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

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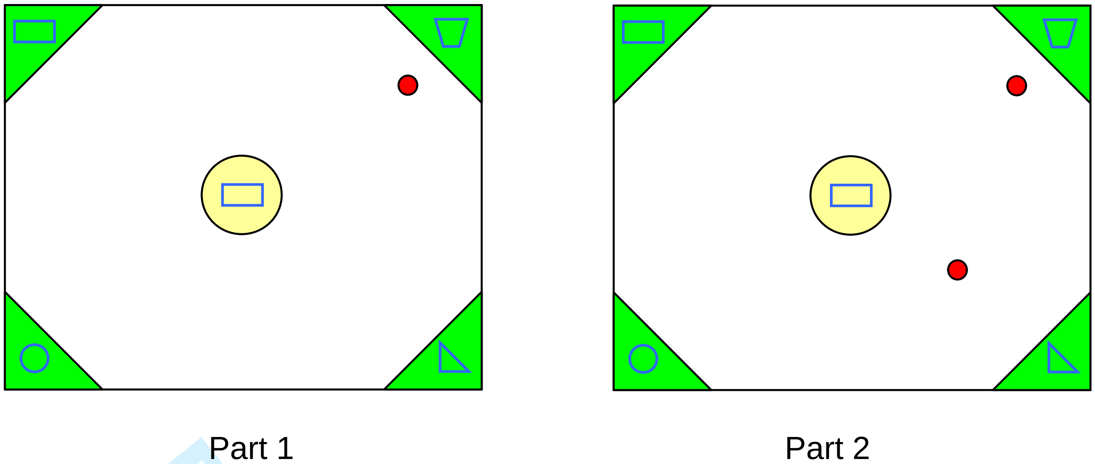

Figure 1: OMEDA computer screen

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.

An investigation of the effects of the common cold on simulated driving 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 dectection 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 studies[1], 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 campaigns[2] 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 case[7]. This has been confirmed in a survey[8] and extrapolation of this to the whole driving population suggests that 125,000 people in the UK have a road traffic accident while suffering from a cold or influenza. Results from a driving hazard perception task[8] 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 2.3m (7.5ft) onto the normal stopping distance of 96m (315ft) if travelling at 70mph (113km/h).

Research using a simple driving simulator[9] (resembling a computer game) has shown the people with an upper respiratory tract illness responded more slowly to unexpected events and were more likely to steer inaccurately. Another study[10] using a very realistic driving simulator found that basic driving skills were not impaired but that situational awareness was reduced when the person had a cold. The present study continued to examine this topic in detail, using a sophisticated simulation that incorporates the skills necessary for safe driving. In addition, the study also included a laboratory task which evaluated participants' ability to detect potential collisions[11] which is a key skill in driving but also something that cannot be repeatedly examined in a simulator.

Method

The study was carried out with the approval of the ethics committee, School of Psychology, Cardiff University, and the informed consent of the volunteers.

Experimental design

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

Procedure

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.

OMEDA (Object Movement Estimation under Divided Attention)

OMEDA[11] is a computerised dual-task with two parts. Part 1 of OMEDA allows experimenters to obtain an individual's error in Time-To-Collision (TTC) estimation. Different target speeds can be simulated, as can various degrees of occlusion. A secondary task is also incorporated in the form of a visual divided attention task. This requires the identification of peripheral duplication of stimuli presented centrally (in this case geometrical shapes).

Part 2 of OMEDA provides a quantified estimate of collision detection error under various degrees of occlusion and for a series of target speeds, with the same secondary task as for Part 1. Participants do not need to be computer literate in order to be able to do this task, as the response keys are a foot pedal (for the primary task) and a hand button (for the secondary task).

In Part 1 the participant is presented with a computer screen where the corners are covered by green triangles and in the centre of the screen is a yellow circle. The yellow circle varies in size between two and 250 pixels. From one of the four corners (randomly allocated), a red target, in the form of a circle travels towards the middle of the screen. Once it reaches the edge of the yellow circle, it travels underneath it and it is not visible. Therefore, the larger the circle, the more difficult is the task, due to a longer occlusion time. The participant is asked to estimate exactly when the target reaches the middle of the computer screen. They are instructed to press a foot pedal at the exact point the target reaches the middle.

To order to simulate divided attention, whilst participants are estimating when the target reaches the middle of the screen, they are required to complete a pattern matching task. When the target is moving, five shapes appear on the screen (one overlaid on the yellow circle and one in each of the four corners). Participants are instructed to press a hand button immediately if the shape in the middle matches any of those in the four corners of the screen.

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 120º forward view and 50º 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.

Studies[12] have evaluated the behavioural validity of the simulator. The results showed that overall there was a broad correspondence between driving in the simulator and the behaviour of real-world traffic. With regard to speed, the effects of road width, curvature, direction of curve and sequence between road sections were reproduced on the simulator, and there were very high correlations between speed along the real road and speeds in the simulator.

The experimental route was approximately 22 miles in length and comprised of urban, rural and motorway environments, providing a range of speed limits between 30 and 70 mph. Other cars in the scenario provided the opportunity of simulating overtaking scenarios, gap acceptance tasks and car-following situations. The road environment also featured traffic lights and pelican crossings in order to instigate possible violation scenarios; and sub-standard curves were included in both the urban and rural sections.

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

Three car following situations were engineered requiring drivers to maintain their desired headway over a section of road. They were unable to pass the slow moving car in front due to oncoming traffic. These situations allowed measurement of minimum time to collision and variation in headway. In addition, two overtaking scenarios were created: here oncoming traffic was present, but it had sufficient gaps to allow the driver to pass. Propensity to overtake and proximity to the oncoming car were measured. An additional overtaking scenario was created, again using a slow moving vehicle in front. Here drivers were constrained by double white lines; if they chose to overtake, a violation was recorded.

Four sets of traffic lights were placed in the road network. One was programmed to change from green to red as the driver approached. This required the driver to make a stop/go decision, and a violation was recorded if the driver passed through on the red light. Two gap acceptance tasks were incorporated into the road network. The first required the driver to merge from the minor road onto the major road, making a left turn. Traffic on the major road was approaching from the right with varying gaps. The second required the driver to make a right turn across oncoming traffic from a major to a minor road. Again the cars were separated with varying gaps.

