

Chapter 9

Visual Attention in 3-D Space while Moving Forward

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ABSTRACT

One of our cognitive functions is attention, which plays an essential role in veridical behavior. In this chapter, the research on attention in 3-D space is reviewed. In particular, for ecological validity, the shift of attention in 3-D space when observers are in self-motion is discussed. Research in cognitive psychology indicates that elucidating the role of attention in 3-D space is important for understanding a driver's behavior, in order to suitably design the interface of in-vehicle devices. Finally, future research on the connection between attention and safety in driving situations will be discussed.

1. INTRODUCTION

Understanding human cognition and behavior is of basic and practical interest for everyday life. For example, how drivers acquire necessary information from the external environment while moving is not only of interest for traffic safety, but also for the development of adequately designed and laid-out in-vehicle devices. One of the primary

functions of the visual information process is attention. Attention is well known to play an important role in driving situations. When attention is distracted by an event, such as unexpected lane change, a car accident might occur. Approximately 80% of all crashes and 65% of near-crashes result from driver distraction (Dingus, et al., 2006). Hence, a number of cognitive and neuroscience studies have emerged in recent years that focus on researching attention.

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Almost all studies about attention are conducted in 2-D space by using a computer display, however in the “real world” our behavioral space is 3-D. Of course, it is understood that valuable contributions to our understanding of cognitive systems have been made by investigations of attention in 2-D space. The characteristics of attention in a frontal parallel plane, such as attention control, focused attention, and attentional shift have been studied. On the other hand, 3-D attention mechanisms are less well understood. How, specifically, is attention controlled? Is attention the same in 2-D and 3-D space?

Although in-vehicle devices such as car navigation systems have become widespread in recent years, the impact on our safety of processing information from these devices remains unclear. For example, even if a driver’s line of sight is directed forward (far space), focusing on the in-vehicle information (near space) may have a negative effect on the trajectory of the driver’s eye movements (e.g. Horrey, 2009) and allocation of attention (Miura & Shinohara, 1998; 2001, Shinohara, Nakamura, Tatsuta, & Iba, 2010). This suggests that the distraction of attention in 3-D space would increase the risk of traffic accidents.

In this chapter, the characteristics of attention in 3-D space are discussed. First, we demonstrate attention theory based on traditional studies in 2-D space. The review of these findings might be helpful in understanding attention in 3-D space because basic paradigms share similarities. Next, we introduce recent findings for attention in 3-D space that contribute to traffic safety. Finally, we propose some perspective on future research directions.

2. THEORY OF SPATIAL ATTENTION

The main categories of spatial attention include distribution of attention, shift of attention, and switching of attention. These attention functions have not been fully elucidated; however,

researchers in the field of cognitive psychology have attempted to create models of spatial attention. The spotlight model is a basic model of spatial attention (Eriksen & Eriksen, 1974; Posner, Snyder, & Davidson, 1980; Shulman, Remington, & McLean, 1979). This model hypothesizes that information is processed within a limited area (approximately 1 deg. in visual angle), and that information outside this area cannot capture attention. Eriksen & St. James (1986) and Eriksen & Yeh (1985) have proposed the zoom lens model, which is an extension of the spotlight model. In this model, the domain subtended by attention is variable and depends on task demand. Finally, the gradient model assumes that attention has a gradient distribution in space (LaBerge & Brown, 1986). The models described above are conducted in 2-D space, and have meaningfully contributed to our understanding of spatial attention.

How does attention operate in space? The spatial cueing paradigm (Cost-Benefit paradigm) is a common method used to show the characteristics of spatial attention (Posner, Nissen & Ogden, 1978; Posner, Snyder, & Davidson, 1980). In this paradigm, a “precue” is presented before the target is presented. This method allows us to examine the components of spatial attention, i.e., engagement, disengagement, and shift.

There are three possible relationships between the precue and the target. In Figure 1, on valid trials (a), the target appeared in the space indicated by the precue. On invalid trials (c), the target appeared in the opposite space indicated by the precue. Finally, on neutral trials (b), no information was provided about target location. In general, the valid, invalid, and neutral trials constituted different percentages of the total trials and these types of trials were randomized within a session. Typically, results show that reaction times are accelerated in the valid trials (attentional benefit), delayed in the invalid trials (attentional cost), and the neutral trials are considered baseline (Figure 2). The effect of precues on the response could describe some characteristics of attention such

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