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Role of prospective memory in driving behavior

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Abstract

Realisation of delayed intention distributes the running cognitive resources of an individual from the ongoing task. Understanding this theoretical account in the complex task such as driving requires an understanding of how Prospective Memory influences driving behaviour. The present study is an attempt to investigate to what extent the PM contributes in driving behaviour. A sample of 145 licensed drivers (mean age 45 years) was recruited to complete the self-reported measures on prospective-retrospective components of memory and driving behaviour. The results indicated that PM failures overall contribute to errors in driving behaviour. The errors of slip are particularly related to prospective memory failure with explaining total 22.7% variance in driving errors.

Keywords: Prospective memory; Retrospective memory; Driving; Error; Slip

1. Introduction

Prospective memory is “realization of delayed intention” (Ellis, 1996). In other words it refers to a process that helps an individual to carry out an intended or planned action after a delay in near future (Ellis, 1996; McDaniel & Einstein, 2007). Brandimonte & Passlungh, 1994, formulated five major stapes of PM. Step one is the encoding of intention to be remembered, it includes three sub-phases i.e. (i) formation of intention, (ii) retrospective component (past-oriented actions and incidental in nature), and (iii) prospective component (planning and monitoring of information regarding the to-be-performed action).

Nomenclature:
1. PM – Prospective Memory
2. RM – Retrospective Memory
2. PRMQ – Prospective Retrospective Memory Questionnaire
3. DBQ – Driving Behaviour Questionnaire

Step two refers to retention interval where intentions are retrieved. In step three, an intended action should be retrieved for successful prospective memory performance, this phase is also known as performance interval. Step four explains the initiation and execution of the intended action, and step five involves the evaluation of the outcome which relates to remembering of performed action. Prospective memory has implications ranges from simple to complex goal oriented real life situations

The whole PM concept works on how an intention is formulated (Walter & Meier, 2014). PM involves working and long-term memory processes depending on time between intention and action, as well as attentional processes (Wittmann, 2009). Generally, a dual-task setup is suggestive for PM studies in laboratories where participants engaged in an ongoing task are checked for specified secondary task response at realization of pre-determined cue (Einstein & McDaniel, 1990). Similarly, in case of a complex real world scenario, the setup could be multitasking, in which certain priority based PM cue responses are needed for successful implementation of PM. Smith et al., (2000) developed a self-reported measure known as Prospective Retrospective Memory Questionnaire of prospective and retrospective slip in everyday life (Crawford et al., 2003). PRMQ has 16 items, 8 for PM and 8 for RM respectively. It has further subscales of short term and long term memory; self and environmental cued. Kliegel and JÄger (2006), validated PRMQ and provided the evidence for using PRMQ subscales in differentiating between prospective and retrospective memory task performance.

Failures in PM describe situations where individuals forget to perform an intended task. Interruptions to pre-flight procedures and subsequent PM failures have been shown to contribute to planes crashing (Dismukes & Nowinski, 2005), and mid-surgery disruptions have resulted in physicians leaving instruments or sponges in patients following surgery (Gawande, Studdert, Orav, Brennan, & Zinner, 2003). Retrieval of delayed intention always occurs simultaneously to an on-going task, which demonstrates that such delayed intentions can compromise the speed and accuracy of an independent ongoing task. The multitasking framework for PM retrieval has been proposed which distinguishes between a strategic process that actively monitors the target intention whilst concurrently performing any ongoing task, and an automatic process that spontaneously retrieves the intention in response to target presentation.

Driving a car is a complex multitasking operation (Cummings, Kilgore, Wang, Tijerina, & Kochar, 2007; Salvucci, Liu, & Boer, 2001) which uses all the subjective capabilities of a driver and considers the immediate driving conditions. Such complex system imposes concurrent task demands on operators which are more like series of a task involving prospective remembering. While driving, driver needs to encode the on-road instructions (time based or event based cues) or other secondary task in form of intentions to process those from prior knowledge towards implementing those in the near future. Holding the intentions till the cue encounter which trigger the preparatory behaviour in form of realization of delayed intentions. The failure of the anticipatory behaviour in implementation of intentions and improper mental construction of future events can lead to interruptions, distractions and preoccupations which impose constraints on the current task. This may cause failure to perform the intended task. For i.e. while performing one task, driver monitors several tasks concurrently by periodically switching attention back and forth among tasks. But if problems arise in the current task, drivers are vulnerable to *cognitive tunnelling,* whereby they forget to switch attention (Patten et al., 2004, Ververs & Wickens, 2000) caused by intention realization failure. This situation is similar to distracted driving and concerns the time-based Prospective memory.

