Differences in Driver Distractibility Between Monolingual and Bilingual Drivers

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Abstract. The present research sought to bridge the gap between research on driver distraction and the bilingual advantage by testing monolingual and bilinguals in a driving simulation similar to those encountered by drivers on a daily basis. The Lane Change Test (LCT) was used to test driving performance in the presence of a delayed digit recall task (2-back task) and three types of peripheral detection tasks (PDTs). Although performance came to be degraded as the complexity of tasks increased, the overall performance of the bilinguals was more negatively affected than their monolingual counterparts across the LCT, PDT, and 2-back task. Implications and limitations are discussed.

Keywords: Attention · Bilingual advantage · Driving · *n*-back task · Peripheral detection task

1 Introduction

Driver distraction and inattention has become an important factor in road safety, due to the proliferation of electronic devices and technology in modern automobiles. Consequently, drivers are presented with increasing amounts of information that can be relevant or irrelevant to the driving task. This information requires that drivers perceive, process, and select appropriate actions for all of the stimuli they encounter. From yielding to pedestrians crossing the street to monitoring traffic signals, drivers must remain alert and vigilant of their surroundings for safe and effective driving. Often, however, drivers face sources of distraction that divert their attention from the driving task, which may compromise safety. It is not surprising, therefore, that interest and research on driver distractibility is increasing. Research has shown that distractions such as talking on a cellular device can produce slower reactions to traffic [1] and increased difficulty processing new information [2]. Another focus of research on distractibility is how the characteristics of the driver him or herself influences distractibility. Factors such as driver experience, age and gender have been shown to affect driving [3, 4], although the results are not straightforward. In the present investigation, we examined another driver characteristic, bilingualism, on driver distractibility, because previous research has shown differences between bilinguals and monolinguals on several cognitive tasks.

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Bilingualism is the ability to read, write, speak, and understand two or more languages [5]. Research suggests that cognitive differences exist between bilinguals and their monolingual counterparts [6]. For example, when compared to monolinguals, bilinguals have shown an increased ability to process verbal and perceptual information [7]. They are also more efficient at adjusting their attention to fit changes in the demands of a task [8–11]. This research has led some to suggest that the ability to fluently speak multiple languages creates a bilingual "advantage" in terms of better allocation of one's attentional resources. It is theorized that this advantage stems from a bilinguals' need to inhibit one language when using another language [7, 12].

In the preset study, we examined whether the bilingual advantage would affect driver distractibility, given the various cognitive demands made on drivers and the previously-noted cognitive advantages of bilinguals. Driving performance was measured with a standard Lane Change Test (LCT) and a modified Peripheral Detection Task (PDT). Typically, the PDT presents a single visual stimulus and the participant must detect its presence. We varied the PDT tasks to determine whether more ecologically-valid stimuli would show effects of distractibility on performance. Participants responded to either the left-right location of the stimulus or its movement. Dual task driving performance was assessed with a working memory task performed simultaneously with driving.

2 Method

2.1 Participants

Fifteen college students (8 monolingual) ranging from 21 to 31 years of age ($M = 24$) participated in this study. Nine females and six males participated in this study. Participants had normal or corrected-to-normal vision, and reported having no known hearing deficits. All participants were right-handed, had a California Class C non-commercial driver's license for three or more years prior to the experiment, and had, on average, 7 years of driving experience. All participants spoke fluent English; secondary languages amongst bilingual participants included Spanish, Cantonese, and French.

2.2 Measures

Bilingualism Measure. Participants were asked to complete a demographics questionnaire that included items that pertained to both driving and language. Language questions were obtained from previous language questionnaires [13, 14] and asked participants to rate their skill level for their reading, writing, speaking and listening ability. The rating scale ranged from "Very Poor" (1) to "Native-Like" (7). Bilingual participants were selected only if their reported secondary language ability ranged from "Functional" (4) to "Native-Like" (7).

Lane Change Test. The LCT was used to assess driving performance. The LCT is a driving simulation that is easy to implement and has been evaluated for reliability, validity, and sensitivity [15, 16]. The LCT features a 3-kilometer straight-lane track that presents lane change signs roughly every 150 m. Participants were instructed to drive at 60 km/hour for the length of the track and to make a total of 18 lane changes indicated by a lane change sign as quickly and efficiently as possible (Fig. 1). Participants used a G27 Logitech Force-Feedback Racing Wheel and pedal system to drive in the simulation. Three tracks (3 min each) were completed for every experimental condition. Participants were instructed to give priority to the driving task when completing additional secondary tasks. Given the response nature of the secondary tasks, all driving was completed with the left hand.

