the error in shape estimation, under different
23 occlusions and target speeds
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32 *Driving Simulator*
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35 The experiments were carried out on a fixed based driving simulator at the
36 University of Leeds presenting a 120° forward view and 50° rear view. The
37 system features a fully interactive Silicon Graphics (Onyx RE²) driving
38 simulator with a six degree of freedom vehicle model. A servo motor linked to
39 the steering mechanism provides control over handling torque and speed and
40 digitised samples of engine, wind, road noise and other vehicles are provided.
41 Photo-realistic scene texturing allows presentation of various road types and
42 features.
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49 Studies¹² have evaluated the behavioural validity of the simulator. The results
50 showed that overall there was a broad correspondence between driving in the
51 simulator and the behaviour of real-world traffic. With regard to speed, the
52 effects of road width, curvature, direction of curve and sequence between
53 road sections were reproduced on the simulator, and there were very high
54 correlations between speed along the real road and speeds in the simulator.
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3 Prior to the experimental drive, participants completed a fifteen minute
4 familiarisation drive. The drive comprised urban, rural and motorway sections,
5 similar to the experimental drive, but contained none of the scenarios under
6 investigation. Once the familiarisation drive was completed, drivers were
7 deemed ready to proceed to the next stage. The experimental route was
8 approximately 22 miles in length and comprised of urban, rural and motorway
9 environments, providing a range of speed limits between 30 and 70 mph.
10 Other cars in the scenario provided the opportunity of simulating overtaking
11 scenarios, gap acceptance tasks and car-following situations. The road
12 environment also featured traffic lights and pelican crossings in order to
13 instigate possible violation scenarios; and sub-standard curves were included
14 in both the urban and rural sections.
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25 Speed measurements were taken every 10 metres throughout the whole
26 journey. In addition, indices of safety critical behaviour such as minimum time
27 to collision in following tasks and the incidence of overtaking manoeuvres
28 were recorded. Traffic light violations, speed violations and curve negotiation
29 behaviour were also noted.
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35 Three car following situations were engineered requiring drivers to maintain
36 their desired headway over a section of road. They were unable to pass the
37 slow moving car in front due to oncoming traffic. These situations allowed
38 measurement of minimum time to collision and variation in headway. In
39 addition, two overtaking scenarios were created: here oncoming traffic was
40 present, but it had sufficient gaps to allow the driver to pass. Propensity to
41 overtake and proximity to the oncoming car were measured. An additional
42 overtaking scenario was created, again using a slow moving vehicle in front.
43 Here drivers were constrained by double white lines; if they chose to overtake,
44 a violation was recorded.
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53 Four sets of traffic lights were placed in the road network. One was
54 programmed to change from green to red as the driver approached. This
55 required the driver to make a stop/go decision, and a violation was recorded if
56 the driver passed through on the red light. Two gap acceptance tasks were
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3 incorporated into the road network. The first required the driver to merge from
4 the minor road onto the major road, making a left turn. Traffic on the major
5 road was approaching from the right with varying gaps. The second required
6 the driver to make a right turn across oncoming traffic from a major to a minor
7 road. Again the cars were separated with varying gaps.
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13 Attention to surprise events was measured in terms of performance on a
14 choice reaction task incorporated into the road network. Drivers were
15 required to respond to red and green squares that appeared in front of them.
16 If the square was green, they were asked to ignore it and continue driving. If
17 the square was red, they were asked to continue driving, and to flash the
18 headlights once, in response. Throughout the whole drive there appeared
19 three red and three green squares in a random sequence. In subsequent
20 drives the positioning of the squares was changed, in order to prevent
21 associative learning effects. Their response to the stimuli was recorded in
22 terms of reaction time, false/correct hits and missing responses.
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30 *Participants*

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33 Previous research suggests that the effects of the common cold on
34 behavioural measures are large. A sample size calculation suggested that 20
35 participants should be tested (minimum group size=9). Twenty five
36 participants were recruited for this study. Ten were assigned to Sample 1 and
37 15 to Sample 2. All participants had a full driving licence and had been driving
38 for less than 5 years. A roughly equal number proportion of males and
39 females were recruited and all 11 volunteers were paid for their participation.
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	<i>Sample 1 (Healthy)</i>	<i>Sample 2 (Colds)</i>
<i>Males/females</i>	<i>4/6</i>	<i>10/5</i>
<i>Mean age (males)</i>	<i>20 years (range: 18-21)</i>	<i>20 years (range: 18-25)</i>
<i>Mean age (females)</i>	<i>22 years (range: 20-24)</i>	<i>21 years (range: 19-24)</i>

