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Can we talk about speed? The effect of verbal protocols on driver speed and perceived workload

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Abstract

In recent naturalistic driving studies, verbal protocols analysis (VPA) has become a popular method for assessing road users' situational awareness and mental processes while on-road. This method requires participants to provide concurrent verbal protocols about the driving task. Despite its increasing use in road safety research, it is unknown whether providing verbal protocols influences driving behavior and performance. The aims of this study were to examine the effect of providing concurrent verbal protocols on speed regulation and perceived workload, and to determine whether these effects are moderated by practice. Twenty participants with a full license drove an instrumented vehicle around a pre-determined route, twice while performing concurrent verbal protocols and twice while driving in silence. The results indicate that performing concurrent verbal protocols does not have a significant impact on driving speed, speed variability, percentage of time spent over the speed limit or ratings of perceived workload. However, speed variability decreased significantly with practice driving the route. These findings suggest that performing verbal protocols does not disrupt driving performance as reflected in measures of speed, which supports the claim that VPA is an appropriate method for on-road studies. Further important research questions regarding validating the VPA method for on-road studies are discussed.

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Keywords: Verbal protocols; VPA; On-road studies; Driver performance; Situational awareness; Speed

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1. Introduction

Verbal Protocol Analysis (VPA) has a long history of application in studies examining the cognitive processes underpinning human behavior[1, 2]. Although early applications emerged in areas such as process control and distributed teamwork, recently the method hasbecome popular forassessing situational awareness and mental processes in on-road driving studies[3-5]. Typically, this involves participants providing concurrent verbal protocols while they drive around a pre-determined route. Participants are instructed to "think aloud" and are usually given minimal prompting. Despite its increasing application in this context, there has been little investigation into whether performing concurrent verbal protocols changesdrivingbehavior and the driving experience[4].

One particular concern is that performing concurrent verbal protocols may influence driving behavior and performance,increase driver workload and/or distract the participant from the driving task. In the broader road safety literature, for example,anumber of studies have shown that talking on a hands-free mobile phone negatively impacts driving performance. Specifically, drivers talking on a hands-free mobile phone exhibit lower mean speed[6], greater variation in speed[7] and a greater percentage of time exceeding the speed limit[8]. These findings suggest that performing verbal protocols could potentially have a negative impact on drivers' capacity to regulate the speed of the vehicle.

Alternatively, it could be argued that performing concurrent verbal protocols may enhance driving performance by focusing attention on the driving task. Some forms of advanced driving training use a method similar to concurrent verbal protocols to train driver situation awareness. When undertaken for an extended period of time, this type of training has been shown to improve driver situation awareness, as measured by post-test cognitive task analysis interviews[9]. This suggests that if performed over an extended period of time, performing verbal protocols may have a positive impact on speed regulation.

Given the increasing use of VPA in studies of road user behavior, the impact of providing verbal protocols on driving performance represents a critical question for road safety researchers, and indeed researchers adopting the method in other areas. These questions are particularly pressing as studies draw conclusions on the impact of road environment design on situation awareness and behavior[4]. Further research is required to confirm that study findings are not in fact a product of the drivers being influenced by the requirement to provide concurrent verbal protocols.

The aim of this study is to examine the effect of performing concurrent verbal protocols on speed regulation and perceived workload. As a secondary aim, the study will also examine whether any impacts are moderated by practice. It is predicted that initially, compared to driving while silent, performing verbal protocols will have a negative impact on speed regulation and perceived workload. However, it is predicted that these effects will be ameliorated with practice, and that speed regulation may even improve when performing concurrent verbal protocols.

2. Method

2.1. Design

A (2) × (2) repeated measures design was used. The first factor was providing a concurrent verbal protocol(verbal protocol, control) and the second factor was study route lap (1, 2), which resulted in four experimental conditions. The requirement to provide a concurrent verbal protocol was counterbalanced so that equal numbers of participants experienced the verbal protocol and control conditions first. Participants drove the same pre-determined route under all conditions. The dependent variables were mean speed, speed variability, the percentage of time spent over the speed limit and ratings for perceived workload.

2.2. Participants

Participants were recruited through newsletter lists maintained by the research team and were compensated with a $50 voucher for their time. Ethics approval was granted by the University of the Sunshine Coast Human Ethics Committee.

2.3. Materials

2.3.1. Instrumented vehicle

Data collection was undertaken in the Centre for Human Factors and Sociotechnical Systems' instrumented vehicle,the On Road Capability (ORCa). ORCais a standard Ford Focus 2.0L Trend sedan,instrumented with a Racelogic video VBOX pro. The VBOX aggregates and stores vehicle data, and includes inputs from 2 HD video cameras, a single microphone, the vehicles CAN bus and the VBOX's on-board GPS and accelerometer. The data is written to an SD card, which can be exported to excel or SPSS.

2.3.2. Route selection

A 15km urban route, located in the suburbs around the University of the Sunshine Coast, was used for the on-road study. The route comprised a mix of arterial roads (60km/h speed limit), and highways (100km/h speed limit). The highway section was not used in the current analysis.