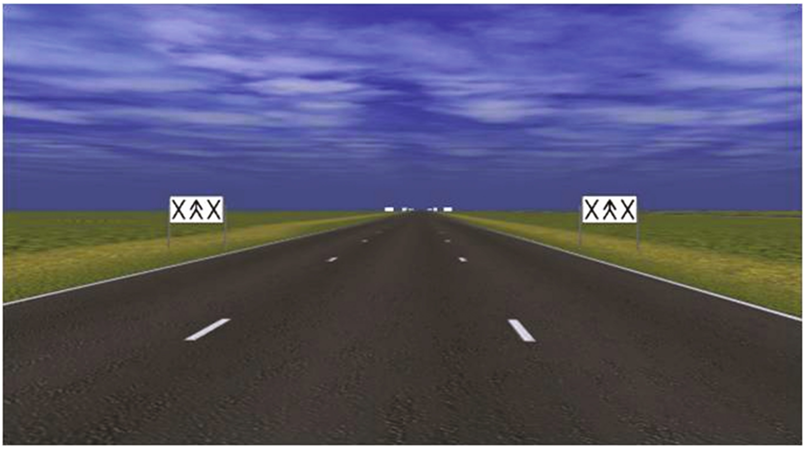
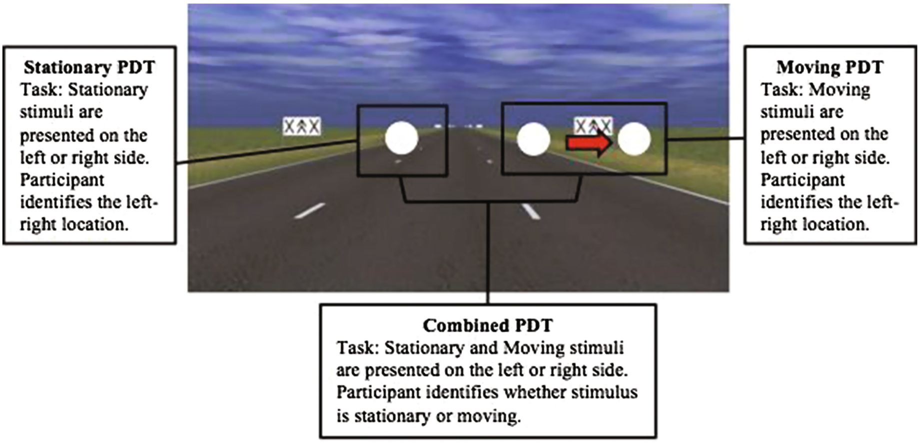


Fig. 1. LCT instructing a change to the center lane

Peripheral Detection Tasks (PDTs). Participants were instructed to make the appropriate button presses on an Ergodex keyboard with their right thumb and index finger when they identified a visual stimulus. The PDT stimuli were white circles that were projected onto the LCT image along the horizon line through the duration of each track. Participants were asked to complete three different PDTs in which stimuli were either (1) all stationary, (2) all moving, or (3) combined stationary and moving. For the two former conditions, participants were asked to determine the left-right location of the stimuli, and for the latter condition, whether the stimuli were stationary or moving (see Fig. 2). The white circles were randomly presented on either side at either 13” or 19” to the right or left of the center of the road and were 500 ms in duration.

***2*-Back Task.** Participants were asked to recall prerecorded auditory items presented from a speaker to the right of the driver. The *2*-back task featured 10-item sets that began with the word “next” and were followed by a random presentation of numbers (digits 0-9) every two-seconds. Every 10-item set lasted roughly 25 s and six sets (60 numbers) were played through the duration of a three-minute LCT track. Participants were instructed to recall the number, or item, they heard two items previously, as shown in Table 1. Thus, in each condition (three tracks) in which the 2-Back Task was used, participants were presented with a total of 180 numbers. This working memory



Stationary PDT
Task: Stationary stimuli are presented on the left or right side. Participant identifies the left-right location.

Moving PDT
Task: Moving stimuli are presented on the left or right side. Participant identifies the left-right location.

Combined PDT
Task: Stationary and Moving stimuli are presented on the left or right side. Participant identifies whether stimulus is stationary or moving.