Attention to surprise events was measured in terms of performance on a choice reaction task incorporated into the road network. Drivers were required to respond to red and green squares that appeared in front of them. If the square was green, they were asked to ignore it and continue driving. If 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.

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

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 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 1.

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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. In addition, they found the primary task easy enough to be able to perform well on the secondary task, with only a total of four identification errors across the whole sample. However, when the task became more difficult in Part 2 of the OMEDA, performance decrements were found for those with colds. Healthy individuals were more likely to identify correctly both collisions and non-collisions. Those with colds appear to be impaired to the extent that they were less likely to be able to identify if the moving targets would or would not collide under various degrees of occlusion. Performance on the secondary task also degraded, such that those who were suffering from a cold made more errors in identifying the matching shape in the periphery of the screen.

Driving performance

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

Speed

For the purpose of data analysis, the experimental road network was divided into sections according to speed limit. Of these sections, where the driver was in free flowing conditions (i.e. not engaged in a car following task) mean speed and standard deviation speed across the section was derived. 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 headway distribution for both healthy and ill drivers in an urban environment (30mph).

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 2).

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. The healthy volunteers had no collisions whereas those with a cold had 8.

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 first session it was located at the end of the road network and in the second session it was moved to half way along the network. Secondly, as a measure of anticipation, speed measures were recorded within the vicinity of the event. Thus, speed was measured at 50 metres before the event (50 metres was chosen as drivers could see the pedestrian but had not yet begun to brake). In addition, speed was also measured at the point at which they initially began to brake. There were no significant difference in these values between the first and the second driving session. This indicates that drivers were not anticipating the event in the second session.

These results demonstrate that drivers with reported symptoms of minor respiratory illnesses are impaired to the extent that they have longer response times and thus negative safety effects with regards to critical events in the driving environment.

Traffic light violations

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

Discussion

The present results confirm the earlier findings that having a cold may impair aspects of simulated driving performance. There appears to be reliable evidence that volunteers presenting with symptoms respond more slowly to unexpected events and drive too closely to the car in front. As described in the introduction, this decrement in driving performance could have implications for road safety. The slowing of reaction times associated with having a cold is comparable to effects of known hazards, such as consumption of a dose of alcohol that would lead to a ban from driving or having to perform at night. The OMEDA task also demonstrated that those suffering from a cold were less able to detect potential collisions. Comparison with a previous study using elderly participants (over 65 years) shows that the detection performance of young adults with a cold falls to that of elderly drivers. There is now a need for an information campaign to provide accurate information about the potential hazards associated with driving while suffering from an upper respiratory tract illness.

There is also evidence that the direct effects of having a cold are not the only ones that need to be considered. A number of studies have shown that individuals who are ill are more susceptible to the effects of other factors which could influence driving (alcohol[13]; prolonged work[14]; and noise[15]). Research also shows that impairments associated with the common cold are not restricted to the time the person is symptomatic but may be observed in the incubation period and after symptoms have gone[6].

One must now ask what underlies the effects here. Previous research has shown that the low alertness state associated with a cold can be reversed by a drug which increases the turnover of central noradrenaline[16]. Indeed, ingestion of caffeine, which increases alertness, has been shown to remove the cold induced performance impairments seen in laboratory tasks[17]. This suggests that a further study examining whether caffeine can remove the effects found here is required. Similarly, it will be important to determine whether medications aimed at producing symptomatic relief also remove the behavioural problems associated with the common cold.

In summary, the present study has used established methods to examine effects of the common cold on simulated driving and collision detection. The finding that having a cold reduces the ability to detect collisions and respond quickly to unexpected events are of practical importance and can be related to plausible underlying mechanisms. The study was small scale and further research is required to determine whether 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 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.

Copyright

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.

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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 studies[1], 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 campaigns[2] 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 morecrashes. Anecdotal evidence, largely consisting of case reports, suggests that this is the case[7]. This has been confirmed in a survey[8] 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 task[8] 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

2.3m (7.5ft) onto the normal stopping distance of 96m (315ft) if travelling at 70mph (113km/h).

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Method

The study was carried out with the approval of the ethics committee, School of Psychology, Cardiff University, and the informed consent of the volunteers.

Experimental design

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

Procedure

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 using a 5 point rating scale (0=not all to 4= very severe). If volunteers scored above 8 on symptoms typical of a cold (pain in chest, sore throat, headache, sneezing, runny nose, blocked nose, hoarseness, cough, hot/cold, sweating, shivering, fever, and phlegm) they were included in the cold group. Healthy volunteers were only included if they had a symptom score of 3 or less (based on the upper respiratory tract symptoms and other symptoms of minor illnesses such as digestive problems).Volunteers were excluded if they were taking medication for their colds. All volunteers were tested when their illness had been present for at least 24 hours and no longer than 96 hours.

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. Those who were healthy at session 1 returned for their second session approximately a week later. 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.

OMEDA (Object Movement Estimation under Divided Attention)

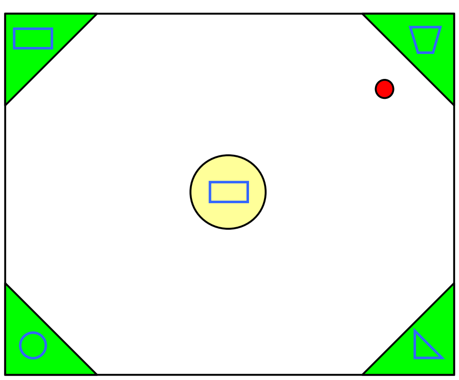
OMEDA[11] is a computerised dual-task with two parts. Part 1 of OMEDA allows experimenters to obtain an individual's error in Time-To-Collision (TTC) estimation. Different target speeds can be simulated, as can various degrees of occlusion. A secondary task is also incorporated in the form of a visual divided attention task. This requires the identification of peripheral duplication of stimuli presented centrally (in this case geometrical shapes).

