Subjective workload and performance of young drivers faced to unexpected pedestrian crossings

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ABSTRACT

Introduction: The aim of the present study is to identify which of subjective workload dimensions are influenced by driving experience and situation complexity, and which ones influence driving performance. **Method**: Fifty-seven young drivers (15 traditionally trained novices, 12 early-trained novices, 15 with three years of experience and 15 with at least five years of experience) were randomly assigned to three situations (simple, moderately complex and very complex) in a driving simulator. Self-reported levels of workload during unexpected pedestrian crossings were collected by a questionnaire (NASA-TLX) between each situation. **Results and discussion:** Three workload subscales decreased with experience and increased with situation complexity, and one subscale was correlated to driving performance.

KEYWORDS

Subjective workload; driving experience; situation complexity.

INTRODUCTION

Epidemiological studies show that young novice drivers have a risk of accident two to four times higher than young experienced drivers (Triggs, 2004). Driving impairments come especially for novices who often have a lack of routine automation (De Craen, Twisk, Hagenzieker, Elffers, & Brookhuis, 2008; Fuller, 2002). In the complex system of traffic (environment – road user – vehicle), the origin of failures mainly come from interactions between the three elements of this system (Van Elslande, 2003). Interactions between environment and road users are particularly interesting inasmuch 90 % of road accidents are due to human errors (Amditis, Andreone, Pagle, Markkula, Deregibus, Rue, Bellotti, Engelsberg, Brouwer, Peters, & De Gloria, 2010). Indeed, subjective workload, i.e. cost perceived depending on the interaction between tasks required and drivers' state (Hockey, 2003), can damage performance if its level is either too high (overload) or too low (underload) (Meister, 1976 ; in De Waard, 1996). Situation complexity provokes thus more or less workload which is perceived differently depending on individuals. Organizing knowledge into schemas with learning provokes a task automation leading to a decrease of workload (Tricot, 1998). It can also lead to a cognitive readiness by anticipating and scheduling situations already known, which is necessary to take an efficient decision, especially in complex situations (Cegarra, & van Wezel, 2012). Conversely, if the activity is not entirely automatized, performing the task implies producing a higher effort. For complex tasks, despite subjective workload enhancement, driving performance can be maintained because compensatory mechanisms are gradually set up with practice (Amalberti, 1996; Cegarra & Hoc, 2006). Nevertheless, required effort can be too high for individual's abilities and can therefore generate overload characterized by an increase of workload leading to performance impairments. Thus, for the same driving situation, the activity can be controlled, or automatized throughout experience enhancement, which leads to a higher effort for novices than for experienced drivers (Patten, Kircher, Östlund, Nilsson, & Svenson, 2006). Therefore, the threshold from which drivers perceive an overload not only depends on situation complexity but also on skills acquired during the driving.

Moreover, some aspects of subjective workload could be more or less influenced by driving experience, and could more or less influence driving performance. Indeed, Hart and Staveland (1988) identified six combinations of relevant factors which characterize subjective workload: mental demands (amount of mental and perceptual activity required), physical demands (amount of physical activity required), temporal demands (amount of pressure felt due to the rate at which the task elements occurred), own performance (successful assessment in doing the task required and satisfaction assessment in accomplishing it), effort (difficulty assessment in having to work mentally and physically to accomplish the level of performance) and frustration (assessment of feeling insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent during the task). According to Gaillard (1993; in Collet, Averty, & Dittmar, 2009), effort and stress are two components that determine workload, with stress enhancement which could increase effort depending on task demands and individuals. Therefore, our hypothesis is that both frustration (associated to stress) and effort should increase with situation complexity and decrease with driving experience. Moreover, task difficulty (mental and physical demands) is associated to task demands and should also depend on situation complexity and driving experience. Conversely, temporal demands should be influenced by these two factors through subjective anxiety enhancement, as time pressure imposed by the situation first activate the emotion and have thus an indirect effect on workload (Monod & Kapitaniak, 1999; in Galy, Cariou, & Mélan, 2012). Finally, performance estimation should be positively correlated to objective driving performance.