Fig. 2. PDT types. Stimuli are not to scale

Table 1. Visual representation of auditory 2-back task

Stimulus:	4	7	0	1	3	…
Response:	(no response)	(no response)	“4”	“7”	“0”	“1”

task resembles a conversation where pieces of information have to be temporarily stored and saved for a later point in the conversation.

NASA-TLX. Subjective workload was assessed using the NASA-TLX [17] a measure that asks participants to rate their perceptions of different items related to workload after completing a task. The levels measured include mental demand, physical demand, temporal demand, performance, effort, and frustration. A web version was used to collect responses [18].

2.3 Simulation Environment

All participants were run in a sound attenuated room where they faced a screen with a projected image. The projected image measured 46” × 61 ¾” and was used to display the LCT and the PDTs.

2.4 Testing Procedure

Each participant completed two 1.5-hour sessions on separate days. Following their written approval to participate in the study, and completion of the demographics questionnaire, participants were seated in front of a table with the steering wheel and pedals facing the projection screen. All participants ran in counterbalanced conditions featuring every combination of PDT (static, moving, and combined), with and without the 2-back task, making a total of six treatment combinations. Participants also completed baseline tracks in which they performed the driving task without any secondary tasks at the beginning of the experiment on the first day and at the end of the experiment on the second day. At the beginning of every condition, participants completed practice runs until they reached an 80 % accuracy rate for the 2-back task and felt comfortable with the PDT. After every condition, participants were asked to complete a web-based version of the NASA-TLX workload instrument (Fig. 3).

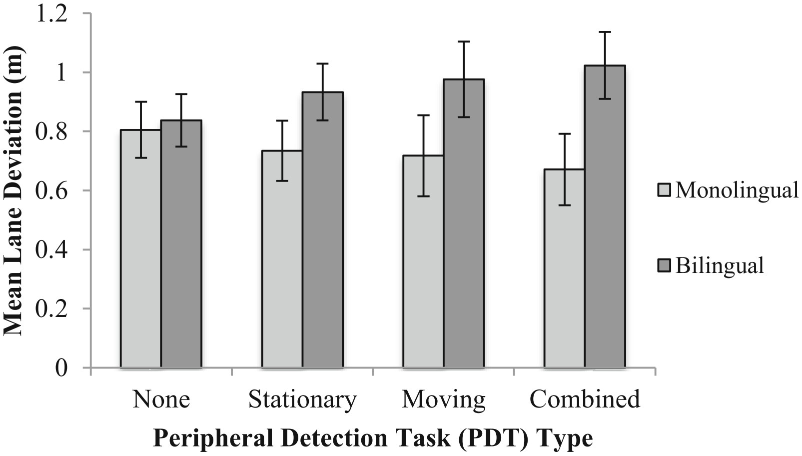


Fig. 3. Mean lane deviation in the driving task as a function of language proficiency and PDT type. Error bars represent ± 1standard error.

3 Results

3.1 LCT Lane Deviations

A 2 (language fluency: monolingual or bilingual) × 2 (2-back task: no 2-back or 2-back) × 4 (PDT type: none, static, moving, or combined) mixed factorial ANOVA was run to assess driving performance. For the LCT, higher lane deviations indicate poorer performance.

A main effect of 2-back task type was found, $F(1, 13) = 7.83$, $p = .02$, $\eta^2 = .38$. When completing the 2-back task, drivers had greater lane deviations, or poorer performance, ($M = .89$ mm, $SE = .07$ m) than when they did not complete the 2-back task ($M = .78$ m, $SE = .08$ m).

Additionally, although no main effect was found for PDT type or language fluency, a significant interaction was found between these two variables, $F(3, 39) = 4.15$, $p = .01$, $\eta^2 = .24$. Follow up analyses revealed that the nature of this interaction stems from differing performance between monolinguals and bilinguals for the combination PDT, $t(13) = -2.12$, $p = .05$, $d = -.49$. Specifically, bilinguals had greater lane deviations, or poorer performance, ($M = 1.02$ m, $SE = .14$ m) than their monolingual counterparts (M = .67 m, SE = .08 m) when driving and reported whether peripheral stimuli were stationary or moving.