Part 2 of OMEDA provides a quantified estimate of collision detection error under various degrees of occlusion and for a series of target speeds, with the

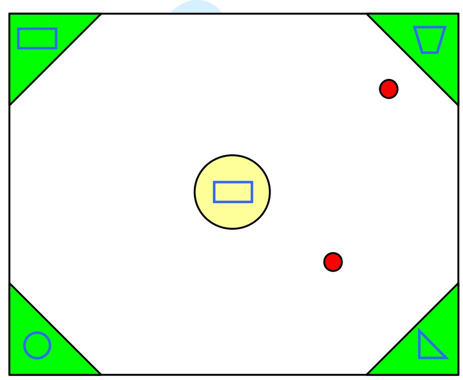
same secondary task as for Part 1. Participants do not need to be computer literate in order to be able to do this task, as the response keys are a foot pedal (for the primary task) and a hand button (for the secondary task).

In Part 1 the participant is presented with a computer screen where the corners are covered by green triangles and in the centre of the screen is a yellow circle. The yellow circle varies in size between two and 250 pixels. From one of the four corners (randomly allocated), a red target, in the form of a circle travels towards the middle of the screen. Once it reaches the edge of the yellow circle, it travels underneath it and it is not visible. Therefore, the larger the circle, the more difficult is the task, due to a longer occlusion time. The participant is asked to estimate exactly when the target reaches the middle of the computer screen. They are instructed to press a foot pedal at the exact point the target reaches the middle.

In order to simulate divided attention, whilst participants are estimating when the target reaches the middle of the screen, they are required to complete a pattern matching task. When the target is moving, five shapes appear on the screen (one overlaid on the yellow circle and one in each of the four corners). Participants are instructed to press a hand button immediately if the shape in the middle matches any of those in the four corners of the screen.



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 120º forward view and 50º 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.

Studies[12] have evaluated the behavioural validity of the simulator. The results showed that overall there was a broad correspondence between driving in the simulator and the behaviour of real-world traffic. With regard to speed, the effects of road width, curvature, direction of curve and sequence between road sections were reproduced on the simulator, and there were very high correlations between speed along the real road and speeds in the simulator.

Prior to the experimental drive, participants completed a fifteen minute familiarisation drive. The drive comprised urban, rural and motorway sections, similar to the experimental drive, but contained none of the scenarios under investigation. Once the familiarisation drive was completed, drivers were deemed ready to proceed to the next stage. The experimental route was approximately 22 miles in length and comprised of urban, rural and motorway environments, providing a range of speed limits between 30 and 70 mph. Other cars in the scenario provided the opportunity of simulating overtaking scenarios, gap acceptance tasks and car-following situations. The road environment also featured traffic lights and pelican crossings in order to instigate possible violation scenarios; and sub-standard curves were included in both the urban and rural sections.

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

Three car following situations were engineered requiring drivers to maintain their desired headway over a section of road. They were unable to pass the slow moving car in front due to oncoming traffic. These situations allowed measurement of minimum time to collision and variation in headway. In addition, two overtaking scenarios were created: here oncoming traffic was present, but it had sufficient gaps to allow the driver to pass. Propensity to overtake and proximity to the oncoming car were measured. An additional overtaking scenario was created, again using a slow moving vehicle in front. Here drivers were constrained by double white lines; if they chose to overtake, a violation was recorded.

Four sets of traffic lights were placed in the road network. One was programmed to change from green to red as the driver approached. This required the driver to make a stop/go decision, and a violation was recorded if the driver passed through on the red light. Two gap acceptance tasks were

incorporated into the road network. The first required the driver to merge from the minor road onto the major road, making a left turn. Traffic on the major road was approaching from the right with varying gaps. The second required the driver to make a right turn across oncoming traffic from a major to a minor road. Again the cars were separated with varying gaps.

Attention to surprise events was measured in terms of performance on a choice reaction task incorporated into the road network. Drivers were required to respond to red and green squares that appeared in front of them. If the square was green, they were asked to ignore it and continue driving. If 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 20 participants should be tested (minimum group size=9). 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 had been driving for less than 5 years. A roughly equal number proportion of males and females were recruited and all ll volunteers were paid for their participation.

	Sample 1 (Healthy)	*Sample 2 (Colds)*
Males/females	*4/6*	*10/5*
Mean age (males)	*20 years (range: 18-21)*	*20 years (range: 18-25)*
Mean age (females)	*22 years (range: 20-24)*	*21 years (range: 19-24)*

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.

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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

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

Driving performance

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

Speed

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

Lateral control

Edgeline/centre line encroachments were not significantly altered as a function of health status nor was the standard deviation of lane position (s.d. 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 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).

It can be seen that those drivers who reported cold symptoms spent 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 3).

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 first session it was located at the end of the road network and in the second

session it was moved to half way along the network. Secondly, as a measure of anticipation, speed measures were recorded within the vicinity of the event. Thus, speed was measured at 50 metres before the event (50 metres was chosen as drivers could see the pedestrian but had not yet begun to brake). In addition, speed was also measured at the point at which they initially began to brake. There were no significant difference in these values between the first and the second driving session. This indicates that drivers were not anticipating the event in the second session.

These results demonstrate that drivers with reported symptoms of minor respiratory illnesses are impaired to the extent that they have longer response times and thus negative safety effects with regards to critical events in the driving environment.

Traffic light violations

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

Discussion

The present results confirm the earlier findings that having a cold may impair aspects of simulated driving performance. There appears to be reliable evidence that volunteers presenting with symptoms respond more slowly to unexpected events and spent a greater percentage of time driving too close to the car in front compared with healthy volunteers. As described in the introduction, this decrement in driving performance could have implications for road safety. The slowing of reaction times associated with having a cold is comparable to effects of known hazards, such as consumption of a dose of alcohol that would lead to a ban from driving (80mg alcohol/100ml blood) or

having to perform at night. The OMEDA task also demonstrated that those suffering from a cold were less able to detect potential collisions. Comparison with a previous study[11] using elderly participants (over 65 years) shows that the detection performance of young adults with a cold falls to that of elderly drivers. There is now a need for an information campaign to provide accurate information about the potential hazards associated with driving while suffering from an upper respiratory tract illness.

