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ORIGINAL RESEARCH

# Effectors of Visual Search Efficacy on the Allegheny Plateau

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**Background.—**Although lost-person search managers try to direct search efforts quantitatively, it has historically been difficult to quantify the efficacy of search efforts accurately. The effective-sweep-width (ESW) methodology represents an avenue for accomplishing this goal but has not yet been widely disseminated among practitioners.

**Methods.—**We obtained ESW values in the summer and winter in a typical disturbed-forest environment in southwest Pennsylvania. We used nonparametric statistics to compare individual ESW values for two types of search objects detected by 18 summer and 20 winter searchers, cumulating the $P$ values for similar comparisons and correcting for false discovery via a stepped method.

**Results.—**We detected robust differences (all at $P < .001$) associated with search object color, season, and vegetation thickness. In contrast with earlier studies, we found a significant correlation between individual searchers' ESWs for different search objects and different types of vegetation ($P < .001$). We also found that adolescent searchers had significantly lower ESW values than adults ($P = .002$). Apparently significant positive correlations between time spent on the course or field search experience and ESW disappeared when teens were excluded from the comparisons.

**Conclusions.—**These results (the first comparison of seasonal ESW effects in identical terrain) represent the first statistical demonstration that the ESW methodology provides more than enough resolution to answer fundamental questions about the efficacy of visual search for lost persons by human searchers. They also add support to the imperative of operationally disseminating these methods among search-and-rescue practitioners, and offer some initial operational lessons for search managers.

*Key words*: rescue work, visual acuity, color perception, seasonal variation, effective sweep width, ESW, search and rescue, SAR

## Introduction

Lost-person searches almost always take place in the absence of fully sufficient resources to search everywhere the subject might be located. Success in the great majority of searches, therefore, hinges on efficient prioritization of limited efforts.

Usually, some portions of the search area are more likely to contain the lost person, or search subject, than others. In addition, variations in the environment within the search area often affect both the ability to detect the subject and the speed at which productive searching can be performed. Standard-of-practice methods for search and rescue (SAR) management attempt to address both of these issues in a quantitative manner. Statistics regarding lost-person behavior can help determine which portions of the search area are more likely and which are less likely to contain the subject[1–3]; reports from search-team leaders can help address the latter issue.

In planning their efforts, incident managers break the search area into a number of sub-areas called "segments" or "sectors" of manageable size for a field team to search. Then the issue becomes one of deciding how much of the available effort should be placed in each of these segments. Note that, because of limited resources, some segments initially may be left unsearched in favor of more promising segments.

One of the tools used to address the question of whether a given segment has been sufficiently searched is direct estimation of probabilities of detection (PODs, often subjectively modified by debriefing officers).[4] By definition, POD is the probability of detecting the search

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object, given (or assuming) that it is present and available to be detected. However, the limited data available suggest that PODs estimated by field-team leaders are almost never accurate.[5]

Searches that fail do so either because all search resources were sent to the wrong places to look and there was no subject there to be detected (ie, the search area was incorrectly defined), or at least some search resources were sent to the right place to look but failed to detect the subject even though the subject was present. There seems to be ample evidence that both situations are common. However, after an initial search fails to turn up any sign of the subject, there is a tendency to assume the subject was not in the searched segments and ignore the equally valid, and probably equally or more likely second possibility (although proper SAR management training warns against this error). This tendency is exacerbated by the glaring problems with estimating PODs subjectively and argues that a better methodology for both predictive (for search-planning purposes) and retrospective (for purposes of evaluating the effectiveness of prior searching) estimation of POD values is needed immediately.

The effective-sweep-width (ESW) methodology promises a vast improvement in deriving accurate, objective PODs. ESW is the lateral distance from the searcher who defines an envelope within which the number of search objects missed inside that envelope equals the number of search objects detected outside. Via an exponential function that factors in distance walked through the area and number of searchers in the team, ESW can be used to calculate objective PODs.[5,6] ESW makes it possible to establish an objective, mathematical relationship between the amount of searching effort expended in a segment and the probability of detecting the search object if it is present in the segment. These more reliable PODs can better aid the search process, by making it possible to allocate the available resources in a way that maximizes the overall probability of success (OPOS), ie, the probability of finding the subject, and minimizes the time it will take, on average, to find the subject. The probability of success (POS) for a segment is the joint probability of the subject being present in the segment and being detected if present. The former is represented by POA (probability of area, also known as POC—probability of containment). Thus, POS is the product of POD and POA. The sum of all the individual (non-normalized) POS values gives the OPOS value.[7]

In order to help build the collective national library of ESW figures, record ESW data for our response area in the Commonwealth of Pennsylvania (PA), and employ statistical analysis to test for the first-time hypotheses regarding effectors of ESW, we undertook two ESW experiments in State Game Lands 203 in Marshall Township, Allegheny County, PA. Following are our results regarding the effects of search object type, season, weather, vegetation, and select individual searcher characteristics on daytime human visual ESWs.

## Methods

We conducted the ESW experiment in the manner of Koester et al,[5] using the IDEA Microsoft Excel worksheet provided by R. Koester and N. Guerra to automatically generate a randomized plan for an ESW course. We deviated from the method, however, in several ways. Because of time constraints we were only able to obtain one measurement of average maximum detection radius (AMDR, a rough estimate of ESW used to calibrate the course) for the winter experiment (at site #1, 17TNE7511798716; coordinates for site #2, which was used as well in the summer experiment, were 17TNE7427798476; these and other coordinates to follow are in US National Grid, Datum NAD 83). Instead of using a spray-painted olive drab work glove for our low-visibility clue, we obtained forest-green work gloves in bulk from Tractor Supply.

In the winter experiment, because of our experience with the clue in the summer experiment (see below) and with other ESW experiments[5] in which the IDEA tool overestimated appropriate lateral distances for difficult-to-see search objects, we forced the worksheet to normalize the placement of that search object to a maximum distance of 1 × AMDR rather than the usual 1.5 × AMDR. Because one of the randomized low-visibility adult search object placements had called for a lateral distance that was a fraction of a meter, we re-randomized that search object to the least represented (in the other placements of that search object type) of 3 bins (defined as 0 to 0.333 × AMDR, 0.333 to 0.667 × AMDR, and 0.667 to 1 × AMDR) using the random number generator on a Casio FX-260 Solar calculator (Casio Computer Company, Ltd., Tokyo, Japan). Finally, in the winter experiment we made use of the post-experiment confirmation box in the search object placement worksheet to record a short description of the vegetation surrounding each search object.

The area we chose was the northern part of State Game Lands 203 in Marshall Township, PA. This venue offered a representative sampling of terrains common to our operational deployments in southwest Pennsylvania. Starting point for the course was 17TNE7407598818; total length was 3,850 m for the summer experiment and 3,650 m for the winter experiment, with the last clues placed at 3,768 m and 3,600 m, respectively.