NEW IN-VEHICLE TECHNOLOGIES: ARE LANE DEPARTURE WARNINGS A GOOD THING?

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Abstract
The expression 'behavioural adaptation' (BA), when used in the context of transportation psychology, describes the collection of behaviours that occur following a change to the road traffic system. Typically, those behaviours that were not intended by the initiators of the change are of particular interest. Their impact on road safety can be positive, negative, or neutral; however, it is the negative effects of BA that are of primary concern to road safety professionals. Lane departure warning (LDW) systems may have the capacity to induce BA, in that drivers may rely on the warnings to keep them oriented and/or alert, rather than devoting adequate attention to the driving task or taking a rest break. This paper describes a simulator study that assessed the ability of LDW systems to induce BA. Those drivers who experienced an accurate warning system followed by a system that failed to provide a warning every third lane departure showed improved lane-keeping performance during both conditions compared to baseline, and reported feeling safer during the second phase, despite the faulty warning accuracy. Results suggest that, because of drivers' tendency to over-estimate their reliability, caution should be used when attempting to predict the safety benefits of LDW systems.

Key words: 1) behavioural adaptation 2) road safety 3) intelligent transportation systems

LES NOUVELLES TECHNOLOGIES SUR LES VÉHICULES : LES ALERTES DE CHANGEMENT DE VOIE SONT-ELLES UNE BONNE CHOSE?

Résumé
L'expression " rétroaction comportementale " (RC), dans le contexte de la psychologie du transport, décrit l'éventail de comportements qui surviennent à la suite d'un changement dans le système de trafic routier. De façon générale, les comportements que l'initiateur du changement n'avait pas prévus sont particulièrement intéressants. Leur impact sur la sécurité routière peut être positive, négative ou neutre. Par contre, ce sont les effets négatifs de la RC qui inquiètent principalement les professionnels de la sécurité routière. Les systèmes d'alerte de départ de voie (LDV) pourraient inciter une RC, car les conducteurs pourraient se fier aux avertissements pour se garder orientés et/ou alertes, au lieu de consacrer une attention appropriée à la conduite ou de prendre une pause. Ce document décrit une étude de simulation qui évalue la capacité des LDV à inciter des RC. Les conducteurs qui ont fait face à un système d'alerte précis suivi d'un système où il n'y avait pas d'avertissement à chaque troisième départ de voie ont amélioré leur tenue de route dans les deux systèmes à l'autre comparativement au niveau de base, et ont affirmé se sentir plus en sécurité durant la deuxième phase de l'expérience, et ce malgré le système d'alerte déficient. Les résultats suggèrent de faire très attention en tentant de prédire les bienfaits en matière de sécurité des systèmes de LDV, car les conducteurs tendent à surestimer leur fiabilité.

Mots clés: 1) rétroaction comportementale 2) sécurité routière 3) système de transport intelligent

INTRODUCTION

Despite a poor understanding of the mechanisms underlying behavioural adaptation (BA), it is often cited as an explanation for the observed discrepancies between engineering estimates of the safety benefits of collision countermeasures and actual experience (5). While the nature and salience of a system change can influence BA, factors such as individual differences in user characteristics may also play a role.

Relatively novel concepts in the study of BA include the notion of trust in automation and the potential contribution of personality variables such as locus of control and sensation-seeking (SS)(1). A comprehensive theory of trust in automation has been developed by Muir (4), who posits that human operators will intervene, or override a system when their trust in the automation falls below some point, or threshold. Alternatively, if the operator trusts the automation too much, they may become complacent and fail to override the system when it is faulty, a phenomenon known as automation complacency. It is possible that drivers who perceive in-vehicle systems to be 'trustworthy' are more likely than others to display BA by over-relying on the technology.

The personality dimension 'locus of control' relates to an individual's assumptions regarding responsibility for positive and negative events. A person who believes that s/he is able to act so as to maximise the possibility of positive outcomes and minimise the possibility of negative ones is described as having an internal locus of control. Conversely, someone who believes that people are helpless and at the mercy of external forces, luck, or fate, has an external locus of control. It is possible that drivers with an internal locus of control rely more on their own skills and abilities while they are driving and, no matter how reliable a safety device, will always maintain direct involvement in the driving task. Those with an external locus of control, on the other hand, may be more likely to give up control to an external device (3). Finally, with respect to SS, due to their propensity for seeking out and accepting higher risk levels, high SS drivers may be more likely than low SS drivers to show BA to in-vehicle safety devices (2).

