"Full monty" or low-key: two traffic management approaches and their effect on change perception

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Abstract

European road authorities differ in their views on whether variable-message signs (VMSs) can be in use continually or that they should only display information when necessary. This study compared the two approaches in terms of the ease with which drivers perceive changes in traffic management information on VMSs. In a 2x3 design, change detection for variable speed limits on VMSs was measured for information addition and information change under three conditions of information discriminability. Participants were shown videos of a single motorway – in order to create a more natural setting in which they are familiar with the road – while using an intentional approach in which participants were aware that something could change. The preliminary results are discussed in relation to detectability of, recollection of, and expectations about the new speed limit. This research gives more insight into change detection failure for the two traffic management approaches and possible countermeasures.

Introduction

On a vast majority of the many European motorways drivers may encounter one or more varieties of dynamic traffic management (DTM). Most of the DTM information is presented on variable-message signs (VMSs) and may include information regarding delays, route advice, road work warnings, graphic congestion displays, dynamic lane closures and variable speed limits. Road authorities like to use DTM as it enables them to influence real-time driver behaviour, by just changing the information for drivers to fit the present situation on the road and/or the road network. In this way road authorities can improve both traffic safety as well as traffic circulation. As congestions dissolve and road works stop at a certain moment, DTM information does not have to be displayed continually. When not in use for DTM, VMSs may therefore be left blank or display other information, for example road safety messages, information on the weather, and amber alert (Tay & de Barros, 2010). However, VMSs and their maintenance are costly. For this reason, among others, some road authorities might argue it is better to use VMSs continually while others feel that the VMSs should only display information when necessary for DTM purposes.

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One question is: will drivers still detect changes in DTM information if the VMSs are in use continually? Studies have shown that our ability to detect changes around us is limited (for a review see Simons & Levin, 1997) and that this visual limitation also applies to the driving domain (Velichkovsky et al., 2002; McCarley et al., 2004; Caird et al., 2005; Lee et al., 2007; Galpin et al., 2009; White & Caird, 2010; Martens, 2011; Koustanaï et al., 2012). This limitation in detecting changes which are in fact clearly visible is called change blindness. In semi-naturalistic studies in which drivers were familiarised with a route in a driving simulator, drivers failed to notice changes in driving related stimuli, such as fixed road signs, the priority at an intersection and variable speed limits on gantries (Martens & Fox, 2007; Charlton & Starkey, 2011; Harms, 2012). Even changes that are expected may still go unobserved (Rensink et al., 1997). Harms (2012) found that in her repeated measures driving simulator study, nine out of twenty-four participants expected that the speed limits on VMSs could change while only five of them actually detected the change.

Changes are regularly accompanied by other transient stimuli that catch attention. When transient motion signals are masked the changing object will be more difficult to detect. Such masking could occur due to a lapse of time, also known as gap-contingency. This occurs when items change during a temporal gap (Rensink, 2002). From the driver's seat of a car that speeds along a motorway, DTM information displayed on subsequent intermittent overhead gantries can be regarded as a continuous flow of information interrupted by lapses of time necessary to drive from one gantry to the next. Transient motion signals that accompany a change in the DTM information while driving to the next gantry, will be masked by the temporal gap that resulted from the lapse of time. This makes it more difficult to detect the change. Studies have also shown that it is more difficult to detect a change when already visible information changes slightly as compared to information that is added to a scene (for a review see Rensink, 2002). Therefore the current research focusses on the ease of detecting and identifying changes in information on VMSs which are left blank occasionally as compared to VMSs which are used continually and examines the effect of adding transient motion signals as a possible countermeasure for change detection failures.

Method

Experimental design

Using an intentional approach, in which the observer is instructed to fully expect a change and devotes all available resources to detecting it (cf. Simons & Mitroff, 2001), participants were shown fifteen short videos and one practice video. All videos represented a motorway equipped with three gantries displaying variable speed limits (VSLs) on electronic signs per driving lane, similar to Harms (2012). To familiarise participants with the motorway and its surroundings, the first video was displayed unchanged and viewed thirteen times. To prevent any interference from participants who might expect the change to happen in the last (15^{th}) video, the change was introduced in the 14^{th} video. In this video, the VSLs were changed from 100 km/h to 80 km/h on the second and the third gantries. Video 15 consisted of a recollection test.

