THE UNIVERSITY OF TEXAS AT AUSTIN

Gaze Control and Attention Fixation

In a Complex Natural Environment

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When engaged in a natural behavior, specific fixation patterns are combined with that ongoing conscious task. A major issue arises when unexpected stimuli are introduced while performing a certain goal oriented task, such as driving. How will we cope and react when something novel and unexpected is thrown into the equation?

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INTRODUCTION

When engaged in a natural behavior, specific fixation patterns are combined with that ongoing conscious task. A major issue arises when unexpected stimuli are introduced while performing a certain goal-oriented task, such as driving. How will we cope and react when something novel and unexpected is thrown into the equation? For example, what happens when, while driving, a kickball rolls into the street and you are headed for a collision path with it?

Most visual scenes contain more information than we can perceive in a brief exposure. If a certain scene is viewed for a minimum amount of time, our eyes will only be drawn into a few objects. It is not possible to retain a photocopy of the entire visual world for fast, accurate information. This process of selecting particular information isn't random, but is guided by factors relevant to the activity. Top-down factors depend on cognitive awareness and goals. While walking towards a door, the goal is known as "I need to reach the door" and our visual attention will jump towards the door and identify any obstacle in our way. So if we fixate on a bike that is in the path to the door, that fixation is through top-down factors.

Bottom-up factors deal with the issue of visual stimuli attracting out attention when we didn't cognitively want to search for it. Neurons in Area MT seem to be sensitive to looming stimuli, which is when an object is noticed when it's heading towards you for a collision.

Any selective perceptual system must choose the right visual computations and select the appropriate time to carry them out. In order to deal with the unpredictability of the natural world there are a few insights as to how this may occur. Firstly, the world isn't as unpredictable as one would think and we’re quite exceptional with learning where something novel is concerned. Secondly, there must be some bottom up mechanism for attracting attention when it’s necessary.

Shinoda et al. (2001) ran an experiment that asked subjects to either “follow the car” or “follow the car and obey traffic rules” while in a driving simulation. The results confirmed that top down strategies that had goals about where to look did indeed affect fixation. Subjects obeying the traffic rules spend nearly three times longer fixating on intersections than the group who were only ordered to follow the car.

In 1875, Ernst Mach observed that purely visual information could induce a strong sense of self-motion—like an experience of moving when sitting in a stopped train as the adjacent train starts to move. Mach proposed the existence of a spatial sense, distinct from vision, which could nonetheless be activated by visual information. This vestibular system (best known as the system that can make you dizzy when you spin) is also able to measure something about self-motion in a straight line. Because the system is stimulated each time we start to walk or move, its activity is one source of information about our self-motion. It’s clear that we can use this information to sense their motion to some extent, especially their changes in motion (Israel, Grasso, Georges-Francois, Tsuzuki,& Berthoz, 1997).

Gibson (1966) identified purely visual consequences of physically moving (such as patterns of visual motion across the whole visual field) that specified self-motion. Visual motion produced by self-motion is generally called visual (or optic) flow. The specific pattern of visual flow at the eye depends both on the self-motion of the observer and on the spatial structure of the environment. Gibson showed that visual flow can be informative about both at the same time. A great deal of evidence has accumulated indicating that people are quite sensitive to the information in visual flow that specifies the direction and distance traveled (e.g., Lappe, Bremmer,&van den Berg, 1999; Warren & Hannon, 1988) and that visual-flow speed influences walking speed (Mohler, Thompson, Creem- Regehr, Pick, &Warren,

2007). What is even more surprising is how well people are at keeping track of how far they have walked even when they are blindfolded (Loomis, Da Silva, Fujita, & Fukusima, 1992).

Several advances in technology such as new mobile eye trackers that can be used in natural environments and the development of complex virtual environments now allow investigation of active gaze control in natural tasks in controlled conditions (Droll, Hayhoe, Triesch, & Sullivan, 2005; Shinoda, Hayhoe, & Shrivastava, 2001; Triesch, Ballard, Hayhoe, & Sullivan, 2003; Turano, Geruschat, Baker, Stahl, & Shapiro, 2001). These studies have found that the eyes are positioned at a point that is not the most salient but is relevant for the immediate task demands. Fixations are tightly linked in time to the evolution of the task, and very few fixations are made to regions of low interest regardless of their saliency (Hayhoe et al., 2003; Land et al., 1999; Sprague & Ballard, 2003, in press).

