International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:12, No:10, 2018

The Effect of Closed Circuit Television Image Patch Layout on Performance of a Simulated Train-Platform Departure Task

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***Abstract*—**This study investigates the effect of closed circuit television (CCTV) image patch layout on performance of a simulated train-platform departure task. The within-subjects experimental design measures target detection rate and response latency during a CCTV visual search task conducted as part of the procedure for safe train dispatch. Three interface designs were developed by manipulating CCTV image patch layout. Eye movements, perceived workload and system usability were measured across experimental conditions. Task performance was compared to identify significant differences between conditions. The results of this study have not been determined.

***Keywords*—**Rail human factors, workload, closed circuit television, platform departure, attention, information processing, interface design.

I. Introduction

A focus on operational efficiencies and reliable service delivery have challenged the way in which railway services are being designed and delivered. Australian rail operators have looked to new technologies to deliver efficiency gains, whilst ensuring safety performance and reliability is not compromised. Rail operators are looking to the designers of rollingstock to integrate technologies that enable flexible modes of operation. One such mode of operation is driver only operation (DOO). In DOO, the driver is supported by advanced technology systems that enables them to safely and efficiently execute tasks that have historically involved multiple personnel.

The integration of advanced onboard CCTV systems is one method by which technology can support the driver when performing platform departure tasks in DOO. On-board CCTV displays mounted on the driver's workstation can stream images from CCTV cameras mounted on the exterior of the train, to the driver. The images are presented in real time and can be used by the driver to determine if it is safe to close the train doors and once closed, commence departure sequences from the platform. On-board CCTV displays can also be used by the driver to effectively monitor the platform train interface during train departure [1].

Performance of the platform monitoring task is of critical importance, as platform train interface incidents contribute to a significant proportion of the risk faced by rail users and operators [2], [3]. A failure to adequately detect or respond to undesirable events at the platform train interface have been implicated in a number of operational incidents both in the United Kingdom [4], [5] and within Australia [6]. A recent review shows the risk related to train dispatch accounts for 10% of the risk to passengers and public at the platform train interface [7].

During the platform departure task, the driver in DOO relies on a CCTV interface to acquire task-related information, which is then interpreted to comprehend the current situational environment. Following comprehension of the current situation, a decision is generated, and an appropriate action initiated. The process of platform departure is congruent with a traditional staged model of information processing [8]. Throughout this process, cognitive resources are expended as attention is focused on perceiving and interpreting an array of CCTV images, in a relatively time constrained and dynamic environment.

Cognitive resource theory posits that there is a finite amount of attentional resources that can be expended before attentional capacity is exceeded [9]. Once exceeded, the cognitive resources available are fewer than the resources required to maintain task performance. The result is a deterioration in task performance and an increase in perceived cognitive load. In addition, depletion of cognitive resources are hastened by increases in the cognitive demands of a task [10]. Decision making under uncertainty, multiple competing task requirements, working under time constraints and complex information acquisition can all increase the cognitive demands of a task [11].

From a resource theory perspective, the availability of cognitive resources increases the capacity to respond to the cognitive demands of the task. As a consequence, increasing the availability of cognitive resources would be expected to moderate task performance. The availability of cognitive resources can be modified in a number of ways, including the shedding of tasks, a willingness to accept lower levels of performance, the introduction of energetic agents and/or efficiencies in the way in which information is acquired and processed [12], [13].

Given that the way information is acquired and processed can increase the availability of cognitive resources, changes to the way a driver acquires information during a platform departure task may affect the cognitive load imposed by the

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task. If information can be presented to the driver in a way that reduces information processing requirements, the cognitive load imposed by the task is likely to be reduced and as a result task performance improved. The CCTV interface is the primary source of visual information for the driver during platform departure tasks.

Manipulating the total number of image patches presented on the CCTV interface is one method to reduce the cognitive load imposed by the CCTV monitoring task [14]. However, depending on the total length of the train and the number of doors to be monitored, the ability to manipulate CCTV image patches is often limited. The image patch characteristics are another factor that will contribute to the cognitive demands of the monitoring task. That is, high resolution images with sufficient contrast and minimal distortion are likely to reduce the cognitive resource demands of the CCTV monitoring task [15].