In a 2x3 design, change detection was measured for information addition (IA) and information change (IC), under three conditions of information discriminability (see Table 1). In the IA condition, the VSL signs were always turned off, unless the speed limit changed; in the IC condition, the VSL signs were always turned on, hence depicting a speed limit on every VSL sign (see Figure 1). The three conditions of information discriminability varied in how the changed speed limit was displayed. In the Basic condition, it was displayed by solely depicting the speed limit itself; in the Flash condition, it was shown with alternating orange flashers; in the Wave condition, it appeared as if the depicted speed limit was moving in a wave-like manner (see Figure 2). To ensure that all participant groups were equally able to detect changes, participants were assigned to one of the six groups based on age and gender, as some studies reported an age-related decline in the detection of changes (Costello et al., 2010; Caird et al., 2005; Rizzo et al., 2009; Wascher et al., 2012).

Table 1. The 2x3 design

	Varieties of information discriminability		
	Basic	*Flash*	*Wave*
Information addition	Group 1	Group 2	Group 3
Information change	Group 4	Group 5	Group 6

Participants

One hundred an forty one participants completed the experiment, though only 133 participants did so successfully, since eight participants were excluded as they used a computer screen smaller than the video's resolution. Participants were recruited using invitations from both fellow participants and the researcher, including advertisements on the internet and an invitation on a birth announcement card. Participants' age varied from 19 to 75 years (*M* = 42.8 years, *SD* = 11.5), and both male and female Dutch drivers participated (86 males and 47 females). All participants possessed a driving licence and reported normal or corrected to normal eyesight. Participants were not paid for their participation. The groups of participants did not differ significantly for age, gender, education, years of driving licence possession and amount of kilometres driven in the past twelve months.

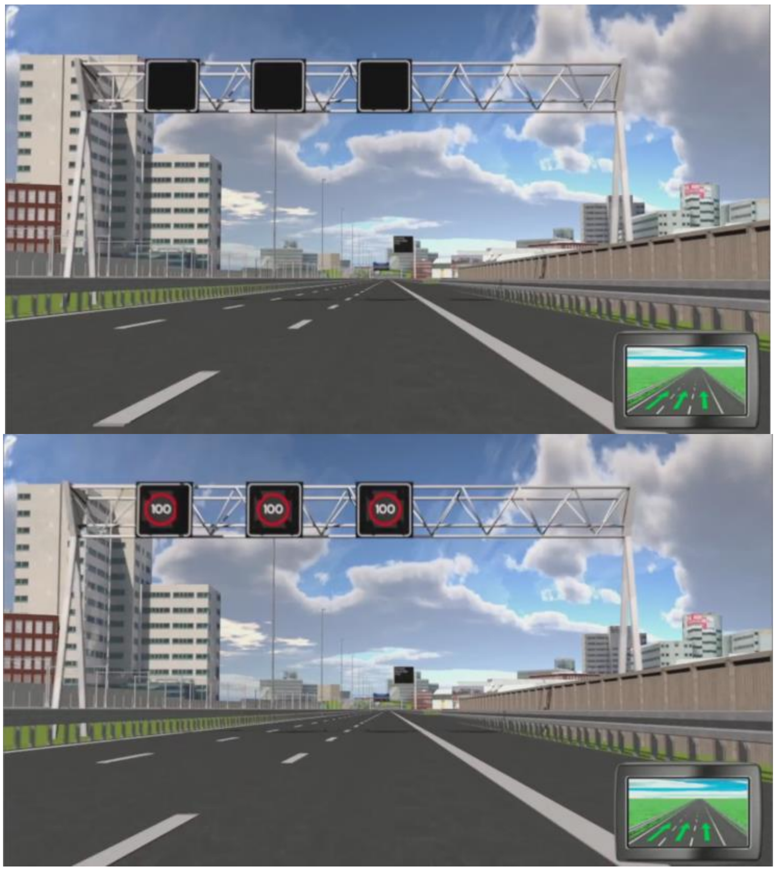

Figure 1. Screen shot of the second gantry in the information addition condition (top) and in the information change condition (bottom) in video 1 to 13.