Naturalistic eye-movement studies have revealed that fixations appear to have the purpose of obtaining quite specific information. Visual routines can make use of higher level information to limit the amount of information that needs to be analyzed to that relevant to the current task, thus reducing the computational load. The fact that the visual information selected is specific to a particular task goal led Ballard et al. (1997) to suggest that visual routines promote computational efficiency.

Gaze control is model based. Humans must be aware of the structure of the world to allocate their gaze correctly. Gaze control is proactive and is often anticipated in visually guided behavior. This experiment will evaluate the variations in latency between fast and slow veering cars and determine whether each type of speed affects our ability to detect unexpected events. I hypothesize that the probability of fixating on a fast swerving car is greater than a slow veering car or the control. I also hypothesize that the latency of fixating on a fast swerving car is less than a slow veering or control car.

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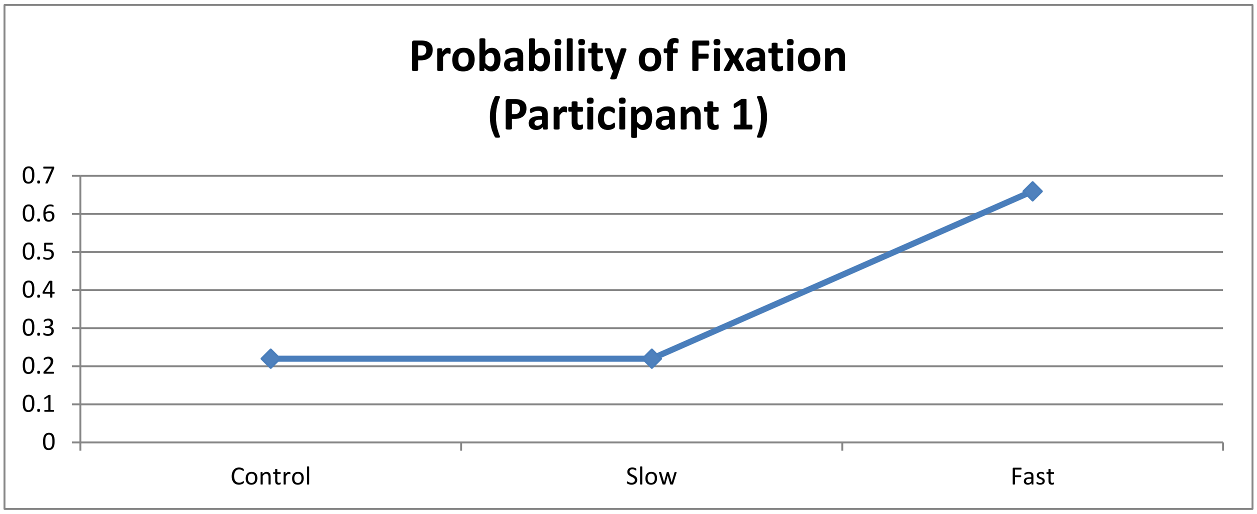
METHODS

Subjects ran trials at the University of Texas Virtual Reality Lab using a car simulator, which was fashioned like the regular cockpit of a car's driver-side. A bass speaker is situated underneath the cockpit to rumble the cockpit as well as the subject as they are driving. The rumbling of the speaker is used to help assist in creating a more realistic environment of motion and vibration to the body to better adjust to the virtual experience. The participants were fitted with a head mounted display which projected the virtual environment on a screen seen by each eye. Each head unit has a camera focused on the subject's eye in order to record eye fixations. Data analysis is calculated using RIT software on Mac computers.

Participants were ordered to complete 6 trail runs, wherein each run would contain three vehicles that would change lanes as oncoming traffic. Each run would have a combination of fast and slow lane changing cars, but the combination would never be repeated. The possible combinations were FSF, FFS, SFF, SFS, SSF, and FSS. While subjects ran through each trail their eye fixations would be tracked and afterwards the tracking data would be overlaid to identify latency times. Probabilities of fixations will also be noted when the tracking data is processed.

