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Driving on Rough Surface Requires Care and Attention

Akira Kawamura [a], Kazuya Tomiyama [a], Riccardo Rossi [b]*, Massimiliano Gastaldi [b], Claudio Mulatti [c]

[a]*Kitami Isstitue of Technology, Department of Civil and Environmental Engineering, 165 Koen-cho, Kitami 090-8507, Japan*
[b]*University of Padova, Department of Civil and Environmental Engineering, via Marzolo 9, Padova 35131, Italy*
[c]*University of Padova, Department of Developmental Psychology, Via Venezia 8, Padova 35131, Italy*

Abstract

The main aim of this work was to understand to what extent driving on a poor-quality surface requires more central, attentional resources than driving on a smooth surface. A dual-task experiment was devised in which participants were asked to perform two tasks concurrently: the first, main task was simulated driving. Participants drove on three kinds of surface: smooth, rough, and very rough, the surface quality defined according to the International Roughness Index. The second task was one of tone discrimination: participants listened to one of three possible tones of differing pitch and were asked to classify it verbally according to its pitch. Both Reaction Times and error rates were used.
The following prediction was tested: if the quality of the road surface affects attentional resources while driving, then, as the quality of the road surface deteriorates, the interference which driving exerts on tone discrimination should increase.
Results showed that, as the quality of the road surface worsened, RTs in the tone discrimination task tended to decrease and errors to increase.
This finding is clearly of interest as regards safety: a functionally compromised surface not only affects the external, physical aspects of the driver/vehicle pair, but also the driver's cognitive level, with a potentially dangerous fall in accurate coping with driving at the same time, and on the monitoring and interpretation of sources of danger while driving.
As results showed that surfaces of different qualities directly affect cognition, this work appears to be significant and involves socially useful developments.

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Keywords: Road safety; Road roughness; Driver performance; Driving simulator

* Corrisponding author
E-mail address: Riccardo.rossi@unipd.it

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1. Introduction

This work regards the effects of the quality - or state or roughness - of road surfaces on drivers' attentional resources. We were interested in understanding to what extent driving on an uneven, rough surface requires more attentional resources than driving on a smooth, plain one. The literature contains many studies concerning the effects of road surface roughness on drivers' behavior: roughness not only negatively affects their performance, but this negative impact is usually amplified by irregularities in the roadway (e.g., curves, bulges, pot-holes, etc.) (Baldock et al., 2008). Increases in roughness negatively affect vehicle speeds (Yu and Lu, 2014) and lead to a reduction in perceived ride comfort (Ihs, 2004). It has also been reported (Edquist et al., 2009; Martens et al. 1997) that drivers reduce their speed in order to lessen the noise and vibration caused by rough road surfaces. In this sense, road roughness may be viewed as a determinant in drivers' speed control. Roughness has also been found to affect drivers' capability to control their vehicles (Elliot et al., 2003). This leads us to consider as potentially dangerous any sudden variations in road roughness, especially when drivers cannot appropriately deal with them by, for example, slackening speed.

In the light of these premises, analysis of the effect of road roughness on drivers' performance becomes of interest, because of its implications for vehicle control and road safety.

To study whether increased roughness is associated with increased attentional demands on drivers, we carried out a dual-task experiment (Pashler, 1994) in which participants were asked to perform two tasks simultaneously.

The first, main task was (simulated) driving. Participants drove on three kinds of surface: smooth, rough, and very rough. The quality of the road surface was defined in terms of the International Roughness Index (IRI). Developed by the World Bank in the 1980s, this is a profile-based roughness statistic which has become a standard indicator of road roughness world-wide (Sayers et al., 1986). The concept underlying the IRI calculation is that of modeling a quarter of a car moving on the road surface and calculating the accumulated suspension deformation divided by the distance traveled by the quarter part. According to the IRI scale, IRIs of 1, 6 and 12 mm/m (those used in this study) approximately correspond to "Airport Runways & Superhighways", "Older Pavements & Maintained Unpaved Roads" and "Damaged Pavements & Rough Unpaved Roads", respectively.

The second, concurrent task involved tone discrimination. In each trial, participants wore headsets through which they listened to one of three possible tones of different pitch and were asked to classify it according to its pitch. Both Reaction Times (RTs, measured from the onset of the tone to the onset of the drivers' verbal responses) and error rates were used.

The logic underlying our manipulation is straightforward and rests on the assumption that central attentional resources are limited (Pashler, 1994; Logan et al. 2001; Meyer and Kieras, 1997). If two tasks are to be performed simultaneously and both use central attentional resources, then the two tasks compete for gaining access to the capacity-limited, central attentional mechanism.

In the tone discrimination task, participants were asked to select the correct response from three alternatives as quickly as possible. Although it was relatively simple, the process of mapping the correct response to the presented stimulus requires central resources (Pashler, 1994), at least if the driver is under pressure, e.g., due to lack of time. Instead, driving - whether on a road or in a driving simulator - is a complex task involving at least continuous monitoring of the environment, including the behavior of the vehicle, quite detailed decision-making, and action coordination and execution. Not surprisingly, it has been shown that driving requires central resources (Levy et al., 2006; Rossi et al., 2012).

Thus, if a tone must be discriminated rapidly while driving, this very action will compete with tone discrimination to gain access to attentional resources. That is, driving - the main task - will interfere with tone discrimination. The extent to which this will happen clearly depends on the amount of attentional resources driving requires: the more resources required, the more strongly driving will interfere with tone discrimination. Thus, if the quality of the road surface affects attentional resources during driving, then, as the quality of the road surface worsens - i.e., as the IRI increases - the interference driving exerts on tone discrimination should increase. As the IRI increases from 1 to 6 to 12 mm/m, either RTs or error rates in tone discrimination should also increase. This prediction was tested in our experiment.