Task

Participants were instructed they would see fifteen videos showing the same motorway from a driver's perspective. They were asked to imagine driving the car. In videos 1 to 14, participants had to detect and identify all changes between the current and the previous videos. It was pointed out that the number of changes they would encounter would vary between participants and that it could range from several changes to none at all; in fact, all participants encountered two changes in video 14. To report a change, participants had to press the spacebar on the keyboard. In accordance with Crundall (2012), the screen subsequently turned black while the video was stopped. Participants then described the change they had seen or reported that they had either seen the change but failed to identify it, or had pressed the spacebar accidentally. In video 15, participants performed a recollection test in which several roadside elements – including all speed limits – were omitted. The video stopped at each deleted item and a yellow circle marked the spot where the item had been present in all previous videos. Participants had to report what had been visible at that spot in video 14 and were instructed to guess when necessary. They then reported how confident they were of their answer.

Figure 2. Screen shot of the second gantry under three conditions of information discriminability in video 14. From top to bottom: Basic, Flash, and Wave.

Measures

To detect whether participants noticed the two changes, both detection accuracy and reaction time were measured during videos 1 to 14. Simultaneously, change identification was measured by the descriptions of the detected changes. To ensure changes were attributed to elements of the road and its surroundings, no other traffic was present in the videos. The task in video 15 measured accurate recollection of the changed speed limits and a few other deleted items that had not changed. The deleted items in video 15 included all speed limits, a part of the signposting, route information on a variable message sign (VMS), and a billboard containing a traffic-related advertisement from a recent government campaign.

Finally, participants filled in a questionnaire concerning the omitted items they had encountered. The questions ranged from relatively general ("Did you notice anything special about the speed limits in video 1 to 14?"), to asking whether they had seen the change. This was done by suggesting that there had been two groups: one group for whom the speed limit on the gantries had always been 100 km/h and another group for whom the speed limit on the gantries had decreased from 100 km/h to 80 km/h. While in fact all participants belonged to the second group, they were asked to which group they thought they belonged and how confident they were of their decision. These questions were also asked for the other deleted items, always implying that there were two groups per omitted item and suggesting that it was possible to belong to a group that had encountered either several changes, one change, or no change at all in video 14. Participants were also asked whether they expected that the speed limits – as well as the other deleted items - could change.

Equipment

Participants accessed the experiment on their own computer through a website using a personal entry code. The website could be viewed on a Windows or Apple operating system using a mainstream web browser such as Internet Explorer, Firefox or Google Chrome. Internet access and a keyboard were required. The experiment was not suitable for smart phones or tablets.

The videos showed a forward view of the road ahead, and a navigation device was displayed in the lower right corner. The video resolution was 1136 pixels wide and 640 pixels high. Dedicated software automatically gathered the screen resolution of the computer participants used and recorded space bar hits during video viewings. These responses were sampled with a precision of $1/10^{th}$ of a second. The videos were equipped with car sounds, e.g. engine noise, to make the viewings more realistic. To ensure that participants could hear the audio signal, an audio test was embedded at the beginning of the experiment.

Procedure

Before the actual experiment started, participants received written instructions which explained their task and the procedure. The instruction also requested participants not to pause or to be assisted or disturbed during the experiment. Participants were told that the aim of the experiment was to gain more insight into the perception of changes in the road environment.

The experiment began with a short questionnaire containing questions on participant characteristics. To become familiar with the change detection and identification task, participants viewed one practice video which was self-paced. After viewing the fifteen 40-second videos, participants received a short follow-up questionnaire on the videos they had seen. The experiment took 20 minutes to complete.

Results

Change detection accuracy

Almost three out of four participants (70.5%) did not realise they viewed the same video thirteen times. Alleged changes that have been reported included adjusted travel times on the roadside VMS, the appearance of an emergency bay, the congestion indication on the roadside VMS changing from kilometres into travel time, adjustments in the delineation, new or moved road signs and buildings, and “the car is moving faster”. After several video viewings the response rate declined (see Figure 3).