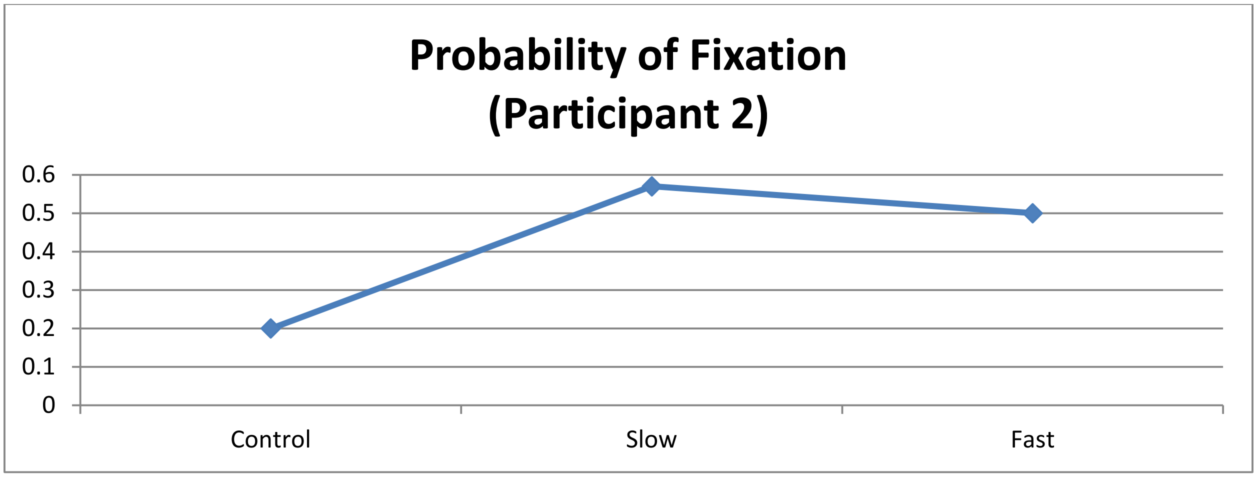
Probability of fixation was calculated by divided the number of fixations by the number of car swerving events. So, if 2 out of 9 fast cars were fixated, then the probability of fixation would be 2/9. Latency was calculated by taking the difference from when the car began to change lanes from when the subject fixated to where the car switching lanes was located. In order to calculate milliseconds, the frame number was divided by 10 and then multiplied by 17.

RESULTS



	Probability of Fixation on Car
Control	.22
Slow Lane Change	.22
Fast Lane Change	.66

Participant 1 had the same probability of fixation for the slow lane change as for the control, which was 2/9. For these two instances the subject only fixated 2 out of 9 times. There was a substantial increase in fixation, 6/9, when there was a fast lane change. The fast lane change drew much more attention for subject 1. This is congruent with my hypothesis that fast lane changes will have a higher probability of fixation.



	Probability of Fixation on Car
Control	.20
Slow Lane Change	.57
Fast Lane Change	.50

Participant 2's control was similar to the previous with a probability of 3/15, which is .20. The previous control probability was roughly .22 for the other subject. The control fixation seems to have a steady amount of probability. The slow lane change cars gave a probability of 4/7 and the fast change produced 4/8. Both lane changing speeds produced the same attention response in the subject, yet still showed a difference from the control. This somewhat supports the idea that fast lane changing vehicle will have a higher probability of fixation over the control, but it doesn't show significant difference from the slower lane changing vehicle.

