



# Tracking and discrete dual task performance for different visual spatial stimulus-response mappings with focal and ambient vision



Steve N.H. Tsang<sup>\*</sup>, Alan H.S. Chan

Department of Systems Engineering and Engineering Management, City University of Hong Kong, Kowloon Tong, Hong Kong, China

## ARTICLE INFO

### Article history:

Received 5 September 2016

Received in revised form

29 August 2017

Accepted 6 September 2017

### Keywords:

Multitasking

Spatial S-R compatibility

Multiple resources

Displays and controls

Visual displays

## ABSTRACT

The effect of spatial compatibility for various display-control configurations on human performance was studied with a dual-task paradigm using a tracking task and a discrete response task. Degradation of performance on both tasks within the visual modality was observed and was considered to be most likely due to resource competition resulting from simultaneous task operation. It was found that the more complicated the mapping for the discrete spatial compatibility response task, the more severe the interference with the tracking task. Although performance on both the tracking and spatial response tasks was impaired, the magnitude of impairment was not as great as expected, implying that focal and ambient vision required for the tracking task and spatial task, respectively, might be deployed, at least partly, from separate resources. Participants here seemed to successfully use focal vision for tracking and ambient vision for identifying signal lights concurrently, reducing the expected keen competition for visual resources.

© 2017 Elsevier Ltd. All rights reserved.

## 1. Introduction

Displays and controls play an important part in the configuration of human-machine systems where displays provide operational information and controls enable the input of necessary actions to change the states of the systems. Displays and controls are important in many tasks, ranging from simple machine operation to car driving and complex aircraft cockpits. In order to facilitate interaction and communication between people and machines, effective design of human-machine interfaces is of the utmost importance. The effect of spatial compatibility on display-control configurations has long been regarded as one of the main considerations in human-machine interface design. With the advancement of technology, operators are often required to simultaneously monitor and control more than one display and/or control, leading to multitasking. As a result, it is vital to have a thorough understanding of the influence of the spatial compatibility effect on human multitasking performance to shed light on the design of advanced and complex human-machine interfaces.

### 1.1. Spatial stimulus-response compatibility (SRC) effects

The concept of the spatial stimulus-response compatibility (SRC) effect was introduced by Fitts and his colleagues in the 1950s (Fitts and Seeger, 1953; Fitts and Deininger, 1954). The SRC effect is about the variation in performance that can occur as a result of the compatibility of the spatial arrangements of displays and controls. While some arrangements facilitate response performance, others hinder performance (Fitts and Seeger, 1953; Fitts and Deininger, 1954). An explanation of the response advantages provided by SRC effects was given by the coding hypothesis of Umiltà and Nicoletti (1990), which suggested that different spatial relationships between stimulus and response require different levels of encoding, such that compatible S-R combinations can enhance response speed and accuracy due to lower coding demands and higher rates of information transfer. Whereas incompatible S-R combinations will usually require additional translation steps to interpret the relationship between displays and controls, thereby lengthening reaction time and reducing response accuracy. In general, studies examining SRC effects have consistently reported that compatible pairings are responded to faster and with higher accuracy than incompatible pairings (Proctor and Vu, 2006; Chan and Chan, 2010, 2011; Liu and Jhuang, 2012). Thurlings et al. (2012) provided some novel insights from the brain activity perspective using event-related potential (ERP) based

<sup>\*</sup> Corresponding author.

E-mail address: [nhtsang2-c@my.cityu.edu.hk](mailto:nhtsang2-c@my.cityu.edu.hk) (S.N.H. Tsang).

brain–computer interfaces (BCIs). In ERP-BCIs, differences between brain responses to stimuli that are attended to and ignored are used. Their study used a tactile ERP-BCI for navigation which required control–display mapping (CDM) between a visual display and stimuli from a vibrating tactile control device. The study showed that congruent CDMs (both display and control horizontal or both vertical) produced better task performance (enhanced the P300 wave and increased estimated BCI performance) than the incongruent CDM (vertical display, horizontal control). In general, compatible spatial relations between stimuli and responses lead to direct and natural mapping (Proctor and Vu, 2006), for example, if a computer program/interface for scrolling has high congruence between control inputs and display outputs, users will find it easier and more intuitive to use, thereby increasing their overall performance (Chen and Proctor, 2013) and (possibly) satisfaction.

SRC effects have far-reaching implications for optimizing human–machine/computer interface design, yet previous studies on display and control compatibility and response performance have been mostly limited to a single-task paradigm (Proctor and Reeve, 1990; Proctor and Vu, 2006; Chan and Chan, 2009a, 2010). The results of such studies may not be very applicable to the many complex dual-task or multi-task conditions that exist in practical situations. To date there has not been an analysis of the attentional resource sharing and competition that is necessary for dual-task processing involving an SRC task. It is therefore important and timely to investigate SRC effects for multi-task paradigms to improve understanding and design of advanced human-machine/computer systems.

