Modeling Peripheral Vision for Moving Target Search and Detection

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Yang JH, Huston J, Day M, Balogh I. *Modeling peripheral vision for moving target search and detection.* **Aviat Space Environ Med 2012; 83:585–93.**

Introduction: Most target search and detection models focus on foveal vision. In reality, peripheral vision plays a significant role, especially in detecting moving objects. ***Methods:*** There were 23 subjects who participated in experiments simulating target detection tasks in urban and rural environments while their gaze parameters were tracked. Button responses associated with foveal object and peripheral object (PO) detection and recognition were recorded. In an urban scenario, pedestrians appearing in the periphery holding guns were threats and pedestrians with empty hands were non-threats. In a rural scenario, non-U.S. unmanned aerial vehicles (UAVs) were considered threats and U.S. UAVs non-threats. ***Results:*** On average, subjects missed detecting 2.48 POs among 50 POs in the urban scenario and 5.39 POs in the rural scenario. Both saccade reaction time and button reaction time can be predicted by peripheral angle and entrance speed of POs. Fast moving objects were detected faster than slower objects and POs appearing at wider angles took longer to detect than those closer to the gaze center. A second-order mixed-effect model was applied to provide each subject's prediction model for peripheral target detection performance as a function of eccentricity angle and speed. About half the subjects used active search patterns while the other half used passive search patterns. ***Discussion:*** An interactive 3-D visualization tool was developed to provide a representation of macro-scale head and gaze movement in the search and target detection task. An experimentally validated stochastic model of peripheral vision in realistic target detection scenarios was developed.

Keywords: peripheral vision, target detection, recognition, search and target acquisition.

MODELING OF SEARCH and target acquisition (STA) has been a major concern for military simulations. For example, simulation models considering individual soldiers such as COMBAT XXI, OneSAF, and JSAF use the ACQUIRE algorithm for calculating visual detection probabilities. However, it has been shown that the ACQUIRE algorithm does not sufficiently reflect the performance of human observers (3,8,9), i.e., false positive detection and correct detection should be taken into account and modeled. Although frequencies of false positive detection can be modeled as a certain probabilistic property, the location of false positives still remains to be explored. Furthermore, since the ACQUIRE model was originally developed to represent imaging sensors, only a limited field of view is considered (16). As this model was extended to represent unaided human vision, this limitation was not addressed. Therefore, all combat simulations that use ACQUIRE-based models ignore what happens in the peripheral field of view of human observers. The motivation for this work is to address this deficiency in our current simulation by developing a model of detection outside of the foveal field of view that can be used in conjunction with the current methodologies to provide a better representation of unaided human vision.

Current target detection mechanisms in urban environments use the so-called 'windshield wiper' approach (4), where the visual field is split into several adjacent and non-overlapping fields of view and the target detection mechanism is applied to each field of view independently, generally in a sweep from left to right and back. The way of determining the locations to which the target detection mechanism is applied is far from actual human behavior. Jungkunz (8,9) investigated more likely fixation locations with respect to eccentricity, saliency, and distracters in the scene. He found that the maximum distracting capability is not tied to maximum saliency, but the distractor attracts the gaze less if its eccentricity from the initial fixation location gets longer.

Target detection algorithms, including those used in the above studies, have been mainly concerned with human eye movement, specifically where the foveal gaze moves and how long the gaze stays during the search task. For example, probably the best-known model of visual attention (6,7,11) uses saliency to determine the focus of attention. Improvements on this model employ machine-learning methods to train a detector on objects of interest (10) or gaze patterns of human subjects performing a similar task (13). While these models do perform better target detection than saliency-only in the indicated studies and are based to mimic human unaided search algorithms, they do not provide insight as to how peripheral vision influenced those movements.

The fovea provides high visual acuity within 2° of visual angle and this acuity decreases with higher eccentricity from the center of the visual field (5,14,15). On the other hand, peripheral vision is good at fast detection of

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This manuscript was received for review in October 2011. It was accepted for publication in January 2012.

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DOI: 10.3357/ASEM.3230.2012