The present study was designed to assess 1) whether reliable and/or unreliable LDW systems are capable of inducing BA in drivers, and 2) whether locus of control and SS contribute to the development of BA.

METHOD

Study Design

The study used a 3 x 3 mixed design with Session (baseline, test, and post-test; within-subjects) and Warning Accuracy (ACC, INACC, and CTRL; between-subjects) as factors.

Participants

Sixty university students between the ages of 21 and 34 who had a valid driver's license for at least five years completed two personality questionnaires, Montag and Comrey's Driving Internality-Externality scale (3) and Zuckerman's sensation-seeking scale (6). A median split was performed on the Internality-Externality scores and the 30 individuals with the most extreme scores were invited back to participate in the simulator study. These participants were subsequently divided into three groups (ACC, INACC, CTRL) that were balanced across age, gender, handedness, driving experience, and sensation-seeking score.

Equipment

Driver testing was done using a Systems Technology Incorporated (Hawthorne, CA) fixed-base driving simulator (STISIM), which consists of four inter-connected Pentium computers, including a vehicle dynamics computer and three graphics display computers. Graphics were projected onto three 76 x 89 cm screens directly in front of the driver, providing a 135 degree forward field of view. The simulator housing consisted of a regular adjustable car seat, a fixed steering wheel box positioned 115 cm from the screens, and a gas/brake pedal box attached to the flooring. A Navi brand navigation system, used for the secondary distraction task, was positioned to the right of the steering wheel box at dash level (see Figure 1).

Figure 1. Study set-up

Procedure

Following a 10-minute driving familiarization session and a 10-minute session during which only the secondary, number-entry task was performed, participants completed a 30-minute practice session (driving while performing secondary task) followed by three 30-minute sessions (baseline, test, and post-test; driving while performing secondary task). During the baseline condition, all subjects drove without a LDW system. During the test condition, the ACC group drove using an accurate LDW system, which generated a rumble-strip sound whenever the vehicle came within 22cm of either lane boundary. The INACC group drove using an inaccurate LDW system, which generated accurate warnings, false positives (one every seven minutes) and false negatives (every third warning, on average). The CTRL group received no warnings. In the post-test session, the two warning groups (ACC and INACC) drove using a second inaccurate system (accurate warnings and false negatives only), while the CTRL group again drove unaided. The use of cruise control in all conditions ensured a constant vehicle speed of 70 kph. Participants were not informed whether they would be using a reliable or an unreliable LDW system.

Before being exposed to the LDW system, all participants were read a description of how a LDW system works, and were asked to rate the degree to which they thought they would trust such a system to do what it was designed to do. Following the test and post-test sessions, participants who had been exposed to LDW systems (ACC and INACC groups) were asked to rate their trust in the specific system that had been installed on their 'vehicle'. As well, after each driving session, all participants rated their feelings of safety and subjective workload using Likert rating scales.

RESULTS

Driving performance measures

Participants who used an accurate system during the test session followed by an inaccurate system during the post-test session (ACC) received significantly fewer warnings (Figure 2), made fewer lane departures (Figure 3), and deviated less within the lane (Figure 4) compared to baseline, a pattern opposite to that of the CTRL group, who deviated significantly more during the post-test session ($p<.05$; Figure 4). During the test and post-test sessions, the ACC group received significantly fewer warnings and deviated less within the lane ($p<.05$) than the CTRL group (Figures 2 and 4).

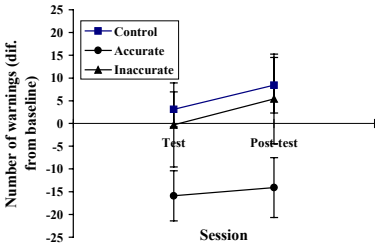

Fig. 2. Number of warnings

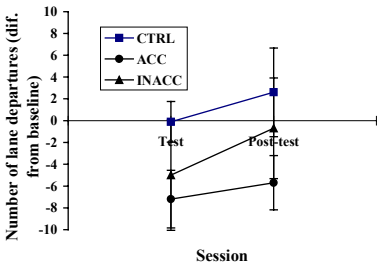

Fig. 3. Lane departures

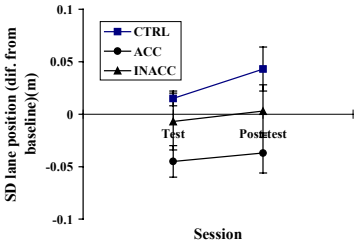

Fig. 4. SD lane position

Trust in LDW system

Participants in the ACC group rated their trust in the LDW system as significantly greater than baseline after both the test and the post-test sessions ($p<.05$; see Figure 5). These ratings did not differ significantly from the INACC group, which also showed slight increases in their ratings of trust.