Further, Smith (2003) also suggested that maintaining the PM in at least some situations requires attentional resources which could result in a detectable drop in the ongoing task performance. Such drop in ongoing performance has been observed with text-based and key pressing tasks, very little has been investigated as for how internal self-generated switching (cognitive distractions), which require the driver to viably keep up an inward discourse around a random issue, meddle with the driving undertaking (Trawley, et al., 2017). Trawley et al. (2017), findings suggested that event based tasks were more cognitively demanding than time based task which were in contrast to the existing findings which suggests time-based tasks are more cognitively demanding (Field & Greoger, 2004, Einstein et al. 1995, Park et al.1997; Khan & Sharma, 2007). Trawley et al., found that drivers given event-based errands showed greater difficulty in mirroring lead vehicle speed changes as compared to the time-based group. Observational road safety work by Greogry et al., (2014) has suggested that PM failures may be responsible for speeding. The combination of current theoretical accounts of PM in context of driving suggests that drivers are vulnerable to commit errors both in case of distraction due to secondary tasks and failures in PM.

In general, errors are defined as failure of planned actions intended to achieve their goal (Mandler, 1975 & 1985). Most extensive research on errors and driving behaviour was conducted by Reason et al., (1990). They developed a 50-items driver behaviour questionnaire (DBQ) and identified five classes of aberrant driver behaviour: slips, lapses, mistakes, unintended violations and deliberate violations; i.e. intending to drive within the speed limit, but accidentally pressing the accelerator (a slip), forgetting the speed limit (a lapse), or thinking that the speed limit is 70 mph when it is actually 60 mph (a mistake) and intentional violations occur when the driver's intentions were to perform the action, such as deliberately exceeding the speed limit. Slips and lapse are errors of omission and mistake is an error of commission. Slip and lapse occur at the skill-based level and mistake at rules and knowledge-based levels. Study results showed that, in general, errors (slips and mistakes) and violations decrease with age. Aberg and Rimmo (1998) replicated the study with 1400 Swedish drivers aged between 18 and 70 years and extended the analysis to distinguish between errors of inexperience and errors of inattention and found that error of inattention increases with age. Reason et al.'s work has since been replicated in a number of different regional studies in combination with other questionnaires (Blockey and Hartley, 1995; Chapman, Ismail, & Underwood, 1999; Conner & Lai, 2005; Dobson et al., 1998; Kontogiannis et al., 2002; Xie and Parker, 2002; Lucidi et al., 2010; Maxwell, Grant, & Lipkin, 2005; Parker, Stradling, & Manstead, 1996; Schwebel, Severson, Ball, & Rizzo, 2006).

Studying driving behaviour has always been a challenge for researchers because neither both behavioural and observational methodology could assess the true responses nor simulation set-up can (as it is a virtual replica of real-world). Eventually, all these methodologies have generously contributed in studying and understanding overall driving behaviour (especially cognitive mechanisms). The principle thought process behind any of such study is to tap those psychological factors (cognitive and memory failure) which could adversely impact drivers' execution and can push them in a dangerous situation (driving error). According to Reason (1990), the notion of intention and error is inseparable. Slips and lapse occur mainly because of attentional and memory failure respectively and mistakes are due to planning errors. So driving-error classification based on DBQ is suggestive to identify the role of PM in driving behaviour. The current study aims at exploring the role of memory failure (retrospective memory and prospective memory) in driving behaviour. The study will examine the role of PM in overall driving errors as well as the contribution of PM failure in each of the driving error.

2. Material and Method

2.1 Participant

A sample of 145 drivers between the age of 20 and 64 years old (mean = 35 and SD = 10.24) with minimum two years of driving experience with the valid driving license were administered for the study, where each participant was approached individually. Participants were reported to be individuals with no history of brain injury. They all mentioned professional training in motor driving school before they received their license.

2.2 Instruments and Procedures

At first, participants were introduced to with the purpose of the study in written and their consent forms were sought for the same. It followed by a personal-detail-form where participants were asked to indicate their age, gender, driving experience in years, monthly mileage, details of driving license, seating capacity of the car, the frequency of driving in a number of days per month, medical history and they're willing to participate in the future study. Then, the respective participants gave their responses on Prospective Retrospective Memory Questionnaire (PRMQ, Smith, et al 2000), it is a self-report measure of prospective and retrospective memory slips in everyday life. Participants were asked to rate themselves how often each of these things happened to them on five point scale (5-very often to 1-never). Lastly, the participants answered the DBQ (Reason et al, 1990) to assess their driving behaviour. Participants were asked for their responses on a six-point scale (0-never, 5-nearly all the time) across different driving situations to measure the driving errors of slip, mistake, violation and unintended violation.