There is also evidence that the direct effects of having a cold are not the only ones that need to be considered. A number of studies have shown that individuals who are ill are more susceptible to the effects of other factors which could influence driving (alcohol[13]; prolonged work[14]; and noise[15]). Research also shows that impairments associated with the common cold are not restricted to the time the person is symptomatic but may be observed in the incubation period and a few days after symptoms have gone[6].

One must now ask what underlies the effects here. Previous research has shown that the low alertness state associated with a cold can be reversed by a drug which increases the turnover of central noradrenaline[16]. Indeed, ingestion of caffeine, which increases alertness, has been shown to remove the cold induced performance impairments seen in laboratory tasks[17]. This suggests that a further study examining whether caffeine can remove the effects found here is required. Similarly, it will be important to determine whether medications aimed at producing symptomatic relief also remove the behavioural problems associated with the common cold.

In summary, the present study has used established methods to examine effects of the common cold on simulated driving and collision detection. The findings that having a cold reduces the ability to detect collisions and respond quickly to unexpected events are of practical importance and can be related to plausible underlying mechanisms. The study was small scale using relatively inexperienced drivers and further research is required to determine whether 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 awareness of these effects by using information campaigns and 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% (5.4)	51.7 (4.3)	F = 4.80, p <0.05

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

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

Copyright

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

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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.

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 studies[1], 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 campaigns[2] 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 case[7]. This has been confirmed in a survey[8] 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 task[8] 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 2.3m (7.5ft) onto the normal stopping distance of 96m (315ft) if travelling at 70mph (113km/h).

Research using a simple driving simulator[9] (resembling a computer game) has shown thate people with an upper respiratory tract illness responded more slowly to unexpected events and were more likely to steer inaccurately. Another study[10] using a very realistic driving simulator found that basic driving skills were not impaired but that situational awareness was reduced when the person had a cold. The present study continued to examine this topic in detail, using a sophisticated simulation that incorporates the skills necessary for safe driving. In addition, the study also included a laboratory task which evaluated participants' ability to detect potential collisions[11] which is a key skill in driving but also something that cannot be repeatedly examined in a simulator.

Method

The study was carried out with the approval of the ethics committee, School of Psychology, Cardiff University, and the informed consent of the volunteers.

Experimental design

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

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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. Those who were healthy at session 1 returned for their second session approximately a week later. 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.

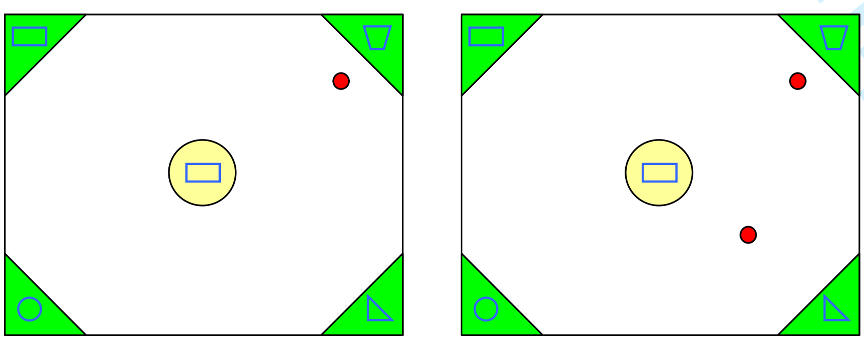
OMEDA (Object Movement Estimation under Divided Attention)

OMEDA[11] is a computerised dual-task with two parts. Part 1 of OMEDA allows experimenters to obtain an individual's error in Time-To-Collision (TTC) estimation. Different target speeds can be simulated, as can various degrees of occlusion. A secondary task is also incorporated in the form of a visual divided attention task. This requires the identification of peripheral duplication of stimuli presented centrally (in this case geometrical shapes).

Part 2 of OMEDA provides a quantified estimate of collision detection error under various degrees of occlusion and for a series of target speeds, with the same secondary task as for Part 1. Participants do not need to be computer literate in order to be able to do this task, as the response keys are a foot pedal (for the primary task) and a hand button (for the secondary task).

In Part 1 the participant is presented with a computer screen where the corners are covered by green triangles and in the centre of the screen is a yellow circle. The yellow circle varies in size between two and 250 pixels. From one of the four corners (randomly allocated), a red target, in the form of a circle travels towards the middle of the screen. Once it reaches the edge of the yellow circle, it travels underneath it and it is not visible. Therefore, the larger the circle, the more difficult is the task, due to a longer occlusion time. The participant is asked to estimate exactly when the target reaches the middle of the computer screen. They are instructed to press a foot pedal at the exact point the target reaches the middle.

In~~To~~ order to simulate divided attention, whilst participants are estimating when the target reaches the middle of the screen, they are required to complete a pattern matching task. When the target is moving, five shapes appear on the screen (one overlaid on the yellow circle and one in each of the four corners). Participants are instructed to press a hand button immediately if the shape in the middle matches any of those in the four corners of the screen.



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 120º forward view and 50º 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.

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

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

Three car following situations were engineered requiring drivers to maintain their desired headway over a section of road. They were unable to pass the slow moving car in front due to oncoming traffic. These situations allowed measurement of minimum time to collision and variation in headway. In addition, two overtaking scenarios were created: here oncoming traffic was present, but it had sufficient gaps to allow the driver to pass. Propensity to overtake and proximity to the oncoming car were measured. An additional overtaking scenario was created, again using a slow moving vehicle in front. Here drivers were constrained by double white lines; if they chose to overtake, a violation was recorded.

Four sets of traffic lights were placed in the road network. One was programmed to change from green to red as the driver approached. This required the driver to make a stop/go decision, and a violation was recorded if the driver passed through on the red light. Two gap acceptance tasks were incorporated into the road network. The first required the driver to merge from the minor road onto the major road, making a left turn. Traffic on the major road was approaching from the right with varying gaps. The second required the driver to make a right turn across oncoming traffic from a major to a minor road. Again the cars were separated with varying gaps.