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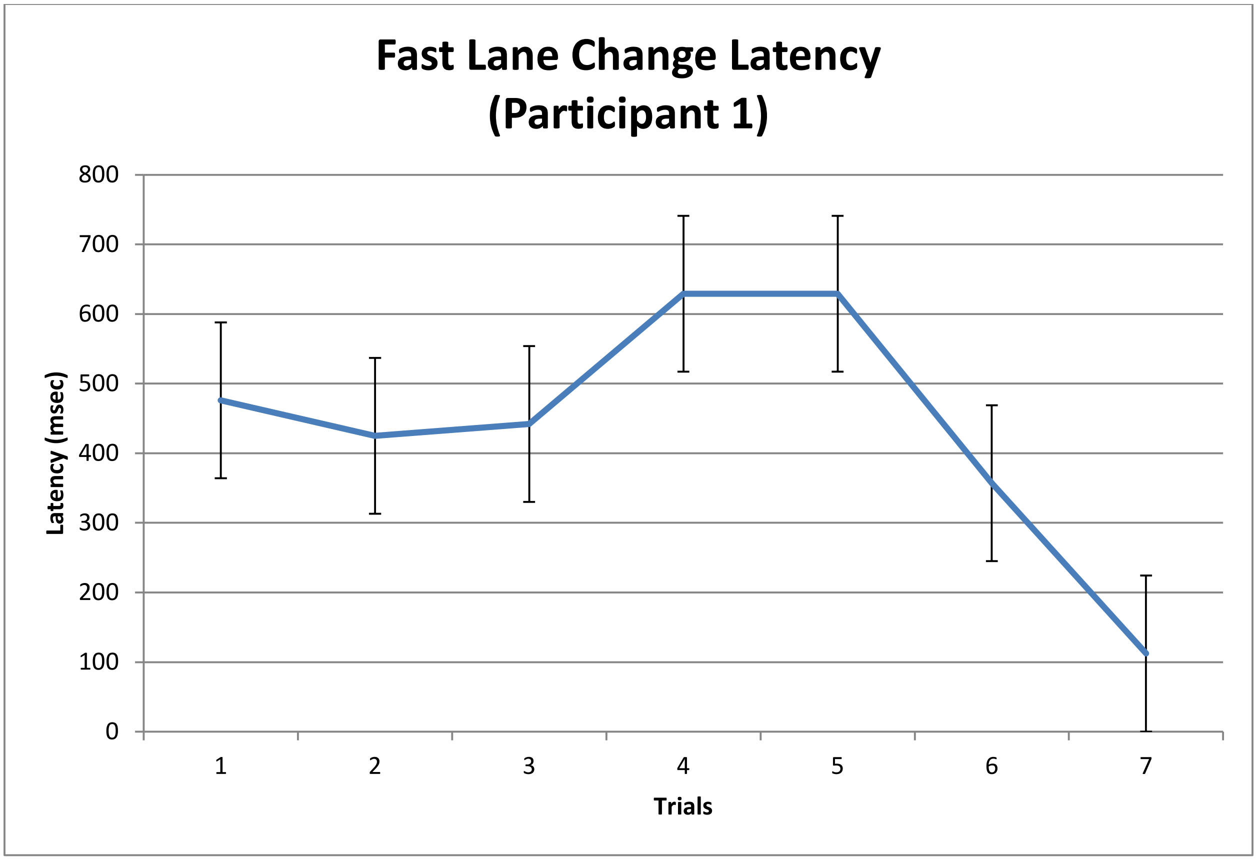
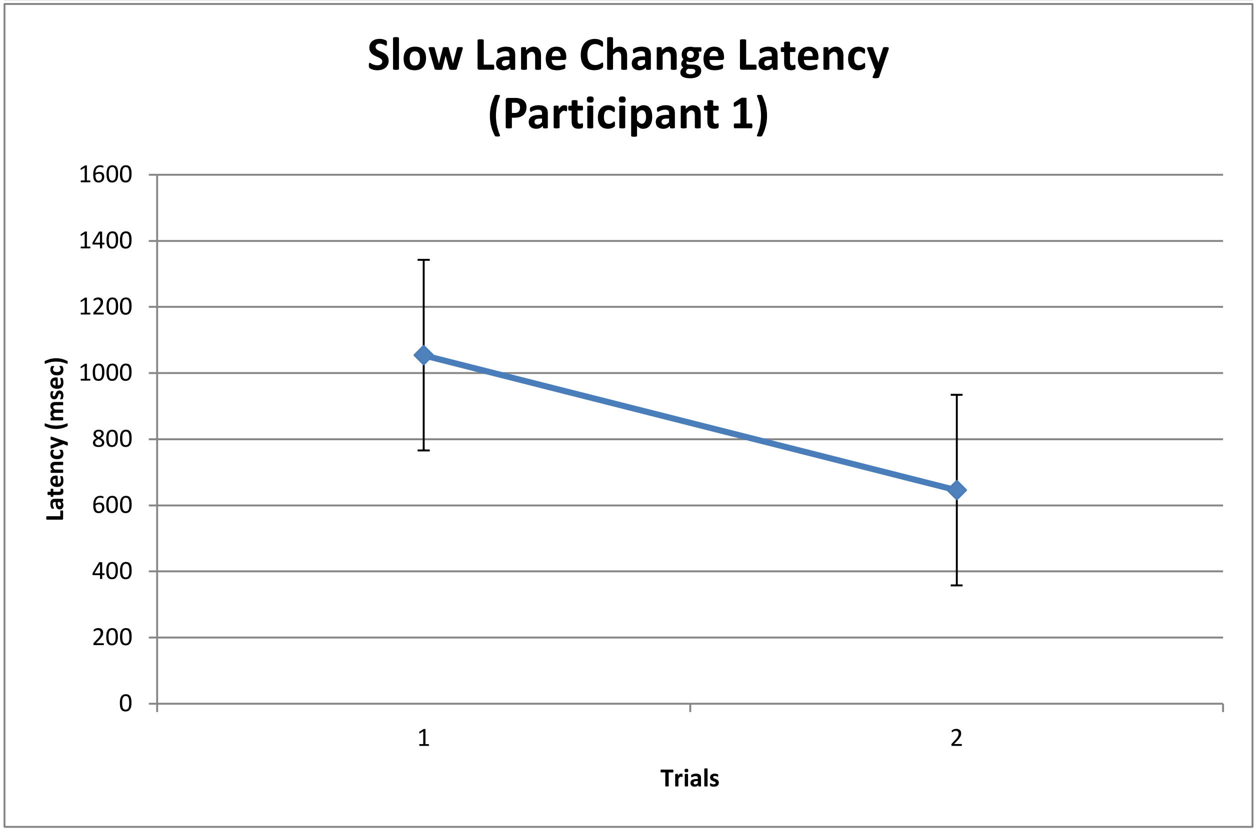