3.2 2-Back Task

A 2 (language fluency: monolingual or bilingual) × 4 (PDT type: none, static, moving, or combined) mixed factorial ANOVA was run to assess differences in 2-back performance. A marginally significant main effect was found for language fluency, $F(1, 11) = 4.26$, $p = .06$, $\eta^2 = .28$, where bilinguals made a greater number of mistakes (M = 16.93, SE = 3.94) than monolinguals (M = 4.96, SE = 4.26). There was no significant main effect found for PDT type or interaction found between language fluency and PDT type (Fig. 4).

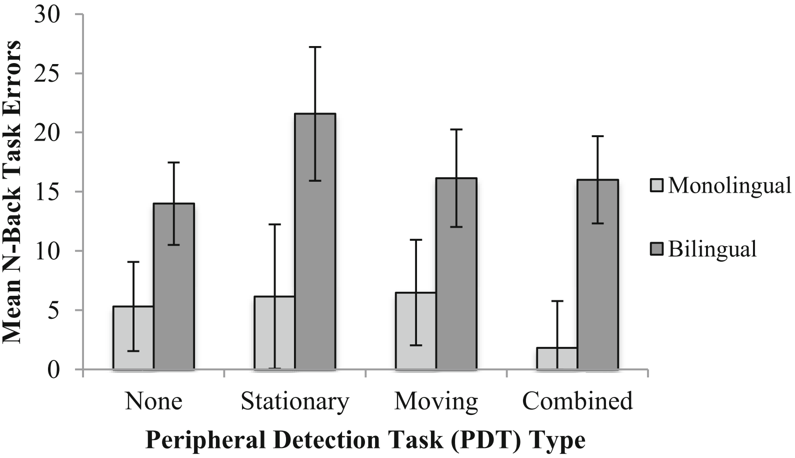


Fig. 4. N-back task errors as a function of PDT type and language proficiency. Error bars represent ± 1 standard error.

3.3 Peripheral Detection Tasks

A 2 (language fluency: monolingual or bilingual) × 2 (no 2-back or 2-back) × 2 (driver side: left or right) × 2 (eccentricity: near or far) × 3 (PDT type: none, static, moving, or combined) mixed factorial ANOVA was run on PDT reaction time.

A main effect of 2-back task was found for PDT reaction time, $F(1, 13) = 15.03$, $p = .002$, $\eta^2 = .54$. Participants were slower in responding to the PDTs when they complete the 2-back task (M = 885.02 ms, SE = 64.89 ms) than when they completed no 2-back task (M = 771.16 ms, SE = 47.75 ms).

A marginal main effect for PDT type was also found, $F(2, 26) = 3.07$, $p = .06$, $\eta^2 = .19$. Specifically, participants were slower in responding to the combination PDT (M = 874.93 ms, SE = 47.44 ms) than the stationary PDT (M = 800.24 ms, SE = 66.93 ms; $p = .05$) and moving PDT (M = 809.11 ms, SE = 58.66 ms; $p = .06$). No significant differences were found between the stationary and moving PDTs.

Finally, a significant interaction was found between language fluency, PDT type, and 2-back task, $F(2, 26) = 5.43$, $p = .01$, $\eta^2 = .30$. The effects of the 2-back task on PDT response latencies differed between monolinguals and bilinguals. Although monolinguals performed similarly for all three types of PDT, bilingual response times were longest for the combination PDT compared with response times in the stationary and moving PDT. In the combination PDT, bilingual response latencies were significantly longer for the 2-back task, compared with no 2-back task (Fig. 5).

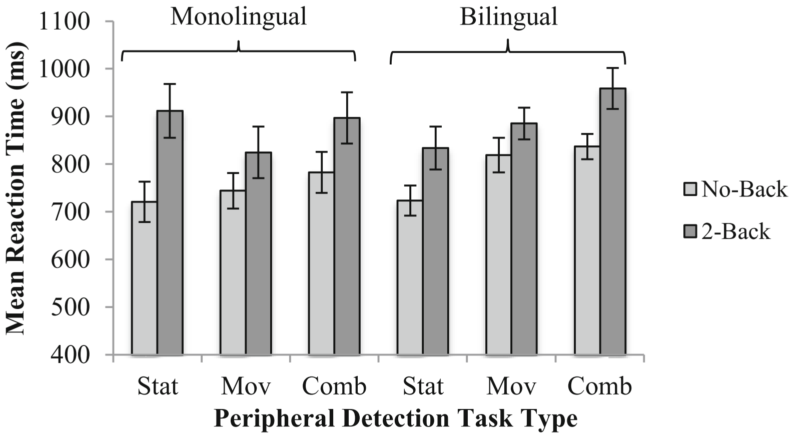


Fig. 5. Reaction time as a function of PDT type, *n*-back task, and language proficiency. Error bars represent ± 1 standard error.