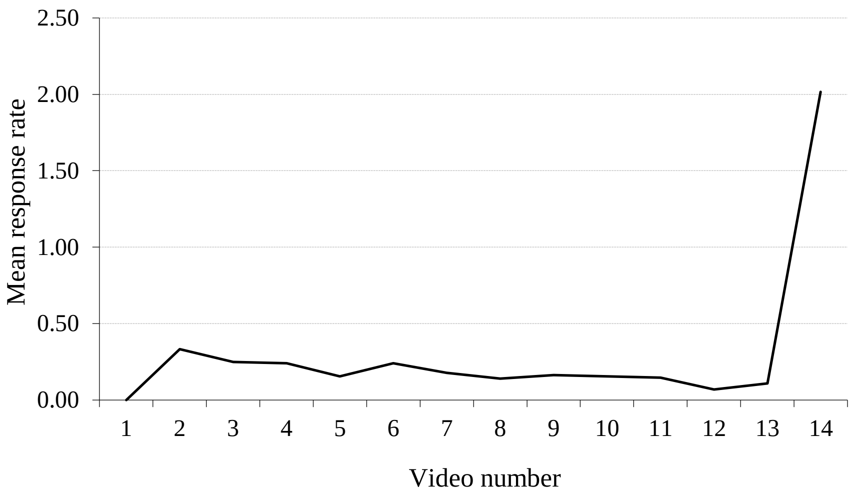

Figure 3. Graph of the mean response rate per video. The response rate for video 1 was zero, as video 1 could not be compared with a preceding video. Video 14 included the two changes.

In video 14, 85.3% of the participants accurately responded to both speed limit changes. Other participants either only responded to the first speed limit change (11.6%), the second speed limit change (2.3%), or did not respond to the changes at all (0.8% , n = 1). Due to a technical error four participants were unable to stop video 14, hence n = 129 for video 14.

Speed limit recollection

While viewing video 15, 34.6% of the participants accurately recollected the speed limits shown in video 14. Most participants (51.1%) falsely recollected all speed limits on VMSs to have changed to 80 km/h and 3.8% claimed that only the last speed limit had changed to 80 km/h. The recollected speed limit sequences of the remaining 10.5% of the participants varied widely (see Figure 4). There was no significant difference in correct speed limit recollections between both IA and IC and between the varieties of information discriminability. On average, the participants who answered correctly were confident of their answer (4.33 on a 5-point Likert scale). Participants who, incorrectly, recollected a sequence of 100 km/h, 80 km/h, 80 km/h and 80 km/h yielded the highest mean confidence rate, 4.41 on a 5-point Likert scale (see Table 2).

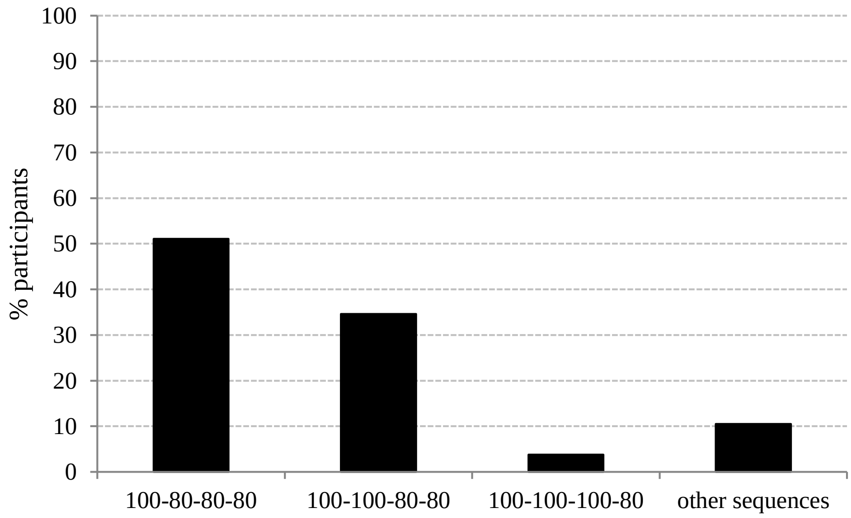

Figure 4. Recollected speed limit sequences in video 15. The correct sequence is 100 km/h, 100 km/h, 80 km/h, and 80 km/h.