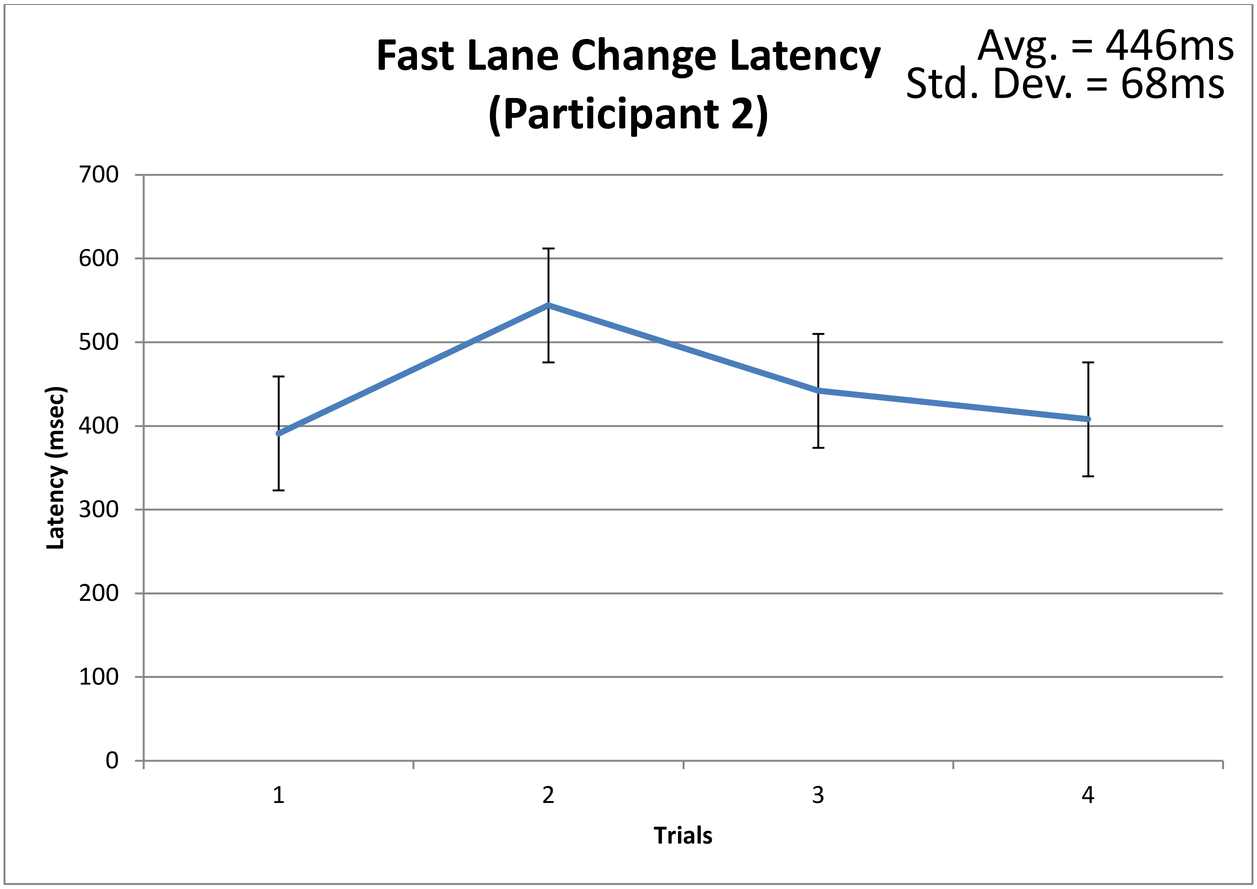
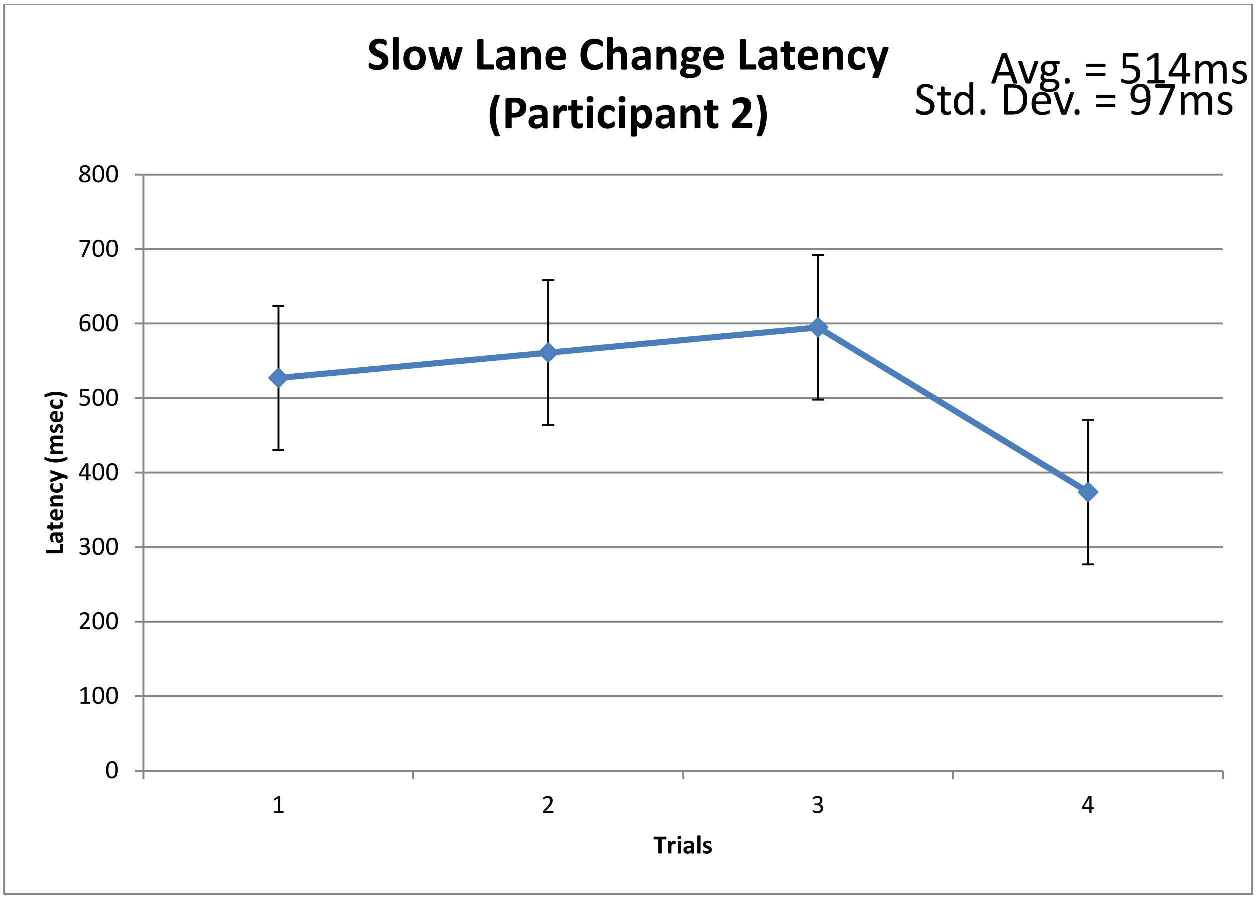