Another approach which may reduce the cognitive demands of the task is by modifying the way in which CCTV image patches are presented on the CCTV interface. An ordered and logical presentation of CCTV image patches that supports drivers in conducting an effective systematic search pattern may demand fewer cognitive resources to process and interpret. CCTV image patch arrangements that do not align with the drivers spatial understanding of the train, or that do not allow for the development of efficient search methods using image patch features, may impose a higher demand on cognitive resources and impact task performance.

This study uses a high fidelity mock-up of an intercity train to evaluate if CCTV interface design has an impact on the performance of a simulated platform departure task. Specifically, the study manipulates CCTV image patch layout across different experimental conditions to assess if task performance, in terms of target detection and target response latency, varies across interface design conditions. Perceived workload and eye tracking metrics were recorded and evaluated. The aim of the present study is to determine if CCTV interface design affects task performance, perceived workload and system usability.

II. Methodology

A. Participants

The participants comprised both operators from a railway operator in New South Wales (N = omitted) and members of the public (N = omitted). They were recruited as part of a rollingstock development project and ranged in age from (omitted) to (omitted) years (M= 0 years, SD = 0.0). Experience in passenger railway operations ranged from (omitted) to (omitted) years (M= omitted years, SD =omitted). Participants with different levels of experience were recruited because there is expected to be an association between operational experience and CCTV task performance and it was important to ensure a level of variability amongst the cohort. All participants had normal or corrected to-normal visual acuity.

B. CCTV Interface Designs

Three CCTV interface designs have been developed that each display up to ten image patches. Each image patch represents the view of one car (up to ten cars can be monitored in this system).

Interface design A, identified as 'horizontal extended', features 10 image patches presented in two rows of four and one row of two image patches. The layout of this interface has been developed to support operators performing a serial search of the train from the leading car (in the direction of travel) to the rear car. Some railway operators [16] promote techniques referred to as 'Z' scanning methods for performing CCTV image patch checks. The 'Z' scan method involves a driver attending to each CCTV image patch in a set order from top left to bottom right. This visual scanning technique includes several horizontal eye movements with a few diagonal movements and no vertical eye movements. Reference [17] suggests that horizontal eye movements impose the least amount of effort, and when all things are considered equal are preferred over vertically oriented eye movements.

Interface design B, identified as 'horizontal short', features four rows of three image patches. This layout was developed to minimise the length of diagonal saccadic eye movements required to cover all ten image patches on the CCTV interface. No vertical eye movements are required to perform a visual scan of the 10 CCTV image patches. Both interface A and interface B do not consider image patch features and how the features of the presented image may be utilised to support visual processing of the scene.

Interface C, identified as the vertical interface, presents image patches from top to bottom in three columns. This layout presents the train cars in the order in which the train is geographically located adjacent to the platform. This layout may encourage the operator to utilise the platform boarding line as a salient feature to judge if targets are apparent directly adjacent to the train.

C. Experimental Design

This study investigated the effect of CCTV image patch layout on task performance, perceived workload and system usability in an experiment using a within-subjects design. CCTV interface design with three levels (vertically oriented, horizontal extended, and horizontal) was the within subject manipulation. Conditions were counterbalanced to control for sequence effects.

D. The Platform Departure Task

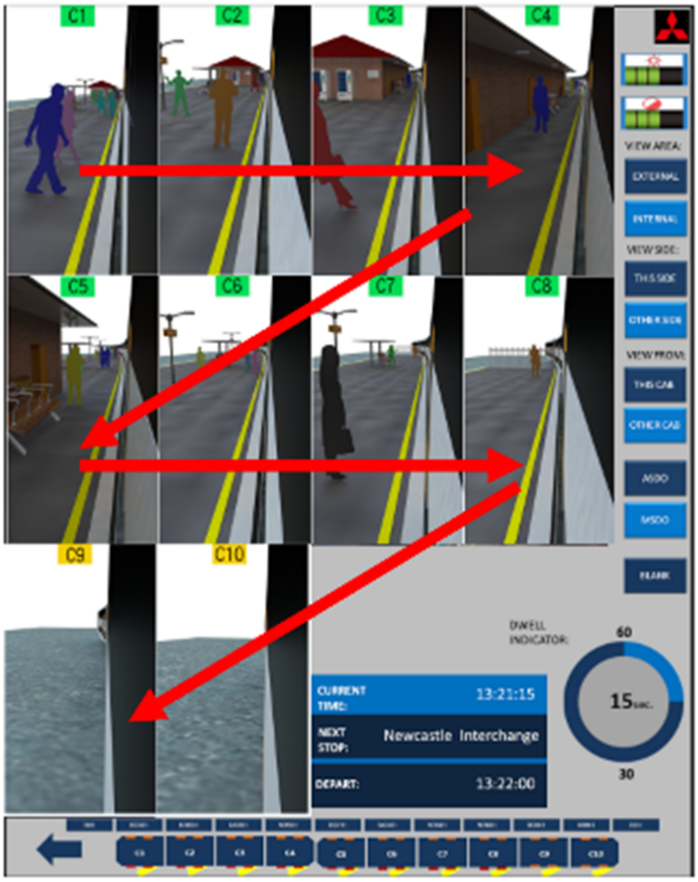
The task of the participant in each test condition was to monitor 10 CCTV image patches presented simultaneously on the CCTV display, portraying a 10-car train stationary at a platform with doors closed. Participants were tasked with determining if there were any targets apparent in the operational scenario. Targets were deemed to by any condition in which it was apparent that passengers would be at risk of injury if the train was to depart. These targets consisted of variations of six targets selected to be representative of situations where an undesirable event would occur if the train were to depart. Targets were recorded in controlled environments and consisted of variations of the following targets, as used in similar studies [18], [19]:

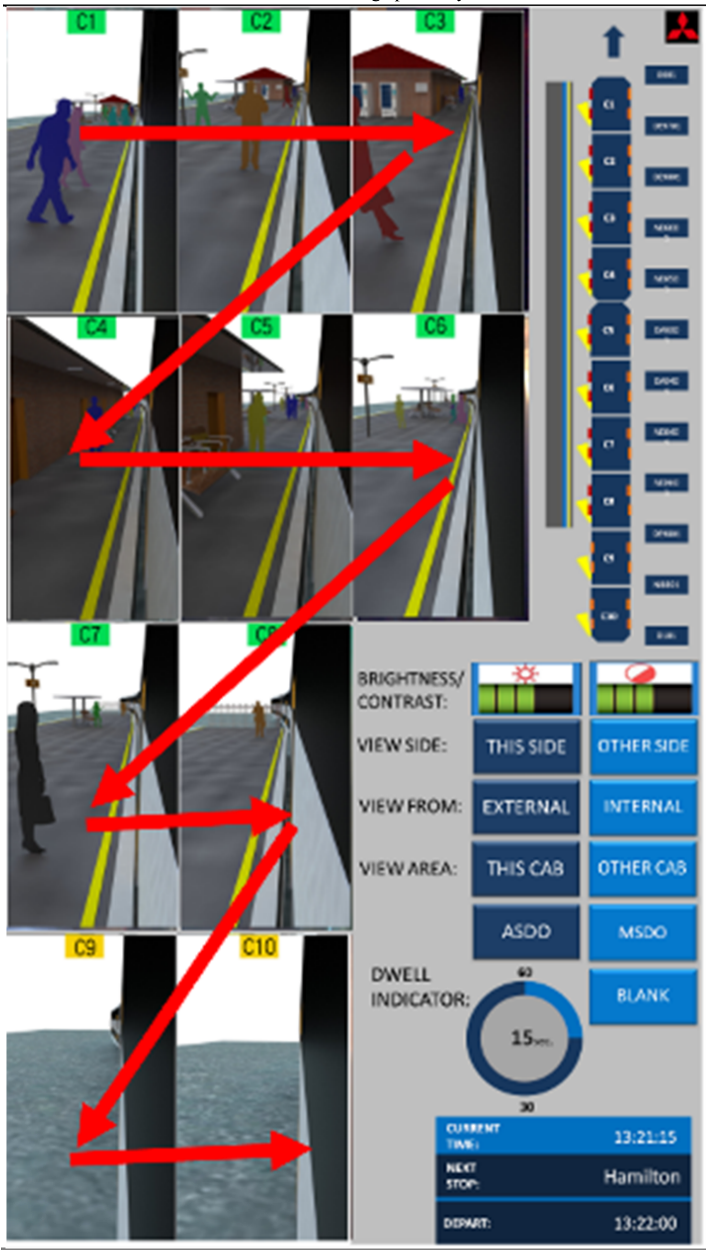
- An adult trapped aware - an adult passenger standing against/trapped in the train doors making vigorous efforts to attract attention.
- An adult caught unaware - an adult passenger standing tight against the train but, either as yet unaware they have clothing/backpack/scarf caught or otherwise making little effort to attract attention assuming the doors will re-open.
- A two year old child, 825 mm tall and 150 mm deep (side on view), dressed in neutral colours close to the train doors.
- A pram left on platform close to the train doors
- Adult partial fall in platform gap (one leg in gap, body on platform)
- Child trapped in platform gap (head only visible)