METHOD

Participants

Fifty-seven young drivers (33 males and 24 females) were divided up into four groups depending on their driving experience. Two groups were composed of novice drivers who obtained their driving license within the last two months, with 15 Traditionally Trained Drivers (TTD)[1] aged between 18-20 (M = 19, SD = 0.84) and 12 Early-Trained Drivers (AAC – Apprentissage Anticipé de la Conduite[2] aged 18. The two other groups consisted in 15 drivers aged 21 arriving at the End of the three-year Probationary Period (EPP)[3], and 15 Experienced Drivers (ED) aged between 23-30 (M = 26.87, SD = 2.97) with at least five years of experience.

Experimental setup

The experiment was carried out on the SIM²-IFSTTAR fixed-base driving simulator equipped with an ARCHISIM object database (Espié, Gauriat & Duraz, 2005). The driving station comprised one quarter of a vehicle (see Figure 1). The image projection (30 Hz) surface filled an angular opening that spanned 150° horizontally and 40° vertically. The vehicle had an automatic gearbox and was not equipped with rearview mirrors.

Figure 1. Driving simulator

Procedure and statistical analyses

Participants drove on three different rural driving situations (22.5 kms each) in a counterbalanced order. The simple situation consisted in a straight national road with two ways, without any traffic. The moderately complex situation included right and left curves (length: 600 m, radius: 300 m). The most complex situation had double and sharper curves (length: 300 m, radius: 120 m), with oncoming traffic. Whatever the situation was, three scenarios implying a pedestrian were included. The pedestrians, hidden by a billboard, a bus stop or a tree in a random order, crossed the road around 2.7 seconds before the participant arrived at his level. The instructions were to drive at 90 km/h.

The NASA-TLX questionnaire (Hart & Staveland, 1988) assessed the subjective level of workload after each circuit. It comprised 6 subscales: Mental Demands, Physical Demands, Temporal Demands, Own Performance, Effort and Frustration. For each subscale, participants estimated their workload during the last circuit on a 20 points scale ranged from 0 = 'very low' to 20 = 'very high'. For Own Performance dimension, the scale was ranged from 0 = 'success' to 20 = 'failure'. The questionnaire has been modified in order to separate subjective workload associated with the different portions of the three circuits. For each subscale of the questionnaire, the question was attributed to the pedestrian crossings.

Repeated measures ANOVA were carried out in order to test the effects of driving experience and situation complexity on each subjective workload dimension attributed to pedestrian crossings. Bonferroni post-hoc tests were subsequently used for pairwise comparisons. Linear regressions analyses then tested the effect of each subjective workload dimension (except from Own Performance dimension) on the number of collisions with pedestrians (performance). The link between subjective and objective performance was tested via a Bravais-Pearson's correlation. For all analyses, statistical significance was set at $p \leq .05$. To clarify the reading, non significant effects are not presented.

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[1] TTD: 20 hours of driving lessons with an instructor.

[2] AAC: 20 hours of driving lessons with an instructor and an additional driving practice with an adult during 3,000 km., driving learning permitted to start at the age of 16.

[3] EPP: from the driving license exam, partial license during three years with restrictions as speed limitation and only 6 points instead of 12 points.

RESULTS

Effects of driving experience on each subjective workload subscale

Driving experience significantly decreased Own Performance ($F(3,53)=6.54$; $p<.001$), Effort ($F(3,53)=2.91$; $p<.05$) and Frustration ($F(3,53)=4.62$; $p<.01$). Own Performance was higher for Early-Trained Drivers (AAC) than for drivers at the End of the Probationary Period (EPP) and Experienced Drivers (ED). Effort and frustration were higher for AAC then for ED (See Table 1 below).

Table 1. Each subjective workload subscale for each group

Subscales	TTD, Mean (SD)	ETD, Mean (SD)	EPP, Mean (SD)	ED, Mean (SD)
Mental demands	13.42 (4.83)	15.92 (3.94)	13.47 (4.46)	12.51 (4.64)
Physical demands	12.42 (4.97)	14.06 (5.15)	11.29 (5.44)	9.47 (4.58)
Temporal demands	13.33 (5.13)	15.53 (5.22)	14.38 (4.24)	12.71 (4.56)
Own performance	8.73 (5.73)	12.42 (6.02)	7.27 (4.90)	6.64 (3.41)
Effort	12.91 (4.63)	15.50 (3.88)	13.13 (4.56)	11.38 (4.67)
Frustration	11.20 (5.71)	13.19 (5.67)	9.00 (4.98)	7.80 (4.41)

Effects of situation complexity on each subjective workload subscale

Situation complexity had a significant effect on Mental Demands ($F(2,106)=3.91$; $p<.05$), Physical Demands ($F(2,106)=6.05$; $p<.01$) and Effort ($F(2,106)=3.77$; $p<.05$). Indeed, each of these three dimensions was lower in simple situation than in very complex situation. Physical Demands were also lower in simple situation than in moderately complex situation (see Table 2 below).