2.3.3. Self-report measures

The NASA Task Load Index(NASA-TLX)[10] was used to assess participant's perceived workload for each condition. The NASA-TLX comprises six workload sub-scales (mental demand, physical demand, temporal demand, performance, effort and frustration level) with each being rated on a scale of 1 (low) to 10 (high). This was administered electronically via tablet in the form of a questionnaire.

2.4. Procedure

In order to control for traffic conditions, all data collection started at 10am and was completed by 2pm on weekdays during light traffic and sunny weather conditions.

After signing aconsent form, participants completed a demographic questionnaire. Participants were then trained to provide concurrent verbal protocols. Verbal instructions were given, after which they practiced performing the verbal protocols in a desktop driving simulator for approximately 10 minutes. Participants received guidance and feedback from the experimenter throughout the practice session. The route was then described using a paper map as a visual aid. When comfortable with the VPA procedure and route, participants were taken to ORCa and asked to prepare themselves for the drive. Participants initially completed twofamiliarization laps of the route accompanied by a researcher. On the first lap the researcher gave verbal directions regarding the route. On the second lap, the researcher only provided directions if requested.

Once the two familiarization laps were completed, all recording devices were turned on and participants drove the route unaccompanied, and were instructed either to perform concurrent verbal protocols or drive in silence (note the order was counterbalanced across participants). At the completion of each lap, participants were asked to pull over andcomplete the NASA-TLXquestionnaire. This was repeated for the second lap on the same condition (i.e. either verbal protocols or control). Participants were then instructed to perform the alternative condition for two laps (i.e. either verbal protocolsor control). Overall, participants completed the NASA-TLX four times, twice after verbal protocols, and twice after driving in silence.

The researcher then drove ORCa back to the University of the Sunshine Coast and participants were reimbursed for their time.

2.5. Data reduction and analysis

The space separated text file output from the VBOX (.vbo format) for each participant was processed using "VBOX file processor" software in order to obtain a reduced set of variables that included speed, time and distance. The route contained a number of traffic intersections that provided potential stop points that were highly unlikely to be consistent between participants or indeed between consecutive laps.The decision was made to remove some sections of the sample where the speed variable was likely to be strongly affected by an external source (i.e. traffic flow or traffic signals). The procedure to remove these sections is as follows.

The processed files were then imported into Microsoft excel where 4 sections were extracted for analysis. The criteria for these sections was that they started 100m after end of merge, a traffic light, or the exit of a roundabout and stopped 100m before a traffic light, or the entrance of a roundabout. In addition, if there were any times when the vehicle came to a complete stop along the route data was removed for 100m before and after the stopping point. One participant encountered road works and stopped for one of the laps, so for this participant an approximately 500m section from the first speed restriction sign to the next intersection was removed in all of their laps.

For most participants the total distance analyzed was around 5665m, however for participant 4, 500m of road works were removed for each lap. Two other participants came to a complete stop due to traffic along the route, for participant 5, 130m was removed from their second VPA lap and for participant 6, 208m of their first VPA lap was removed. The sections that were extracted were consolidated as a single data set for each lap completed, all sections for which data was used had a speed limit of 60km/hr. From each lap/data set three variables were examined, mean speed, speed variability and percentage of time spent above the speed limit.Overall ratings of perceived workload were calculated from the NASA-TLX ratings for each condition.

Preliminary data analysis showed that assumptions of normality were violated for mean speed and speed variability. Mean speed was corrected through the removal of one participants' data with extreme values. Speed variability was corrected through reciprocal transformation. Data were analyzed using repeated measures ANOVAs using a criterion of $\alpha = .05$. To supplement the interpretation of the results, partial η^2 was used an estimate of effect size (0.01 = small effect, 0.06 = moderate effect, 0.14 = large effect;[11]).

3. Results

3.1. Sample

Nineteen participants (10 males, 9 females) aged between 25 and 49 years (M = 38.63, SD = 6.88) were included in the analysis. On average, participants had 20.89 years of driving experience (SD = 7.34). Descriptive statistics for mean speed, speed variability, percentage of time spent above the speed limit and perceived workload are presented for each condition in Table 1.

Table 1. Means (M) and standard deviations (SD) for mean speed, speed variability, percentage of time over the speed limit and perceived workload by condition.

	Control Lap 1		VPA Lap 1		Control Lap 2		VPA Lap 2	
	M	SD	M	SD	M	SD	M	SD
Mean speed	56.01	1.86	55.71	2.50	56.02	1.85	55.71	2.60
Speed variability	35.63	31.36	35.94	32.25	29.01	23.41	37.56	32.52
% of time over the speed limit	23.07	17.96	23.49	15.49	20.04	16.01	22.79	16.58
Perceived workload	25.52	6.41	26.84	6.63	24.84	5.98	26.84	6.63

3.2. Mean speed

On average, there was no significant difference in mean speed for the first in comparison to the second laps; $F(1, 18) = 0.33$, $p = 0.56$, partial $n^2 = 0.01$. On average, there was no significant difference for the verbal protocol in comparison to the control conditions; $F(1, 18) = 0.01$, $p = 0.97$, partial $n^2 = 0.00$. The interaction was non-significant; $F(1, 18) = 0.00$, $p = 0.99$, partial $n^2 = 0.00$.