Attention to surprise events was measured in terms of performance on a choice reaction task incorporated into the road network. Drivers were required to respond to red and green squares that appeared in front of them. If the square was green, they were asked to ignore it and continue driving. If 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 204 participants should be tested (minimum group size=9). 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 had been driving for less than 5 years. ~~and~~ A~~a~~ roughly equal number proportion of males and females were recruited and all ~~. A~~ll volunteers were paid for their participation.

	Sample 1 (Healthy)	Sample 2 (Colds)
Males/females	*4/6*	*10/5*
Mean age (males)	*20 years (range: 18-21)*	*20 years (range: 18-25)*
Mean age (females)	*22 years (range: 20-24)*	*21 years (range: 19-24)*

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 21.

.

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

Driving performance

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

Speed

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

Lateral control

Edgeline/centre line encroachments were not significantly altered as a function of health status nor was the standard deviation of lane position (s.d.

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 groupssessions.

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).

It can be seen that those drivers who reported cold symptoms ~~were more likely to~~ spent~~d~~ 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 3~~2~~).

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, t~~T~~he 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 first session it was located at the end of the road network and in the second session it was moved to half way along the network. Secondly, as a measure of anticipation, speed measures were recorded within the vicinity of the event. Thus, speed was measured at 50 metres before the event (50 metres was chosen as drivers could see the pedestrian but had not yet begun to brake). In addition, speed was also measured at the point at which they initially began to brake. There were no significant difference in these values between the first and the second driving session. This indicates that drivers were not anticipating the event in the second session.

These results demonstrate that drivers with reported symptoms of minor respiratory illnesses are impaired to the extent that they have longer response times and thus negative safety effects with regards to critical events in the driving environment.

Traffic light violations

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

Discussion

The present results confirm the earlier findings that having a cold may impair aspects of simulated driving performance. There appears to be reliable evidence that volunteers presenting with symptoms respond more slowly to unexpected events and spent a greater percentage of time driving too close to the car in front compared with healthy volunteers ~~drive too closely to the car in front~~. As described in the introduction, this decrement in driving performance could have implications for road safety. The slowing of reaction times associated with having a cold is comparable to effects of known hazards, such as consumption of a dose of alcohol that would lead to a ban from driving (80mg alcohol/100ml blood) or having to perform at night. The OMEDA task also demonstrated that those suffering from a cold were less able to detect potential collisions. Comparison with a previous study[11] using elderly participants (over 65 years) shows that the detection performance of young adults with a cold falls to that of elderly drivers. There is now a need for an information campaign to provide accurate information about the potential hazards associated with driving while suffering from an upper respiratory tract illness.

There is also evidence that the direct effects of having a cold are not the only ones that need to be considered. A number of studies have shown that individuals who are ill are more susceptible to the effects of other factors which could influence driving (alcohol[13]; prolonged work[14]; and noise[15]). Research also shows that impairments associated with the common cold are not restricted to the time the person is symptomatic but may be observed in the incubation period and a few days after symptoms have gone[6].

One must now ask what underlies the effects here. Previous research has shown that the low alertness state associated with a cold can be reversed by a drug which increases the turnover of central noradrenaline[16]. Indeed, ingestion of caffeine, which increases alertness, has been shown to remove the cold induced performance impairments seen in laboratory tasks[17]. This suggests that a further study examining whether caffeine can remove the effects found here is required. Similarly, it will be important to determine whether medications aimed at producing symptomatic relief also remove the behavioural problems associated with the common cold.

In summary, the present study has used established methods to examine effects of the common cold on simulated driving and collision detection. The findings that having a cold reduces the ability to detect collisions and respond quickly to unexpected events are of practical importance and can be related to plausible underlying mechanisms. The study was small scale using relatively inexperienced drivers and further research is required to determine whether 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 usinge ~~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 <0.0512
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 12. Performance of healthy and unhealthy drivers on the divided attention part of 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

	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	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 < 0.05p <0.05
Target 2	0.95	1.21	F = 6.09,
	(0.0.6)	(0.06)	p < 0.05p< 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”.

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

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An investigation of the effects of the common cold on simulated driving 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 studies[1], 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 campaigns[2] 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 morecrashes. Anecdotal evidence, largely consisting of case reports, suggests that this is the case[7]. This has been confirmed in a survey[8] 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 task[8] 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

2.3m (7.5ft) onto the normal stopping distance of 96m (315ft) if travelling at 70mph (113km/h).

Research using a simple driving simulator[9] (resembling a computer game) has shown that people with an upper respiratory tract illness responded more slowly to unexpected events and were more likely to steer inaccurately. Another study[10] using a very realistic driving simulator found that basic driving skills were not impaired but that situational awareness was reduced when the person had a cold. The present study continued to examine this topic in detail, using a sophisticated simulation that incorporates the skills necessary for safe driving. In addition, the study also included a laboratory task which evaluated participants' ability to detect potential collisions[11] which is a key skill in driving but also something that cannot be repeatedly examined in a simulator.

Method

The study was carried out with the approval of the ethics committee, School of Psychology, Cardiff University, and the informed consent of the volunteers.

Experimental design

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

Procedure

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 using a 5 point rating scale (0=not all to 4= very severe). If volunteers scored above 8 on symptoms typical of a cold (pain in chest, sore throat, headache, sneezing, runny nose, blocked nose, hoarseness, cough, hot/cold, sweating, shivering, fever, and phlegm) they were included in the cold group. Healthy volunteers were only included if they had a symptom score of 3 or less (based on the upper respiratory tract symptoms and other symptoms of minor illnesses such as digestive problems).Volunteers were excluded if they were taking medication for their colds. All volunteers were tested when their illness had been present for at least 24 hours and no longer than 96 hours.

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. Those who were healthy at session 1 returned for their second session approximately a week later. 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.