Results

Symptom checklist

The symptom checklist showed significant differences in self-reported health. In the first test session, volunteers with a cold scored on average 19.8 (out of a maximum of 52), whilst on their return, this average score fell to 2, which was similar to the scores for those who were healthy on both occasions. Symptom scores for all of the upper respiratory tract symptom scales are shown in Table 1. All of the individual symptoms showed significant differences between the groups except for fever and shivering. This suggests that the participants had colds rather than influenza.

OMEDA

Performance data on both parts of the OMEDA task are presented. Part 1 of the task provides indication of accuracy in terms of time-to-collision estimates of a moving target. Absolute error (in seconds) was computed for both the healthy and unhealthy groups. Performance on the secondary task was also recorded, using the number of errors made in identifying the presence of a matching shape in the periphery of the screen. Part 2 of OMEDA provides data relating to the ability to detect a collision between two moving targets. The results are shown in Table 2.

In Part 1, there were no significant differences between the groups. This is likely due to a ceiling effect, whereby the volunteers found the task easy to complete. Overall, they were able to estimate accurately the TTC, with 50% of the total sample estimating to within 0.3 seconds of the actual TTC (Absolute

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3 error of TTC: Healthy group: 0.40; Ill group: 0.44). In addition, they found the
4 primary task easy enough to be able to perform well on the secondary task,
5 with only a total of four identification errors across the whole sample (Shape
6 identification error: Healthy group: 0.01; Ill group: 0.03). However, when the
7 task became more difficult in Part 2 of the OMEDA, performance decrements
8 were found for those with colds. Healthy individuals were more likely to
9 identify correctly both collisions and non-collisions. Those with colds appear
10 to be impaired to the extent that they were less likely to be able to identify if
11 the moving targets would or would not collide under various degrees of
12 occlusion. Performance on the secondary task was also degraded, such that
13 those who were suffering from a cold made more errors in identifying the
14 matching shape in the periphery of the screen.
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23 *Driving performance*

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25 In order to control for individual differences in driving ability, analyses of co-
26 variance, with the session 2 data as covariates, were carried out on the
27 driving data. Preliminary analyses showed that the two groups were not
28 significantly different at session 2 (when both groups were healthy).
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33 *Speed*

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35 For the purpose of data analysis, the experimental road network was divided
36 into sections according to speed limit. Of these sections, where the driver
37 was in free flowing conditions (i.e. not engaged in a car following task)
38 standard deviation of speed across the section was derived. Analyses of
39 covariance showed no effect of having a cold on standard of speed (Healthy
40 group: mean=4.76 m/s, s.e.= 0.36; Ill group: mean=4.82 m/s, s.e.= 0.30, F
41 <1).
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49 *Lateral control*

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51 Edgeline/centre line encroachments were not significantly altered as a
52 function of health status nor was the standard deviation of lane position (s.d.
53 lane position: healthy group: mean=0.19 m, s.e. 0.3; ill group: mean =0.18m,
54 s.e. = 0.3, F < 1).
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Gap acceptance

Two gap acceptance tasks were included in the road network. The first required the drivers to merge left into traffic approaching from the right, whilst the second required drivers to turn right across oncoming traffic. Gaps in the traffic increased by 1 second, with each vehicle, and the size of the gap that drivers accepted as well as a minimum time to collision to the on-coming car was calculated. There were no significant effects of cold status on gap acceptance.

Overtaking behaviour

In addition to the car following tasks detailed above, two scenarios were created to examine overtaking behaviour. Drivers encountered lead cars travelling below the posted speed limit on a straight stretch of road. There was little opposing traffic, providing the opportunity for drivers to overtake. Both overtaking attempts and successful overtakings were recorded. However it was found that these values were identical (thus once committed to an overtaking manoeuvre, drivers tended to complete it). There was no difference in overtaking behaviour between the two groups.