Table 2. Confidence rates per speed limit sign.

Recollected sequence	*Speed limit 1*	*Speed limit 2*	*Speed limit 3*	*Speed limit 4*	*Mean confidence rate*
100-80-80-80	4.04	4.47	4.56	4.56	4.41 (*n* = 68)
100-100-80-80*	4.15	3.70	4.74	4.72	4.33 (*n* = 46)
100-100-100-80	3.60	3.80	3.60	4.00	3.75 (*n* = 5)
Other	3.93	4.00	4.21	4.36	4.13 (*n* = 14)

* correct speed limit sequence

When asked whether they had noticed anything special about the speed limits in video 1 to 14, 72.2% of the participants reported the changed speed limit. When a response to the changed speed limit was elicited, 97.7% of the participants accurately reported that they had been in the group for whom the speed limit on some gantries had been 80 km/h in video 14. The remaining 2.3%, reported being part of the group for whom video fourteens variable speed limits remained a 100 km/h. On average, these participants were less confident of their answers compared to the participants who had answered correctly (respectively 3.33 and 4.65 on a 5-point Likert scale).

Expectancy

Almost all participants (95.5%) had expected that the speed limits would change compared to 55.6% for the signposting, 91.0% for the route information on a VMS and 37.6% for the billboard. The participants who expected the variable speed limits would never change (3.0 % of n = 133), all responded accurately to the first change in video 14. Although they all recollected the speed limit sequence incorrectly, they correctly attributed themselves to the group whose speed limits had changed. The participants who did not react to the first change (3.1% of n = 129), did expect the speed limits to change.

Reaction time

The mean reaction time for IA did not differ significantly from IC for the first change in video 14. However, the variance in these reaction times is much larger for IC compared to IA, albeit not significantly larger (see Figure 5). Indicative, when the two largest outliers are excluded, Levene's Test of Equality of Variances shows that, although the mean reaction time is the same, the variance in reaction times for IA and IC differs significantly when testing with an α of 0.10, $F(1,121)$ = 2.889, p = 0.092.

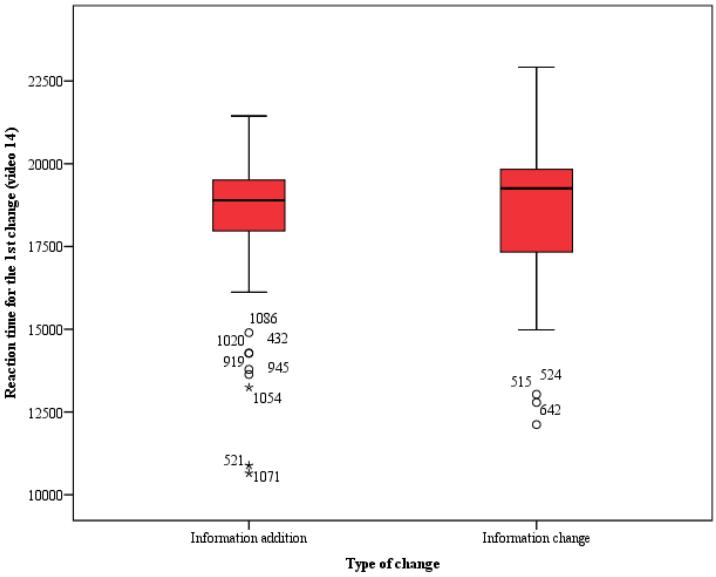

Figure 5. Boxplots of reaction times for the first change in video 14 for information addition (IA) and information change (IC). Reaction times are measured from the start of the video.

For the first change, the mean reaction time differed significantly for the three varieties of information discrimination, $F(2,122) = 3.829$, $p = 0.024$, with Basic yielding the fastest response and Flash the slowest. This difference seized to exist for detection of the second change. Levene's Test of Equality of Variances shows that, for the first change, the variance in the reaction times for Basic, Flash and Wave varies significantly as well, $F(2,122) = 3.440$, $p = 0.035$. Flash has the smallest variance (see Figure 6).