## 1.2. Multitasking theories

In comparison to the single task situation, there may be an increased workload arising from the additional task or tasks in multitask situations, and this extra workload may have an effect on performance (Cullen et al., 2013; Tsang and Chan, 2015; Horrey et al., 2017; Kolbeinsson et al., 2017). A substantial body of literature examines and tries to explain the effects of the extra workload on human performance in multitasking environments. The multiple resource theory of Wickens (1984, 2002, 2008), a variant of the resource capacity theory introduced by Kahneman (1973), is an effective model for predicting multitasking performance. The model categorizes human information processing into four dichotomous dimensions and predicts possible interference between tasks that are processed concurrently. The four dichotomous dimensions underlying the structure of multiple resources are: processing stages, perceptual processing modalities, processing codes, and visual channels. In each dimension, there are two discrete levels representing the need to consume different pools of resources. Efficiency in time-sharing between multiple tasks will be undermined when more than one task requires the same level (resource) for task processing.

Multitasking performance can also be explained by the theory of threaded cognition proposed by Salvucci and Taatgen (2008). Simply put, according to the theory, every task within the multi-task paradigm can be regarded as a thread maintained independently by an active set of task goals to direct procedural processing and have access to different perceptual, motor, cognitive-declarative and cognitive-procedural resources. Essentially, these resources execute processing requests serially one request at a time, and this ‘resource seriality’ is the underlying core assumption of the theory. Because of this assumption, a particular resource can only be utilized in one thread at a time even though more than one thread can be active at the same time, resulting in resource conflict and consequent delayed processing of the other threads competing for the same resource. Each thread is thought of as being

coordinated by a serial procedural resource that integrates and maps inputs from other resources and then starts new processing on these resources. The mappings are governed by condition-action production rules, where a set of conditions and actions is defined by a production rule, such that the conditions must be met for the rule to execute the given actions. The procedural resource can only execute one rule at a time, such that when two threads (tasks) are competing for this resource, the rule belonging to the least recently processed thread will be executed first to ensure every thread has a regular opportunity to acquire the procedural resource so as not to starve any threads. Parallelism in threads resource processing is possible only if the threads do not both concurrently demand the same resource e.g. parallel visual and auditory processing. Threaded cognition has been successfully applied to explain multitasking performance under different circumstances such as driving performance under sleep deprivation conditions, visual pattern-matching and communication, and grammatical encoding and decoding (Gunzelmann et al., 2011; Wang et al., 2012; Kempen et al., 2012).

## 1.3. Visual multitasking

Recently, there has been increased research interest in information processing and performance on multi-task situations such as car driving (Lee et al., 2006; McKeown and Isherwood, 2007; Wu and Liu, 2007; Wu et al., 2008; Lees et al., 2012), medical environments (Bunton and Keintz, 2008; Meneghetti et al., 2012), military and commercial aircraft aviation (Loukopoulos et al., 2003, 2009), control room environments (Laurienti et al., 2006; Sauer et al., 2006, 2008; Aha et al., 2011), and media multitasking (Ie et al., 2012; Moreno et al., 2012; David et al., 2013; Srivastava, 2013). For multi-task environments, there has been a general increase in the number and variety of signals and control devices to be handled concurrently by operators (Kang et al., 2017). This variety requires division of human attentional resources such as visual attention to simultaneously process various sources of visual information in multitasking.

In daily life, visual information is necessary for successful completion of most tasks that have to be performed. A task such as successfully keeping a car in lane while interacting with in-vehicle devices demonstrates that visual information processing may be dichotomized into two different channels - focal and ambient (Horrey and Wickens, 2004; Lansdown et al., 2004; Kujala and Saariluoma, 2011). Put rather crudely, focal vision can be characterized by the presence of fine detail and pattern recognition, whereas ambient vision senses orientation and movement (Wickens, 2002). Previous studies on dual-task performance with focal and ambient vision have shown that where both tasks utilized focal vision, performance was impaired on one or both tasks. However, where the two tasks demanded focal and ambient vision separately, performance was not much affected, presumably due to better and greater use of time-sharing of resources between the two visual channels (Wickens, 2002; Horrey et al., 2006). This visual channel differentiation is seen clearly with driving, where vehicle control tasks are performed with tasks like road hazard detection and in-vehicle display reading. Although it is difficult to effectively maintain the speed of the car and perform in-vehicle tasks at the same time (Summala et al., 1998), vehicle control in terms of lane keeping on a straight road is reliant on ambient vision and, with time-sharing, can be performed effectively with concurrent focal vision dominant in-vehicle tasks. However, Horrey and Wickens (2004) showed that when both tasks were dependent on the same visual channel, like detecting and identifying hazards and discriminating display details for in-vehicle tasks; task interference and consequent task performance degradation

Download English Version:

<https://daneshyari.com/en/article/4971901>

Download Persian Version:

<https://daneshyari.com/article/4971901>

[Daneshyari.com](https://daneshyari.com)