3. Results and Discussion

Table 1 presents descriptive statistics for all measure of interest. The Cronbach coefficient alpha values obtained for PRMQ (PRMQ 16 items; α = .819) and DBQ (DBQ 50 items; α = .817) were in acceptable ranges. Table 2 shows significant correlation between participants driving behaviour scores and prospective retrospective memory scores ($r = .423$, $p < .01$). The scores of driving error of slip in driving behaviour were found to be significantly correlated with scores of prospective memory failure (including all subsets) ($r = .477$, $p < .01$) and driving error of slip with retrospective memory failure (including all subsets) ($r = .415$, $p < .01$) respectively. The correlation between the scores of prospective memory failure and the scores of driving error of slip were comparatively higher than with other sub scales of DBQ (mistake ($r = .437$, $p < .01$), unintended violation ($r = .295$, $p < .01$), violation ($r = .270$, $p < .01$) then with retrospective memory failure. The alpha level of 0.01 were used for all statistical methods.

In addition to correlation, simple linear regression and multiple regression (using stepwise method) were also computed to assess the ability of the prospective memory failure and its subscales (Prospective short-term self-cued, Prospective long-term self-cued, Prospective short-term environment-cued and Prospective long-term environment-cued) to predict the scores of driving error of slip. Regression analysis was used to test if the prospective memory failure predicted the driving error of slip. The result of simple linear regression indicated that prospective memory failure explained 22.7% of the total variance ($R^2 =.227$, $F (1,143) = 42.070$, $p<.01$) (table 3). In table 4 multiple regression analysis (using step-wise method) it was found that prospective short-term self-cued failure however significantly predicted driving error of slip ($\beta = .219$, $t = 2.60$, $p = 0.10$) as compared to prospective short term environmental-cued failure ($\beta = .153$, $t = 1.79$, $p = 0.75$), prospective long term self-cued failure ($\beta = .107$, $t = 1.30$, $p = 0.194$) and prospective long term environmental-cued failure ($\beta = .197$, $t = 2.30$, $p = 0.023$).

Table 1. Descriptive statistics (*N*=145)

Variables	Mean	SD
Demographics		
Age (in years)	35.21	10.28
Experience (in years)	10.11	8.22
Driving Behaviour Questionnaire (DBQ)		
DBQ Errors	47.0966	27.36363
DBQ mistake	17.37	10.897
DBQ violation	8.50	5.303
DBQ unintended violation	17.64	11.728
DBQ Slip	3.59	2.344
Prospective Retrospective Memory questionnaire (PRMQ)		
PM Failures	17.5448	4.06027
Prospective short-term self-cued	4.12	1.579
Prospective long-term self-cued	4.39	1.356
Prospective short-term environment-cued	4.86	1.467
Prospective long-term environment-cued	4.18	1.408
RM Failures	17.6828	4.08368
Retrospective short-term self-cued	4.58	1.378
Retrospective long-term self-cued	4.06	1.580
Retrospective short-term environment-cued	4.19	1.381
Retrospective long-term environment-cued	4.86	1.467

Table: 2 Correlation; Driving behavior and Prospective and retrospective memory (N=145)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 S														
2 M	.844**													
3 V	.723**	795**												
4 VU	.581**	.578**	.610**											
5 PM_SC_STM	.365**	.342**	.253**	.218**										
6 RM_EC_LTM	.337**	.257**	.115	.178*	.409**									
7 PM_EC_STM	.337**	.257**	.115	.178*	.409**	1.000**								
8 RM_SC_STM	.390**	.331**	.187*	.154	.374**	.564**	.564**							
9 PM_SC_LTM	.269**	.255**	.208*	.115	.283**	.175*	.175*	.249**						
10 RM_EC_STM	.344**	.356**	.271**	.267**	.429**	.250**	.250**	.262**	.330**					
11 PM_EC_LTM	.355**	.364**	.246**	.237**	.272**	.383**	.383**	.483**	.374**	.382**				
12 RM_SC_LTM	.119	.179*	.167	.047	.234**	.168*	.168*	.304**	.337**	.418**	.314**			
13 DB TOTAL	.922**	.920**	.923**	.691**	.339**	.249**	.249**	.313**	.255**	.345**	.338**	.158		
14 PM TOTAL	.477**	.437**	.295**	.270**	.725**	.712**	.712**	.600**	.637**	.500**	.715**	.373**	.424**	
15 RM TOTAL	.415**	.393**	.260**	.225**	.509**	.699**	.699**	.746**	.389**	.678**	.551**	.691**	.372**	.771**

N=145, $^{*}p < .05$; $^{**}p < .01$, two-tailed

DB- Driving behaviour, S- Slip, M- Mistake, V- Violations, UV- Unintentional violations, PM- Prospective memory, RM- Retrospective memory, SC- Self cues, EC- Environmental cues, STM- Short term memory, LTM- Long term memory.