Car following

The road network allowed the inclusion of several car following tasks. In two of these tasks the driver was unable to overtake the car in front due to oncoming traffic. This created a “boxed-in” situation that allowed the measurement of the time headway distribution. The lead cars in these scenarios were travelling at a speed that was constant and below the speed limit. Thus in the urban situation the lead car was travelling at 25 mph, in the rural area at 40 mph. Therefore, even if speed limited, it was possible for drivers to adopt short headways if they wished to. Table 3 shows the time headway distribution for both healthy and ill drivers in an urban environment (30mph).

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3 It can be seen that those drivers who reported cold symptoms spent a larger
4 proportion of time at a shorter headway (in the safety critical area of less than
5 2 seconds).
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8 9 *Vigilance*

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11 A choice reaction task required drivers to differentially respond to randomly
12 appearing targets in the visual scene. It was hypothesised that there may be
13 differences in either response times or error rates depending on the health
14 status of the participants. Such differences may arise as a result of
15 decreases in vigilance associated with cognitive impairment. Probably due to
16 the ease of the task, a floor effect was found with regards to the error rates in
17 that drivers demonstrated a high degree of accuracy. Further analysis of the
18 response times to targets however, revealed a significant difference between
19 response times of the healthy and ill volunteers with those with a cold being
20 significantly slower (see Table 3).
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29 30 *Collision with a pedestrian*

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32 A critical event was added as an additional measure of vigilance. At a
33 pedestrian crossing a pedestrian stepped into the road and crossed in front of
34 the driver's path. This event was staged such that drivers were able, with
35 severe braking, to avoid collision with the pedestrian, if braking was initiated
36 immediately. In the first session, the healthy volunteers had no collisions
37 whereas those with a cold had 8 (chi-square = 7.06, $p < 0.01$). In the second
38 session both groups had zero collisions.
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47 These types of critical scenarios are inherently difficult to manipulate and test
48 in the simulator environment, not least due to exposure effects. It could be
49 postulated that on the second trial, participants were anticipating an event of
50 this kind to occur again and thus be cautious on approach to pedestrian
51 crossings. However, several precautions ensure this is not the case. First, the
52 location of the surprise event was different on the two driving sessions. In the
53 first session it was located at the end of the road network and in the second
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3 session it was moved to half way along the network. Secondly, as a measure
4 of anticipation, speed measures were recorded within the vicinity of the event.
5 Thus, speed was measured at 50 metres before the event (50 metres was
6 chosen as drivers could see the pedestrian but had not yet begun to brake). In
7 addition, speed was also measured at the point at which they initially began to
8 brake. There were no significant difference in these values between the first
9 and the second driving session. This indicates that drivers were not
10 anticipating the event in the second session.
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18 These results demonstrate that drivers with reported symptoms of minor
19 respiratory illnesses are impaired to the extent that they have longer response
20 times and thus negative safety effects with regards to critical events in the
21 driving environment.
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25 *Traffic light violations*

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28 A situation was created whereby drivers were forced to make a rapid stop/go
29 decision at one set of traffic lights which turned from green to amber as
30 drivers approached. In concordance with the previous results found on the
31 longer response times and reaction to surprise events, drivers who reported
32 cold symptoms violated the traffic lights twice as often as drivers who were
33 symptom free. However, due to the small number of violations this effect was
34 not significant.
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41 **Discussion**