3.4 Workload

A 2 (language fluency: monolingual or bilingual) × 2 (2-back task: no 2-back or 2-back) × 4 (PDT type: none, static, moving, or combined) mixed factorial ANOVA was run to determine differences in perceived workload assessed through the NASA-TLX. Greenhouse-Geisser corrections were used to address any sphericity violations.

A main effect of PDT was found, $F(1.89, 24.58) = 6.50$, $p = .006$, $\eta^2 = .33$. Conditions with no PDT ($M = 32.28$, $SE = 4.10$) were reported to be less demanding than the stationary ($M = 41.53$, $SE = 4.38$), moving ($M = 40.51$, $SE = 3.90$), and combined PDT conditions ($M = 41.17$, $SE = 4.26$). No significant differences were found between these three latter conditions.

A main effect of 2-back task was also found, $F(1, 13) = 30.50$, $p < .001$, $\eta^2 = .70$. Participants reported higher levels of workload for driving and performing the 2-back task ($M = 52.34$, $SE = 5.08$) than when no 2-back task was completed ($M = 25.40$, $SE = 4.03$).

A main effect of language fluency was found, $F(1, 13) = 5.21$, $p = .04$, $\eta^2 = .29$. Across all tasks, bilinguals reported higher levels of workload ($M = 47.74$, $SE = 5.31$) than monolinguals ($M = 30.01$, $SE = 5.67$).

Finally, there were no interactions found between PDT, 2-back task, or language proficiency for perceived workload (Fig. 6).

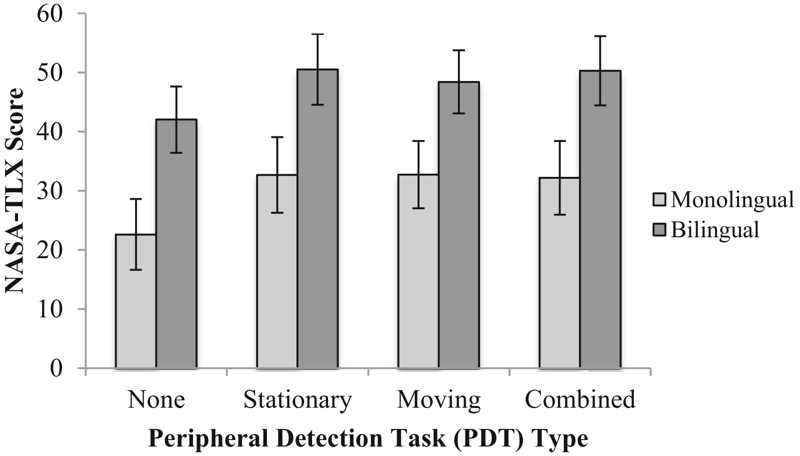


Fig. 6. Subjective workload as a function of PDT type and language proficiency. Error bars represent ± 1 standard error.

4 Discussion

The purpose of this study was to determine whether the previously reported bilingual advantage on standard tests of cognitive processing would apply to distracted driving. We were surprised to learn that bilinguals in our experiment were more affected by the distraction tasks than monolinguals. Although bilinguals and monolinguals performed equivalently on the LCT when performed alone, bilinguals performed worse on the LCT when the PDT and 2-back tasks were timeshared. Moreover, bilinguals had longer response latencies in some PDT conditions, committed more errors on 2-Back tasks and reported higher subjective workload across all task conditions. In summary, although bilingual processing advantages have been shown in many standard laboratory tasks, we showed a bilingual *disadvantage* for the LCT driving task when it was timeshared with the PDT and a working memory task.

The difficulties faced by bilinguals in completing the combinations of the aforementioned tasks can be seen in the results of the NASA-TLX workload measure, in which bilinguals reported experiencing greater workload than monolinguals. This suggests that the ability to handle inter-lingual conflict may only generalize to individual tasks and not to complex timesharing tasks. It should be noted, however, that the results of this study do not suggest the bilinguals are inherently poor drivers. Differences in driving performance were only present when participants had to complete the additional secondary tasks. As such, further work should attempt to use varying levels of task complexity to investigate the point at which monolingual and bilingual dual task performance truly begins to differ.