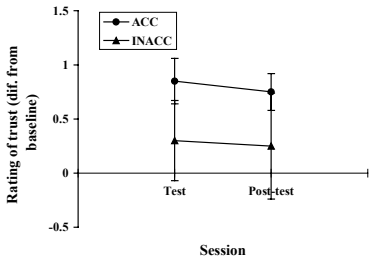

Figure 5. Ratings of trust

Safety

In response to the question "If you had been driving a real car, how safe would you have felt during the task?" participants in the ACC group reported feeling significantly safer (less unsafe) during the post-test session than during baseline ($p<.05$). Interestingly, the ACC group reported feeling significantly safer than the INACC group during the post-test session ($p<.05$), despite both groups being exposed to the same system during this session (Figure 6).

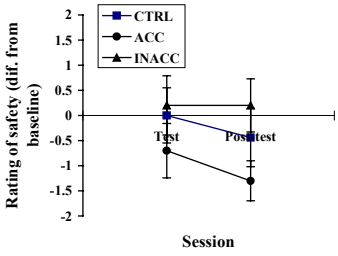

Figure 6. Ratings of safety

Workload

Across all groups, there was a significant reduction in total workload across sessions ($p<.001$; data not shown). In response to the question "How successful were you in accomplishing what you were asked to do?" the ACC group reported feeling more successful during the test session compared to baseline and post-test ($p<.05$); this rating was significantly lower (felt more successful) than the INACC group (Figure 7).

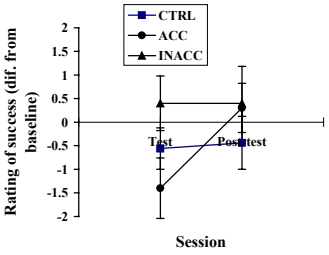

Figure 7. Ratings of success

Personality variables

Although locus of control and SS were not associated with differences in any driving performance measures, both personality variables were found to correlate with whether or not a participant increased their rating of trust following exposure to a LDW system, regardless of its accuracy. Those participants who scored higher on the driving internality scale than the externality scale ($r=-.53$, $p<.05$) and those who scored high on the sensation-seeking scale ($r=-.45$, $p<.001$) were less likely to report an increase in trust in the LDW system (data not shown).

DISCUSSION

Drivers who used an accurate LDW system followed by one that produced a false negative every three warnings significantly improved their lane keeping performance during both sessions over baseline conditions, and compared to drivers who were not exposed to any system. The same drivers reported a higher degree of trust in both the accurate and the inaccurate systems than prior to exposure, regardless of the system accuracy. They also reported feeling safer during the post-test condition (when using an inaccurate system) than without any system, and safer than those drivers using the same inaccurate system, but who had previously been exposed to an inaccurate system. Finally, these drivers reported feeling that they were more successful in accomplishing the task (driving while entering numbers in a navigation system) only when using the accurate LDW system. This suggests that, although they reported trusting both systems, there may have been some awareness of their slightly impaired performance with the inaccurate system.

Driver internality and SS were negatively correlated with whether a driver experienced an increase in trust for the LDW, regardless of its accuracy. Interestingly, only those drivers who reported trusting the system made complete (i.e., centre of vehicle crossed lane boundary) lane departures when a false negative occurred. These results are suggestive of a role for these personality traits in BA; individuals with an external locus of control and those who score low on the SS scale may be more likely to trust a device, regardless of its accuracy. This, in turn, may make them more susceptible to automation complacency and, as in the present study, lead to a failure to ignore a device when it is faulty. In the case of a LDW system, it is obvious why this situation could lead to serious consequences.

Collectively, the results suggest that, while LDW systems may be advantageous in terms of improving lane-keeping performance, caution needs to be used when attempting to predict their overall safety effects. By over-estimating the reliability and accuracy of new in-vehicle technologies such as LDW systems, some drivers appear to be at an increased risk.

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