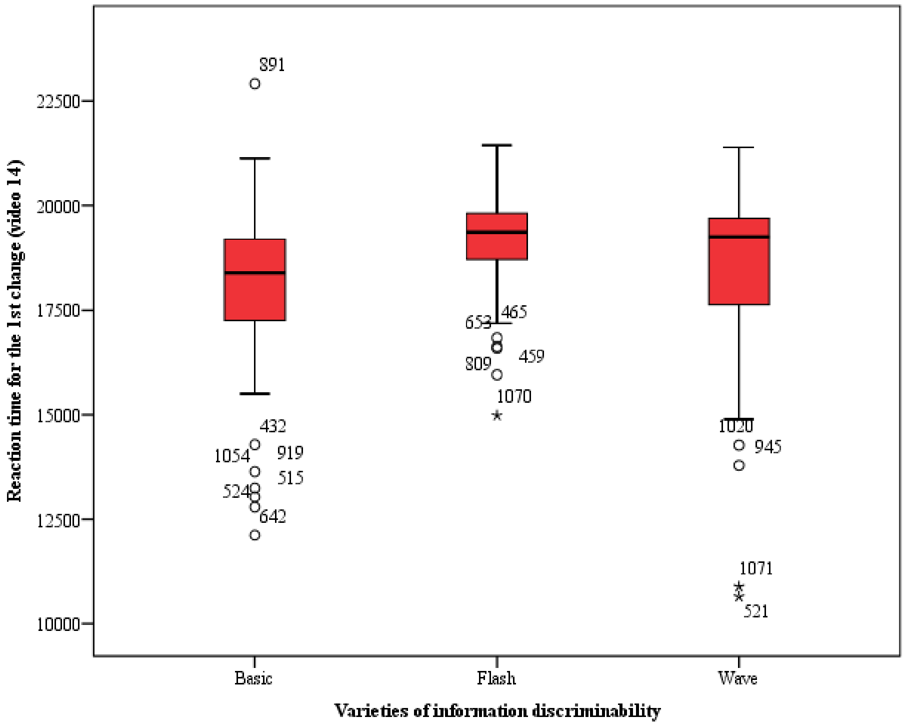

Figure 6. Boxplots of reaction times for the first change in video 14 for the three types of information discriminability. Reaction times are measured from the start of the video.

Conclusions and discussion

Although the study was designed to "force" participants to see the decreased speed limit, still 3.1% did not (timely) detect it; 65.4% did not recollect it correctly; and 2.3% reported afterwards that they had not seen the decreased speed limit at all. The conclusion must be that expecting a change does not necessarily result in change detection. This inability to detect and recollect clearly visible changes to VSLs is consistent with earlier findings (Harms, 2012) and stresses once more the limitations of perceiving information provision, even highly relevant information. This is specifically important for maintaining the correct speed on motorways as perceiving the relevant information is one of the necessary steps to be able to comply with speed limits in the first place.

It remains uncertain whether, without doubt, change detection for VSLs can improve by using either an IA or IC approach. This may be due to the fact that the amount of data was limited. However, the data does contain indications that using an IA approach may lead to less variance in reaction times when a VSL changes. To resolve this issue, more participants should partake in the experiment. Contrary to expectations, equipping the variable speed limits with flashers and therefore adding a transient motion signal to the changed VSL did not increase change detection. This finding is hard to explain. It must be kept in mind though, that reaction times were measured at $1/10^{th}$ of a second and differences were relatively limited. Further analysis with more participants may shed more light on this. However, the clear difference in variance between the three types of information discrimination points out that flashers do indeed decrease overall reaction time to changes in variable speed limits. Introducing a subtle wave to add a transient motion signal to a changed VSL does not appear to improve reaction times or reduce their variance. The wave may have been too subtle or the videos may not be the right instrument to test this.

Large differences in speed on motorways reduce road safety. Even small speed differences may encourage drivers to change lanes and overtake lead vehicles while changing lanes is a potential source of traffic accidents (Hegeman, 2008). Although more research is needed, it appears that with choosing an IC, or “full monty” traffic management approach, road authorities may introduce additional speed differences. Therefore drivers might be safer while driving on a motorway with VMSs that do not display information continually.

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