Although the PDT tasks used here are not commonly used in investigations of LCT, they are more relevant to the driving task: drivers must not only detect stimuli in their environment, but also assess the threat of these stimuli, either to the vehicle or the stimulus itself. Our PDT tasks required more spatial processing than simple detection tasks commonly used in distractibility research. Interestingly, monolinguals were less distracted by the combination PDT than bilinguals despite the fact that the only differences between these groups were due the language processing abilities. The results of this study, however, were obtained from a small sample of participants. Future work should use larger sample sizes and take into account any additional differences between bilinguals and monolinguals such as culture, that my influence performance. As other researchers on bilinguals have noted, future work should build upon this study by investigating other tasks that require processes outside of those used here.

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References

1. Stavrinos, D., Jones, J.L., Garner, A.A., Griffin, R., Franklin, C.A., Ball, D., Sisiopiku, V.P., Fine, P.R.: Impact of distracted driving on safety and traffic flow. Accid. Anal. Prev. **61**, 63–70 (2013)
2. Patten, C.J., Kircher, A., Östlund, J., Nilsson, L.: Using mobile telephones: cognitive workload and attention resource allocation. Accid. Anal. Prev. **36**, 341–350 (2014)
3. Rodrick, D., Bhise, V., Jothi, V.: Effects of driver and secondary task characteristics on lane change test performance. Hum. Factor Ergon. Manuf. Serv. Ind. **23**, 560–572 (2013)
4. White, C.B., Caird, J.K.: The blind date: the effects of change blindness, passenger conversation and gender on looked-but-failed-to-see (LBFTS) errors. Accid. Anal. Prev. **42**, 1822–1830 (2010)
5. Mio, J., Trimble, J., Arredondo, P., Cheatham, H., Sue, D. (eds.): Keywords in Multicultural Interventions: A Dictionary. Greenwood, Westport (1999)
6. Hilchey, M.D., Klein, R.M.: Are there bilingual advantages on nonlinguistic interference tasks? Implications for the plasticity of executive control processes. Psychon. Bull. Rev. **18**, 625–658 (2011)
7. Ben-Zeev, S.: The influence of bilingualism on cognitive strategy and cognitive development. Child Dev. **48**, 1009–1018 (1977)
8. Bialystok, E., Craik, F.I., Klein, R., Viswanathan, M.: Bilingualism, aging, and cognitive control: evidence from the Simon task. Psychol. Aging **19**, 290–303 (2004)
9. Hernández, M., Costa, A., Humphreys, G.W.: Escaping capture: bilingualism modulates distraction from working memory. Cognition **122**, 37–50 (2012)
10. Prior, A., Gollan, T.H.: Good language-switchers are good task-switchers: evidence from Spanish-English and Mandarin-English bilinguals. J. Int. Neuropsychol. Soc. **17**, 682–691 (2011)
11. Prior, A., MacWhinney, B.: A bilingual advantage in task switching. Bilingualism Lang. Cogn. **13**, 253–262 (2010)
12. Green, D.W.: Mental control of the bilingual lexico-semantic system. Bilingualism Lang. Cogn. **1**, 67–81 (1998)
13. Li, P., Sepanski, S., Zhao, X.: Language history questionnaire: a web-based interface for bilingual research. Behav. Res. Methods **38**, 202–210 (2006)

14. Carroll, R., Luna, D.: The other meaning of fluency. J. Advertising **40**, 73–84 (2011)
15. Mattes, S., Hallén, A.: Surrogate distraction measurement techniques: the lane change test. In: Regan, M.A., Lee, J.D., Young, K.L. (eds.) Driver Distraction: Theory Effects and Mitigation. CRC Press, Boca Raton (2009)
16. Rodrick, D., Bhise, V., Jothi, V.: Effects of driver and secondary task characteristics on lane change test performance. Hum. Factors Ergon. Manuf. Serv. Ind. **23**(6), 560–572 (2013)
17. Hart, S.G., Staveland, L.E.: Development of NASA-TLX (Task Load Index): results of empirical and theoretical research. Adv. Psychol. **52**, 139–183 (1988)
18. Sharek, D.: NASA-TLX Online Tool (Version 0.6) [Internet Application]. Raleigh, NC (2009). http://www.nasatlx.com