OMEDA (Object Movement Estimation under Divided Attention)

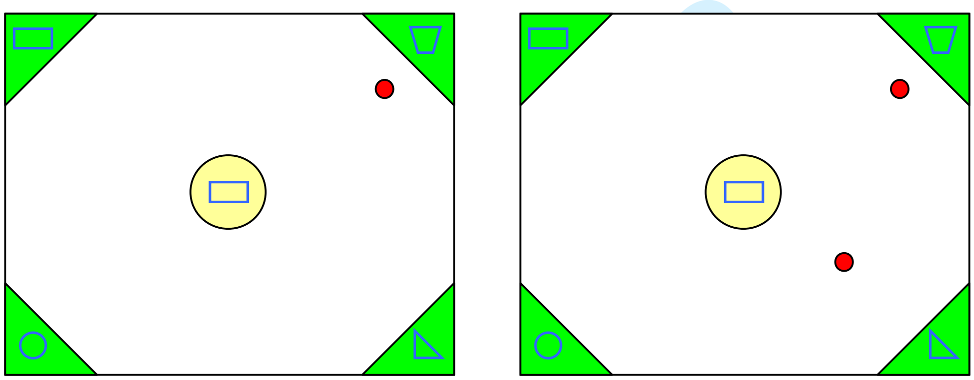
OMEDA[11] is a computerised dual-task with two parts. Part 1 of OMEDA allows experimenters to obtain an individual's error in Time-To-Collision (TTC) estimation. Different target speeds can be simulated, as can various degrees of occlusion. A secondary task is also incorporated in the form of a visual divided attention task. This requires the identification of peripheral duplication of stimuli presented centrally (in this case geometrical shapes).

Part 2 of OMEDA provides a quantified estimate of collision detection error under various degrees of occlusion and for a series of target speeds, with the

same secondary task as for Part 1. Participants do not need to be computer literate in order to be able to do this task, as the response keys are a foot pedal (for the primary task) and a hand button (for the secondary task).

In Part 1 the participant is presented with a computer screen where the corners are covered by green triangles and in the centre of the screen is a yellow circle. The yellow circle varies in size between two and 250 pixels. From one of the four corners (randomly allocated), a red target, in the form of a circle travels towards the middle of the screen. Once it reaches the edge of the yellow circle, it travels underneath it and it is not visible. Therefore, the larger the circle, the more difficult is the task, due to a longer occlusion time. The participant is asked to estimate exactly when the target reaches the middle of the computer screen. They are instructed to press a foot pedal at the exact point the target reaches the middle.

In order to simulate divided attention, whilst participants are estimating when the target reaches the middle of the screen, they are required to complete a pattern matching task. When the target is moving, five shapes appear on the screen (one overlaid on the yellow circle and one in each of the four corners). Participants are instructed to press a hand button immediately if the shape in the middle matches any of those in the four corners of the screen.



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 120º forward view and 50º 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.

Studies[12] have evaluated the behavioural validity of the simulator. The results showed that overall there was a broad correspondence between driving in the simulator and the behaviour of real-world traffic. With regard to speed, the effects of road width, curvature, direction of curve and sequence between road sections were reproduced on the simulator, and there were very high correlations between speed along the real road and speeds in the simulator.

Prior to the experimental drive, participants completed a fifteen minute familiarisation drive. The drive comprised urban, rural and motorway sections, similar to the experimental drive, but contained none of the scenarios under investigation. Once the familiarisation drive was completed, drivers were deemed ready to proceed to the next stage. The experimental route was approximately 22 miles in length and comprised of urban, rural and motorway environments, providing a range of speed limits between 30 and 70 mph. Other cars in the scenario provided the opportunity of simulating overtaking scenarios, gap acceptance tasks and car-following situations. The road environment also featured traffic lights and pelican crossings in order to instigate possible violation scenarios; and sub-standard curves were included in both the urban and rural sections.

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

Three car following situations were engineered requiring drivers to maintain their desired headway over a section of road. They were unable to pass the slow moving car in front due to oncoming traffic. These situations allowed measurement of minimum time to collision and variation in headway. In addition, two overtaking scenarios were created: here oncoming traffic was present, but it had sufficient gaps to allow the driver to pass. Propensity to overtake and proximity to the oncoming car were measured. An additional overtaking scenario was created, again using a slow moving vehicle in front. Here drivers were constrained by double white lines; if they chose to overtake, a violation was recorded.

Four sets of traffic lights were placed in the road network. One was programmed to change from green to red as the driver approached. This required the driver to make a stop/go decision, and a violation was recorded if the driver passed through on the red light. Two gap acceptance tasks were

incorporated into the road network. The first required the driver to merge from the minor road onto the major road, making a left turn. Traffic on the major road was approaching from the right with varying gaps. The second required the driver to make a right turn across oncoming traffic from a major to a minor road. Again the cars were separated with varying gaps.

Attention to surprise events was measured in terms of performance on a choice reaction task incorporated into the road network. Drivers were required to respond to red and green squares that appeared in front of them. If the square was green, they were asked to ignore it and continue driving. If 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 20 participants should be tested (minimum group size=9). 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 had been driving for less than 5 years. A roughly equal number proportion of males and females were recruited and all ll volunteers were paid for their participation.

	Sample 1 (Healthy)	*Sample 2 (Colds)*
Males/females	*4/6*	*10/5*
Mean age (males)	*20 years (range: 18-21)*	*20 years (range: 18-25)*
Mean age (females)	*22 years (range: 20-24)*	*21 years (range: 19-24)*

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.

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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

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

Driving performance

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

Speed

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

Lateral control

Edgeline/centre line encroachments were not significantly altered as a function of health status nor was the standard deviation of lane position (s.d. 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 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).

It can be seen that those drivers who reported cold symptoms spent 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 3).

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 first session it was located at the end of the road network and in the second

session it was moved to half way along the network. Secondly, as a measure of anticipation, speed measures were recorded within the vicinity of the event. Thus, speed was measured at 50 metres before the event (50 metres was chosen as drivers could see the pedestrian but had not yet begun to brake). In addition, speed was also measured at the point at which they initially began to brake. There were no significant difference in these values between the first and the second driving session. This indicates that drivers were not anticipating the event in the second session.