3.3. Speed variability

On average, there was a significant difference in speed variability for the first compared to the second laps; $F(1, 18) = 4.13$, $p = 0.05$, partial $n^2 = 0.18$. On average, there was no significant difference in speed variability for the verbal protocol in comparison to the control conditions; $F(1, 18) = 0.12$, $p = 0.72$, partial $n^2 = 0.00$. The interaction was non-significant $F(1, 18) = 0.64$, $p = 0.43$, partial $n^2 = 0.03$.

3.4. Percentage of time spent over the speed limit

On average, there was no significant difference in the percentage of time spent over the speed limit for the first compared to the second laps; $F(1, 18) = 0.24$, $p = 0.62$, partial $n^2 = 0.01$. On average, there was no significant difference in the percentage of time spent over the speed limit for the verbal protocol compared to the control conditions; $F(1, 18) = 1.11$, $p = 0.30$, partial $n^2 = 0.05$. The interaction was non-significant $F(1, 18) = 0.58$, $p = 0.45$, partial $n^2 = 0.03$.

3.5. Perceived workload

On average, there was no significant difference in overall ratings of perceived workload for the first and second laps; $F(1, 18) = 1.21$, $p = 0.28$, partial $n^2 = 0.06$. On average, there was no significant difference in overall ratings of perceived workload for the verbal protocol compared to the control conditions; $F(1, 18) = 0.42$, $p = 0.52$, partial $n^2 = 0.02$. The interaction was non-significant $F(1, 18) = 0.42$, $p = 0.52$, partial $n^2 = 0.02$.

4. Discussion

The use of naturalistic and semi-naturalistic studies of driver behavior is increasing significantly[12], and such studies are likely to become more and more important given the shifting nature of road transport systems, vehicles, and infrastructure. Whilst the external validity of such studies is evident, there has been little examination of the methodologies used within on-road studies. VPA is one such method that has been applied extensively in on-road studies over the past decade.The aim of this study was to examine the effect of performing concurrent verbal protocols on speed regulation and perceived workload when driving. A secondary aim was to examine whether any potential impacts were moderated by practice. Overall, compared to driving normally,performing concurrent verbal protocols did not have any significant effect on any of the measures of speed regulation or perceived workload, nor were any of these effects moderated by practice.Speed variability decreased with practice; however, this effect was largely only evident in the control condition. Overall, these findings suggest that performing verbal protocols does not distract from the key driving task of managing vehicle speed and does not impose any additional workload on drivers. The findings provide initial evidence that driver performanceis not be impacted by the requirement to provide concurrent verbal protocols.

Workload was included in the study to qualitatively assess participant performance[13]. Participants did not perceive that workload changed with the introduction of concurrent verbal protocols. This suggests that the act of describing the driving situation is somewhat less taxing than other verbal tasks undertaken while driving, such as talking on a hands free mobile phone[6-8].Potentially, performing concurrent verbal protocols is not perceived as more taxing than driving in silence because the verbalizations are directly related to the act of driving.

Speed variability decreased significantly between the first and second laps; however, this effect was largely only evident in the control condition. This could be interpreted as a practice effect, showing an improvement in regulating the speed of the vehicle. This finding also indicates that the sample size for the study was sufficient to detect a large effect, and that differences in speed variability could be detected if present. This adds weight to the conclusion that verbal protocols do not effect driving performance, at least as reflected in measures of speed.

As discussed, VPA has become a popular method for examiningparticipants situational awareness and mental processes while driving[14]. One of the reasons is that the rich data can be used toexamine the cognitive processes of drivers. Encouragingly, the findings from this study are supportive for VPA as an appropriate method for assessing road user behavior; however, caution is urged given that only speed regulation and workload were examined. This study represents the first step in validating VPA as an appropriate method for studying road user cognition and behavior.However, one limitation of this study is that it only examined mid-block driving behavior, further examination of speed behavior while passing through intersections is essential. Further studies are also required to assess the impact on other important aspects of driver behavior and performance, such as steering, braking profiles, headway, lane keeping, and driving errors. In addition, studies exploring the impact of providing verbal protocols on situation awareness are required.Some of these questions will be addressed in a follow-up paper which will includea broad examination of other variables that were measured in the course of this study.

In conclusion, this study found that performing concurrent verbal protocols had no significant effect on speed regulation or perceived workload. These results are positive for the use of concurrent verbal protocols in on-road studies.The findings suggest that verbal protocols can be used both as a standalone data collection method, and in conjunction with vehicle instrumentation to gather data that is not confounded by the data collection method.

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