The participant was tasked to assess the situation using the CCTV image patches and make a decision on whether or not it was safe to apply train power (traction) and depart the platform. Participants were allowed 10 seconds from the initial presentation of the operational scenario to respond with a decision to depart the platform or remain at the platform, imposing time constraints reasonably expected to be encountered in operational conditions. No search/monitoring pattern or strategy was suggested.

Participants were allowed to interact with the CCTV monitor during the operational scenario to reverse camera angles, or to enlarge the image patch whilst determining if the train was safe to depart. The number of CCTV monitor interactions performed by the participant was recorded by the system for further analysis.

TABLE I
CCTV INTERFACE DESIGNS WITH ASSOCIATED IMAGE PATCH LAYOUT

<table>
<tr><th>CCTV Image patch layout</th><th>Layout description</th></tr>
<tr><td>
</td><td>Interface design A
Horizontal extended image patch layout.
From top left- Car one to car four (row 1)
Car four to car eight (row 2)
Car nine to car 10 (row 3)</td></tr>
</table>

CCTV Image patch layout	Layout description
	**Interface design B** Horizontal image patch layout. From top left – Car one to car three (row 1) Car three to car six (row 2) Car seven to car eight (row 3) Car nine to car 10 (row 4)

International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:12, No:10, 2018

<table>
<tr><th>CCTV Image patch layout</th><th>Layout description</th></tr>
<tr><td>
</td><td>Interface design C
Vertically oriented image patch layout.
From top-down – Car one to car four (column 1)
Car five to car eight (column 2)
Car nine to car 10 (column 3)</td></tr>
</table>

If no target was detected in the operational scenario:

1) The participant read out the pseudo-signal information (a task designed to remove visual attention away from the CCTV monitor).
2) Pushed the GO button indicating that power can be applied and the train was safe to depart the platform
3) Once the GO button was pressed, the timing for the operational scenario was stopped and the CCTV monitors blanked indicating the end of that operational scenario.
4) After a delay of two seconds, the next operational scenario was displayed ready for the start of the next trial.

If a target was detected in the operational scenario:

5) If the participant detected a target they pushed the STOP button to end the scenario and stop the timer. The CCTV monitor then blanked.
6) After a two second delay, the next operational scenario was displayed and the system was ready to run the next scenario.

After the final operational scenario in each condition was presented, a five-minute break occurred. After all three test conditions were completed, the evaluation concluded. Fig. 1 depicts the participants' task in each operational scenario.