These results demonstrate that drivers with reported symptoms of minor respiratory illnesses are impaired to the extent that they have longer response times and thus negative safety effects with regards to critical events in the driving environment.

Traffic light violations

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

Discussion

The present results confirm the earlier findings that having a cold may impair aspects of simulated driving performance. There appears to be reliable evidence that volunteers presenting with symptoms respond more slowly to unexpected events and spent a greater percentage of time driving too close to the car in front compared with healthy volunteers. As described in the introduction, this decrement in driving performance could have implications for road safety. The slowing of reaction times associated with having a cold is comparable to effects of known hazards, such as consumption of a dose of alcohol that would lead to a ban from driving (80mg alcohol/100ml blood) or

having to perform at night. The OMEDA task also demonstrated that those suffering from a cold were less able to detect potential collisions. Comparison with a previous study[11] using elderly participants (over 65 years) shows that the detection performance of young adults with a cold falls to that of elderly drivers. There is now a need for an information campaign to provide accurate information about the potential hazards associated with driving while suffering from an upper respiratory tract illness.

There is also evidence that the direct effects of having a cold are not the only ones that need to be considered. A number of studies have shown that individuals who are ill are more susceptible to the effects of other factors which could influence driving (alcohol[13]; prolonged work[14]; and noise[15]). Research also shows that impairments associated with the common cold are not restricted to the time the person is symptomatic but may be observed in the incubation period and a few days after symptoms have gone[6].

One must now ask what underlies the effects here. Previous research has shown that the low alertness state associated with a cold can be reversed by a drug which increases the turnover of central noradrenaline[16]. Indeed, ingestion of caffeine, which increases alertness, has been shown to remove the cold induced performance impairments seen in laboratory tasks[17]. This suggests that a further study examining whether caffeine can remove the effects found here is required. Similarly, it will be important to determine whether medications aimed at producing symptomatic relief also remove the behavioural problems associated with the common cold.

In summary, the present study has used established methods to examine effects of the common cold on simulated driving and collision detection. The findings that having a cold reduces the ability to detect collisions and respond quickly to unexpected events are of practical importance and can be related to plausible underlying mechanisms. The study was small scale using relatively inexperienced drivers and further research is required to determine whether 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 awareness of these effects by using information campaigns and 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% (5.4)	51.7 (4.3)	F = 4.80, p <0.05

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

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

Copyright

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

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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 reduceds 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 studies[1], 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 campaigns[2] 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 morecrashes. Anecdotal evidence, largely consisting of case reports, suggests that this is the case[7]. This has been confirmed in a survey[8] 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 task[8] 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

2.3m (7.5ft) onto the normal stopping distance of 96m (315ft) if travelling at 70mph (113km/h).

Research using a simple driving simulator[9] (resembling a computer game) has shown that people with an upper respiratory tract illness responded more slowly to unexpected events and were more likely to steer inaccurately. Another study[10] using a very realistic driving simulator found that basic driving skills were not impaired but that situational awareness was reduced when the person had a cold. The present study continued to examine this topic in detail, using a sophisticated simulation that incorporates the skills necessary for safe driving. In addition, the study also included a laboratory task which evaluated participants' ability to detect potential collisions[11] which is a key skill in driving but also something that cannot be repeatedly examined in a simulator.

Method

The study was carried out with the approval of the ethics committee, School of Psychology, Cardiff University, and the informed consent of the volunteers.

Experimental design

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

Procedure

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 using a 5 point rating scale (0=not all to 4= very severe). If volunteers scored above 8 on symptoms typical of a cold (pain in chest, sore throat, headache, sneezing, runny nose, blocked nose, hoarseness, cough, hot/cold, sweating, shivering, fever, and phlegm) they were included in the cold group. Healthy volunteers were only included if they had a symptom score of 3 or less (based on the upper respiratory tract symptoms and other symptoms of minor illnesses such as digestive problems).Volunteers were excluded if they were taking medication for their colds. All volunteers were tested when their illness had been present for at least 24 hours and no longer than 96 hours.

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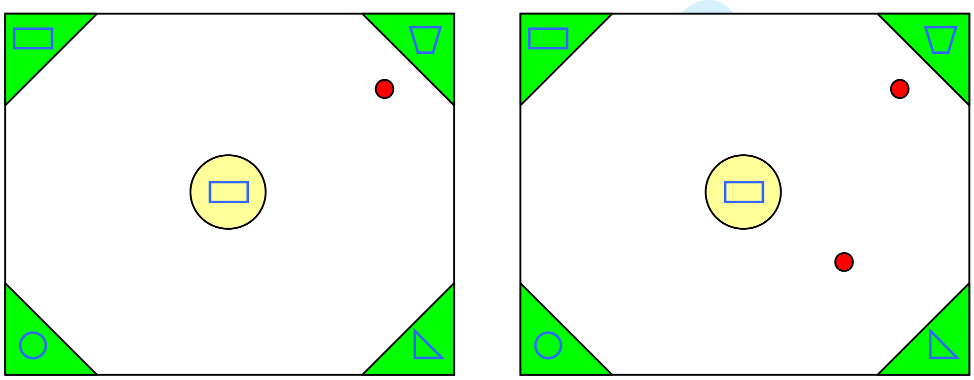
Part 2 of OMEDA provides a quantified estimate of collision detection error under various degrees of occlusion and for a series of target speeds, with the

same secondary task as for Part 1. Participants do not need to be computer literate in order to be able to do this task, as the response keys are a foot pedal (for the primary task) and a hand button (for the secondary task).

In Part 1 the participant is presented with a computer screen where the corners are covered by green triangles and in the centre of the screen is a yellow circle. The yellow circle varies in size between two and 250 pixels. From one of the four corners (randomly allocated), a red target, in the form of a circle travels towards the middle of the screen. Once it reaches the edge of the yellow circle, it travels underneath it and it is not visible. Therefore, the larger the circle, the more difficult is the task, due to a longer occlusion time. The participant is asked to estimate exactly when the target reaches the middle of the computer screen. They are instructed to press a foot pedal at the exact point the target reaches the middle.