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45 The present results confirm the earlier findings that having a cold may impair
46 aspects of simulated driving performance. There appears to be reliable
47 evidence that volunteers presenting with symptoms respond more slowly to
48 unexpected events and spent a greater percentage of time driving too close to
49 the car in front compared with healthy volunteers. As described in the
50 introduction, this decrement in driving performance could have implications for
51 road safety. The slowing of reaction times associated with having a cold is
52 comparable to effects of known hazards, such as consumption of a dose of
53 alcohol that would lead to a ban from driving (80mg alcohol/100ml blood) or
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3 having to perform at night. The OMEDA task also demonstrated that those
4 suffering from a cold were less able to detect potential collisions. Comparison
5 with a previous study¹¹ using elderly participants (over 65 years) shows that
6 the detection performance of young adults with a cold falls to that of elderly
7 drivers. There is now a need for an information campaign to provide accurate
8 information about the potential hazards associated with driving while suffering
9 from an upper respiratory tract illness.
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16 There is also evidence that the direct effects of having a cold are not the only
17 ones that need to be considered. A number of studies have shown that
18 individuals who are ill are more susceptible to the effects of other factors
19 which could influence driving (alcohol¹³; prolonged work¹⁴; and noise¹⁵).
20 Research also shows that impairments associated with the common cold are
21 not restricted to the time the person is symptomatic but may be observed in
22 the incubation period and a few days after symptoms have gone⁶.
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30 One must now ask what underlies the effects here. Previous research has
31 shown that the low alertness state associated with a cold can be reversed by
32 a drug which increases the turnover of central noradrenaline¹⁶. Indeed,
33 ingestion of caffeine, which increases alertness, has been shown to remove
34 the cold induced performance impairments seen in laboratory tasks¹⁷. This
35 suggests that a further study examining whether caffeine can remove the
36 effects found here is required. Similarly, it will be important to determine
37 whether medications aimed at producing symptomatic relief also remove the
38 behavioural problems associated with the common cold.
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47 In summary, the present study has used established methods to examine
48 effects of the common cold on simulated driving and collision detection. The
49 findings that having a cold reduces the ability to detect collisions and respond
50 quickly to unexpected events are of practical importance and can be related to
51 plausible underlying mechanisms. The study was small scale using relatively
52 inexperienced drivers and further research is required to determine whether
53 there are additional smaller effects and whether there are contexts and
54 individuals (e.g. the elderly) in which the impairments may be even greater
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3 than those seen here. Similarly, further research is required to address the
4 issue of awareness of these effects by using information campaigns and
5 prevention by using countermeasures that increase alertness.
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Table 1: Upper respiratory tract symptoms reported by colds and healthy groups on first testing session (scores are the means, s.e.s in parentheses. Significance tested by a Mann-Whitney test)

Symptom	Colds Group	Healthy Group	Significance
Pain in chest	0.93 (0.23)	0.0 (0.0)	p < 0.05
Sore Throat	1.80 (0.24)	0.2 (0.13)	p < 0.001
Headache	1.27 (0.267)	0.0 (0.0)	p < 0.005
Sneezing	1.47 (0.29)	0.10 (0.10)	p < 0.005
Runny nose	2.47 (0.19)	0.40 (0.16)	p < 0.001
Blocked nose	1.93 (0.21)	0.10 (0.10)	p < 0.001
Hoarseness	1.33 (0.30)	0.0 (0.0)	p < 0.005
Cough	2.13 (0.26)	0.20 (0.13)	p < 0.001
Feeling hot/cold	1.47 (0.24)	0.10 (0.10)	p < 0.001
Sweating	1.20 (0.31)	0.10 (0.10)	p < 0.05
Shivering	0.67 (0.21)	0.00 (0.00)	p=0.06
Fever	0.80 (0.30)	0.00 (0.00)	p=0.10
Phlegm	2.33 (0.30)	0.20 (0.13)	p < 0.001
Total URTI score	19.80 (1.96)	1.40 (0.27)	p < 0.001

Table 2. Performance of healthy and unhealthy drivers on the divided attention part of the OMEDA task.

	Healthy	Cold	Chi-square	Significance
Missed collisions	6%	5%	.122	p = 0.727
Detected collisions	27%	22%	3.67	p = 0.012
Correct misses	35%	27%	5.32	p = 0.002
False hits	31%	27%	.971	p = 0.325
Divided attention error	0.34%	1.68%	2.87	p = 0.014

Table 3. Significant effects of health status on outcomes from the driving task

a. Mean percentage of time spent at a headway of less than 2 seconds (s.e.s in parentheses)

	Healthy	Ill	
	39.2%	51.7	F = 4.80,
	(5.4)	(4.3)	p < 0.05

b. Mean response times (seconds) in choice reaction task (s.e.s in parentheses)

	Healthy	Ill	
Target 1	1.01	1.33	F = 4.35,
	(0.10)	(0.11)	p < 0.05
Target 2	0.95	1.21	F = 6.09,
	(0.0.6)	(0.06)	p < 0.05

Contributors

APS wrote the research proposal, designed the study, wrote the statistical analysis plan, analysed the data and drafted and revised the paper. He is guarantor.

SJ implemented the study, analysed the data and revised the paper.

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