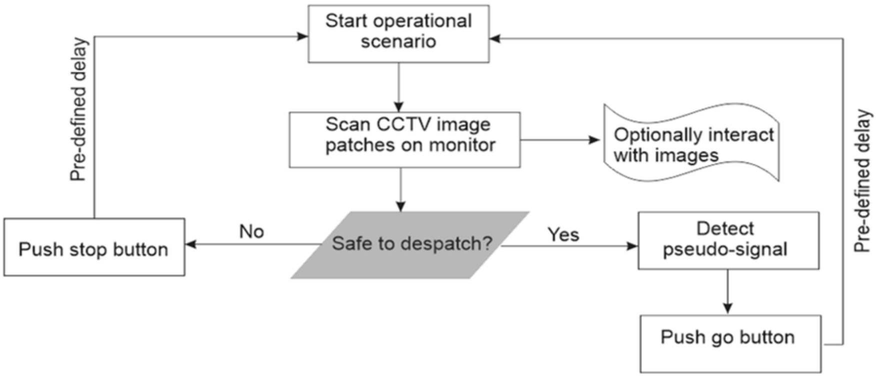


Fig. 1 Diagram of the platform departure task completed during the trial

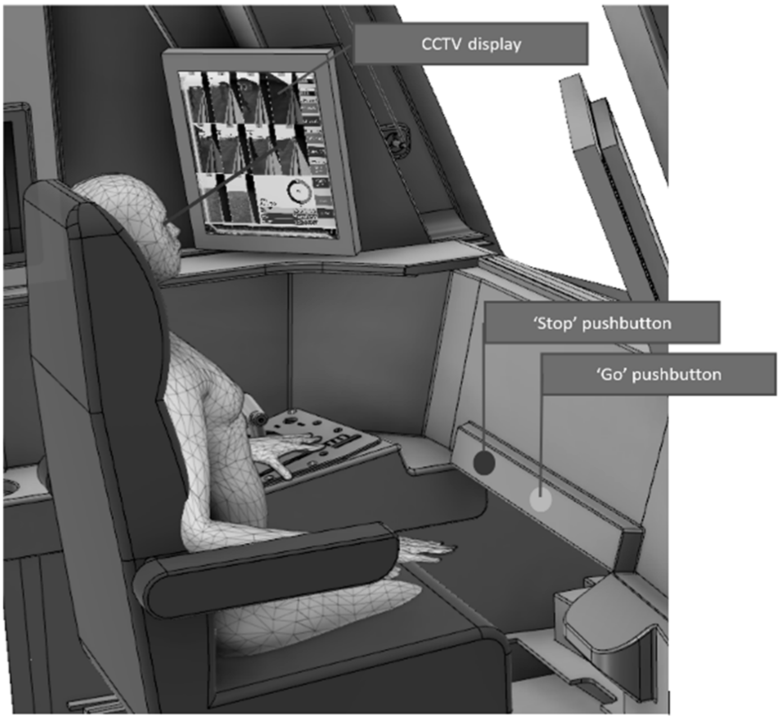


Fig. 2 Depiction of the apparatus setup. The experiment was conducted at a full scale mock-up of a future intercity passenger train

E. Procedure

The participants completed the study in sessions of one hour. On arrival, they were asked to complete a consent form and a short demographic questionnaire. The demographic questionnaire was administered to capture the general (years in railway operations) and specific (years in current position) experience of the participants. In addition, the questionnaire captured self-assessments of fatigue, stress and operational performance [20], [21]. The assessment of these performance shaping factors allowed for statistical control of these variables, should they be shown to be associated with task performance.

Once the questionnaire was completed, participants were seated in front of a high-fidelity mock-up of the driver's workstation with a single 18.5 in. LCD monitor positioned at eye level, 40° from the centreline of the seated participant, at an approximate viewing distance of 900 mm. Two 25 mm diameter pushbuttons were positioned at a central location, within static reach of the seated participants. One pushbutton to indicate 'STOP' and a green one to indicate 'GO' as per the task instructions. Participants were fitted with a head mounted eye-tracker developed by PupilLabs [22] which was then calibrated in accordance with the manufacturers instructions.

Following completion of the calibration process, participants were given a briefing on the train departure task and completed five practice scenarios, comprising of two target scenarios and three non-target scenarios. After the practice scenarios, the first of three experimental conditions commenced. Participants completed 64 operational scenarios in each condition, comprising of 14 target scenarios and 50 non-target scenarios. At the completion of each experimental condition the participant was given five minutes to complete the NASA TLX workload scale and system usability scale. At the completion of all three conditions, participants completed a questionnaire regarding their perception of the task and the usability of the CCTV interface.

F. Measures

1) Task Performance

Task performance was assessed by recording the percentage of targets detected in each condition and the percentage of false positive targets detected in each condition. Response latency in milliseconds was measured and used as an indication of task performance. That is, shorter response latencies were an indication that the target had been detected with greater efficiency than target detections with longer response latencies.

2) Workload

Subjective levels of workload were captured using the NASA-Task Load Index (NASA-TLX). The NASA-TLX is a multidimensional scale that provides an overall or global measure of workload and also identifies specific components of workload. The components are defined along three dimensions imposed on the observer by the task – mental, physical, and temporal demand – and three dimensions related to the interaction of the observer and the task – performance, effort, and frustration [23].

3) System Usability

The system usability scale (SUS) is a subjective tool for measuring global level attributes of system usability. The tool has established reliability [24] and consists of a 10-item questionnaire with five response options for respondents, ranging from strongly agree to strongly disagree.

III. Results

The results of this study are not available. This study is being undertaken as part of a rollingstock design and manufacturing project which is currently in progress. The results of the study will form a later submission.

IV. Discussion

The theoretical and applied implications of the study will be derived following availability of the results. The discussion will form part of a later submission.

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