In order to simulate divided attention, whilst participants are estimating when the target reaches the middle of the screen, they are required to complete a pattern matching task. When the target is moving, five shapes appear on the screen (one overlaid on the yellow circle and one in each of the four corners). Participants are instructed to press a hand button immediately if the shape in the middle matches any of those in the four corners of the screen.



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 120º forward view and 50º 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.

Studies[12] have evaluated the behavioural validity of the simulator. The results showed that overall there was a broad correspondence between driving in the simulator and the behaviour of real-world traffic. With regard to speed, the effects of road width, curvature, direction of curve and sequence between road sections were reproduced on the simulator, and there were very high correlations between speed along the real road and speeds in the simulator.

Prior to the experimental drive, participants completed a fifteen minute familiarisation drive. The drive comprised urban, rural and motorway sections, similar to the experimental drive, but contained none of the scenarios under investigation. Once the familiarisation drive was completed, drivers were deemed ready to proceed to the next stage. The experimental route was approximately 22 miles in length and comprised of urban, rural and motorway environments, providing a range of speed limits between 30 and 70 mph. Other cars in the scenario provided the opportunity of simulating overtaking scenarios, gap acceptance tasks and car-following situations. The road environment also featured traffic lights and pelican crossings in order to instigate possible violation scenarios; and sub-standard curves were included in both the urban and rural sections.

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

Three car following situations were engineered requiring drivers to maintain their desired headway over a section of road. They were unable to pass the slow moving car in front due to oncoming traffic. These situations allowed measurement of minimum time to collision and variation in headway. In addition, two overtaking scenarios were created: here oncoming traffic was present, but it had sufficient gaps to allow the driver to pass. Propensity to overtake and proximity to the oncoming car were measured. An additional overtaking scenario was created, again using a slow moving vehicle in front. Here drivers were constrained by double white lines; if they chose to overtake, a violation was recorded.

Four sets of traffic lights were placed in the road network. One was programmed to change from green to red as the driver approached. This required the driver to make a stop/go decision, and a violation was recorded if the driver passed through on the red light. Two gap acceptance tasks were

incorporated into the road network. The first required the driver to merge from the minor road onto the major road, making a left turn. Traffic on the major road was approaching from the right with varying gaps. The second required the driver to make a right turn across oncoming traffic from a major to a minor road. Again the cars were separated with varying gaps.

Attention to surprise events was measured in terms of performance on a choice reaction task incorporated into the road network. Drivers were required to respond to red and green squares that appeared in front of them. If the square was green, they were asked to ignore it and continue driving. If 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 20 participants should be tested (minimum group size=9). 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 had been driving for less than 5 years. A roughly equal number proportion of males and females were recruited and all ll volunteers were paid for their participation.

	Sample 1 (Healthy)	*Sample 2 (Colds)*
Males/females	*4/6*	*10/5*
Mean age (males)	*20 years (range: 18-21)*	*20 years (range: 18-25)*
Mean age (females)	*22 years (range: 20-24)*	*21 years (range: 19-24)*

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.

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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

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

Driving performance

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

Speed

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

Lateral control

Edgeline/centre line encroachments were not significantly altered as a function of health status nor was the standard deviation of lane position (s.d. 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 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).

It can be seen that those drivers who reported cold symptoms spent 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 3).

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 first session it was located at the end of the road network and in the second

session it was moved to half way along the network. Secondly, as a measure of anticipation, speed measures were recorded within the vicinity of the event. Thus, speed was measured at 50 metres before the event (50 metres was chosen as drivers could see the pedestrian but had not yet begun to brake). In addition, speed was also measured at the point at which they initially began to brake. There were no significant difference in these values between the first and the second driving session. This indicates that drivers were not anticipating the event in the second session.

These results demonstrate that drivers with reported symptoms of minor respiratory illnesses are impaired to the extent that they have longer response times and thus negative safety effects with regards to critical events in the driving environment.

Traffic light violations

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

Discussion

The present results confirm the earlier findings that having a cold may impair aspects of simulated driving performance. There appears to be reliable evidence that volunteers presenting with symptoms respond more slowly to unexpected events and spent a greater percentage of time driving too close to the car in front compared with healthy volunteers. As described in the introduction, this decrement in driving performance could have implications for road safety. The slowing of reaction times associated with having a cold is comparable to effects of known hazards, such as consumption of a dose of alcohol that would lead to a ban from driving (80mg alcohol/100ml blood) or

having to perform at night. The OMEDA task also demonstrated that those suffering from a cold were less able to detect potential collisions. Comparison with a previous study[11] using elderly participants (over 65 years) shows that the detection performance of young adults with a cold falls to that of elderly drivers. There is now a need for an information campaign to provide accurate information about the potential hazards associated with driving while suffering from an upper respiratory tract illness.

There is also evidence that the direct effects of having a cold are not the only ones that need to be considered. A number of studies have shown that individuals who are ill are more susceptible to the effects of other factors which could influence driving (alcohol[13]; prolonged work[14]; and noise[15]). Research also shows that impairments associated with the common cold are not restricted to the time the person is symptomatic but may be observed in the incubation period and a few days after symptoms have gone[6].

One must now ask what underlies the effects here. Previous research has shown that the low alertness state associated with a cold can be reversed by a drug which increases the turnover of central noradrenaline[16]. Indeed, ingestion of caffeine, which increases alertness, has been shown to remove the cold induced performance impairments seen in laboratory tasks[17]. This suggests that a further study examining whether caffeine can remove the effects found here is required. Similarly, it will be important to determine whether medications aimed at producing symptomatic relief also remove the behavioural problems associated with the common cold.

In summary, the present study has used established methods to examine effects of the common cold on simulated driving and collision detection. The findings that having a cold reduces the ability to detect collisions and respond quickly to unexpected events are of practical importance and can be related to plausible underlying mechanisms. The study was small scale using relatively inexperienced drivers and further research is required to determine whether 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 awareness of these effects by using information campaigns and 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% (5.4)	51.7 (4.3)	F = 4.80, p <0.05

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

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