Fast Lane Change Latency (Participant 1)


Slow Lane Change Latency (Participant 1)



Fast Lane Change Latency (Participant 2)

Avg. = 446ms
Std. Dev. = 68ms



Participant 1 had an average fast lane change latency of 493ms and a standard deviation of 112ms. Participant 1 had an average slow lane change latency of 850ms and a standard deviation of 288ms. Results are agreeable with my hypothesis that fast lane change latency would be faster than slower lane change cars.

Participant 2 had an average fast lane change latency of 446ms and a standard deviation of 68ms. Participant 2 had an average slow lane change latency of 514ms and a standard deviation of 97. Results are agreeable with my hypothesis that fast lane change latency would be faster than slower lane change cars.

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DISCUSSION

One explanation for our results might be that, as experienced drivers, participants' attention is driven mainly by a top down process. The goals of driving during the simulation may have been just to stay within your driving lane and look forward, without putting needed attention towards the oncoming lane of traffic. In the natural world, most of us have never had a car from oncoming traffic come straight towards us, intending to crash. Therefore, it may not be a more cognitive goal in our mind to always look onto oncoming traffic. This may explain why control car fixations are so low in probability.

It is also possible that each participant has different thresholds of activation for a given stimulus to elicit a bottom-up reaction. This sort of threshold activations could be biological or genetic. An individual may have a more sensitive visual processing center when identifying a specific kind of stimulus. One key component is likely the degree to which a stimulus affects a participant's optic flow. When the majority of the visual scene is moving in the same manner, a slight movement perpendicular to the flow would be easily noticeable. A car changing lanes will have an optic flow that moves horizontally in the visual field as opposed to the trajectory of everything else in sight.

Another possible confounding effect is participants' desensitization to a stimulus such as an oncoming car changing lanes. This is experienced commonly, rarely resulting in a vehicle actually entering oncoming traffic. Such repetitive experiences might lead participants to devalue such stimuli when deciding where to attenuate.

As predicted, our data shows that participants' probability of fixation on a looming vehicle increases in the fast lane change condition over the control. In fact, participants were nearly three times more likely to fixate on a fast changing vehicle over a control. The data collected in the slow lane change was less conclusive, yet still gave a small increase of fixation probability of the control. Participant 2 was nearly three times likely to fixate on a slowly changing vehicle while participant 1 showed no difference from baseline. When evaluating latency of fixation, fast lane changes produced lower latency than slow lane changes in both participants.

The sample size of our data is quite small and limited, which needs to be enlarged in order to properly generalize to the population. A sample of 2 participants with 6 trial runs is quite a small amount of data collecting, yet it was still somewhat decent enough to find predictable outcomes. Of course, because of the size it may have been a fluke. By increasing the number of trials each participant undergoes, we might eliminate any effects caused by learning and also minimize any aberrations due to participant error.

Another issue to consider for future research may deal with using a different stimulus that is less likely to have been desensitized. This may, therefore, increase the effect on participants' attention. An example might be cars changing lanes that are traveling in the same direction rather than opposite directions.

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