Table 3 Adjusted R^2 when predicting driving behaviour

Model	R	R^2	Adjusted R^2	*SE B*
1	.477[a]	.227	.222	9.612

Predictors: (Constant), PM_TOTAL

Table 4. Summary of multiple regression analysis (N = 145)

Variable	*B*	*SE B*	*β*	*t*	*p*
(Constant)	-4.517	3.677		-1.228	.221
PM_S_STM_TOATL	1.509	.578	.219	2.609	.010
PM_E_STM_TOTAL	1.140	.635	.153	1.795	.075
PM_S_LTM_TOTAL	.858	.657	.107	1.306	.194
PM_E_LTM_TOTAL	1.526	.661	.197	2.307	.023

The study intended to identify the influence of memory failure (prospective memory and retrospective memory) on driving errors and how much does it varies the error-prone performance in driving? A prospective memory intention can be formed when one task is interrupted by another since the interruption makes it necessary to remember to resume the original task after finishing the interrupting task (Dodhia & Dismukes, 2009). The conscious recollection of the prospective memory intention at the appropriate time after the interruption constitutes the prospective component of the prospective memory task (Smith & Bayen, 2004). Relating this to the Gregory et al. (2014) study, drivers needed to form a prospective memory intention to remember to travel at the new reduced speed after the traffic lights turned green. Bowden et al (2017), examined whether speeding following an interruption could be better explained by unintentional prospective memory (PM) failure across three simulated driving experiments, corrected or uncorrected speeding in reduced speed zones increased on average from 8% when uninterrupted to 33% when interrupted. The present study found the driving error measure and prospective and retrospective memory failure measures internally consistent and leading some credence to examine error of omission. The correlation scores between DBQ and PRMQ were found significant. The values of correlation were considerably found higher between the error of slip in driving and prospective memory failure as compared to rest of subscales of DBQ (mistake, unintended violation) and subscale of PRMQ (retrospective memory failure).

The findings explain that both the measures tap error of omission i.e. drift from intended action; slip and share some relation among themselves. According to Reason et al (1990), slips are the unwitting deviation of action from intention. Norman (1983), stated that if the action is not what was intended, this is a slip. According to Rasmussen (1980), slips and lapses are errors identified with the skill-based level of performance. In DBQ the sub-scale of slip includes both slips and lapses, which indicated drift from intended action due to memory and attention failure. Slips are potentially observable as externalized actions-not-as-planned, the term lapse is customarily reserved for the more covert memory failures (Reason et al, 1990). The positive significant correlation shows that both the measures measuring slip are related. The relation between two also explains that error of slip which is drift from intended action has some contribution of prospective memory failure because the basic gist of the prospective memory is the realisation of delayed intention.

The regression analysis shows that out of total variance, 22.7% of the variance in driving error of slip is contributed by prospective memory failure. The variance was found significant at 0.01 level. This explains that in the overall function of error slip, 22.7% is predicted by prospective memory failure. Multiple regression analysis shows that prospective short-term self-cued failure contribute more towards driving error of slip which contradicts the finding that drivers given event-based errands showed greater difficulty in mirroring lead vehicle speed changes compared to the time-based group. And an additional finding that this cost was only evident with the event-based task highlights a potential area of both theoretical and practical interest (Trawley et al, 2017). The result from the current study is in line with predominant view in the literature which suggests time-based or self-initiated tasks are more demanding (Hick et al, 2005).

4. Conclusion

The present study is able to explain the relation between driving error of slip and prospective memory failure and also explains that it predicts the variance in the driving error. The findings suggest further exploration of slip in particular type of prospective memory cue (event/environmental or self/time) contributes more towards driving error of slip. In order to ensure the validity of findings, such an exploration can be of great practical use if carried out in the simulation setting. Such findings could aid in understanding and develop the cognitive profile of drivers and to identify the stage of preparatory behaviour where the drivers are more prone to commit errors.

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