Table 2. Each subjective workload subscale for each situation

Subscales	Simple, Mean (SD)	Moderately complex, Mean (SD)	Very complex, Mean (SD)
Mental demands	12.68 (5.02)	14.02 (4.36)	14.46 (4.37)
Physical demands	10.61 (5.17)	12.02 (5.44)	12.44 (5.07)
Temporal demands	13.23 (5.22)	13.86 (4.77)	14.63 (4.53)
Own performance	7.49 (4.97)	9.00 (5.09)	9.23 (6.16)
Effort	12.16 (4.71)	13.49 (4.46)	13.68 (4.72)
Frustration	9.89 (5.39)	10.32 (5.57)	10.23 (5.71)

No interaction effect between driving experience and situation complexity were observed on subjective workload dimensions.

Subjective workload subscales and collisions' number relationships

In this model, none of the subjective workload dimensions tested influenced the number of collisions. However, the correlation analysis showed that performance was more assessed as a failure when the number of collisions increased ($r = .61$; $p < .001$) (see Figure 2 below).

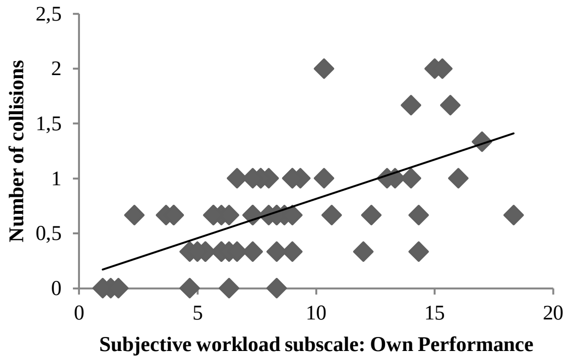

Figure 2. Effect of Own Performance on the number of collisions

DISCUSSION

Three subjective workload subscales (Own Performance, Effort and Frustration) decreased with driving experience. Early-Trained Drivers assessed thus more their own performance as a failure than more Experienced Drivers, probably because they had more collisions with pedestrians than more Experienced Drivers who have more knowledge to take an efficient decision (Cegarra, & van Wezel, 2012). Traditionally Trained Drivers didn't consider they failed more than the other groups. They probably overvalued their abilities and undervalued their accident risk (optimism bias, see McKenna, 1993) compared to more experienced drivers who met more hazardous events, helping them to develop situation awareness (Underwood, Chapman, Bowden, & Crundall, 2002). Early-Trained Drivers assessed that they made more effort in accomplishing the task required than Experienced Drivers. It thus reveals that from five years of experience, drivers have sufficiently automatized the driving to have more available resources to deal with unexpected situations as a sudden pedestrian crossing.

Moreover, Early-Trained drivers also assessed they had more frustration than Experienced Drivers. This result indicates that as drivers think they don't make a great effort, they feel quite relaxed during the task. More data about their subjective anxiety should reveal that Experienced Drivers feel less anxious and therefore less frustrated than novice drivers. Traditionally Trained Drivers should make more effort and should be thus more frustrated than Experienced Drivers inasmuch novices haven't automatized all driving tasks (De Craen et al., 2008; Fuller, 2002). A comparison between objective and subjective workload could show whether the absence of difference between these groups is due to a false self-assessment from novices or not. However, mental and physical demands didn't vary as a function of driving experience, revealing a high variability between the groups.

As expected, the three subscales Mental Demands, Physical Demands and Effort increased with situation complexity. Nevertheless, situation complexity didn't provoke a variation of frustration, which is probably due to the same pedestrian crossing scenario for the three situations.

According to our hypothesis, own performance was positively correlated to driving performance.

Training in simulator with complex and/or unexpected situations could therefore help novice drivers to construct a mental representation of these situations and thus automatize driving tasks in order to decrease their subjective workload and improve their performance.

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