When to move to the next raspberry bush?

Arnab Biswas, *Department of Biological Sciences and Bio-Engineering*, IIT Kanpur,

***Abstract*—Animals, including humans, engage in many forms of foraging behavior in which resources are collected from the world. This paper examines human foraging in a visual search context. A real-world analog would be berry picking. The selection of individual berries is not the most interesting problem in such a task. Of more interest is when does a forager leave one patch or berry bush for the next one? Marginal Value Theorem (MVT; Charnov, 1976) predicts that observers will leave a patch when the instantaneous yield from that patch drops below the average yield from the entire field. Experiments 1 shows that MVT gives a good description of human visual search behavior for varying target densities. Experiment 2 shows a departure from MVT when explicit instructions have been given to search for all possible targets .**

I. Introduction

Recently a lot of research has been done on single target searches in displays that either do or do not contain that target. The single target task has an obvious similarity to a large class of realworld search tasks: Where are my keys? Where is the salt? Am I in this photograph? And so forth. Reasonably enough, the analysis and models of single target search tasks have focused on the speed and accuracy with which those targets are found Much less attention has been devoted to other questions that are relevant to search in the world, notably the question of when to end a search.

This question of search termination becomes much more important if the observer does not know how many targets might be present. This is a characteristic of many real-world search tasks. A radiologist might be looking for all signs of cancer. An intelligence analyst might be trying to determine if anything of note has changed in a swath of territory. In search tasks like these, we remain very interested in the discovery of targets (Did the radiologist find the cancer?), but search termination rules are also important (Did the radiologist miss the cancer because he quit too soon? Did the radiologist fall behind in his work because he spent too much time on each case?).

A. *Visual Search and Animal foraging behaviour*

There is another related class of search tasks in which search termination becomes the primary concern. Consider the search for blueberries in a field of blueberry bushes. In season, the visual search is quite straightforward. Round objects of a certain size and color are the targets. There are many, many of these, they are not hard to find, and the berry picker is not under an obligation to pick every berry. The question of interest here is when it is time to move from one blueberry bush to the next. Intuition will tell you that you do not pick all of the berries off one bush before moving on.

Berry picking is a foraging problem. One of the most influential ideas in Optimal Foraging Theory (OFT), and one with very clear application to the blueberry example, is Charnovs marginal value theorem (MVT; Charnov, 1976). The basic idea is intuitively appealing. The animal wants to maximize his intake of food. As he forages in one location, he depletes the resource in that location. At some point, the rate of return from the current location drops below the average rate of return. At that point, MVT asserts that it is time to move. Note that the average return will depend on the rate with which resources can be extracted from patches of resource and the time it will take to get to the next patch. You cant collect resources while you are traveling to that next patch. Thus, if it is going to take a long time to get to the next patch, you should exploit the current patch for longer There are endless complications and variations on basic foraging and MVT, starting with fundamental questions about what it would really mean to forage optimally. Beyond sweeping ideas about optimality, basic MVT assumes a uniform set of patches and an animal that knows the instantaneous and average rate. Obviously, an animal must learn those rates. What happens if patches vary in quality? What happens if others are foraging in the vicinity?

Nevertheless, MVT is a foundationally important concept in foraging, and in this paper, we will focus on the basic MVT case and some modest variations in order to ask if humans, performing an easy visual search analog of a berry-picking task, behave as predicted by MVT. As we will see, to a first approximation (Experiment 1), the answer is that they do.This behavior is not explained by a single rule, but our data show that MVT is an important determinant of patch-leaving behavior.

If MVT behavior is deeply ingrained in us, this could become a problem when we are faced with foraging tasks that demand that we pick all of the berries. The earlier examples from radiology and intelligence surveillance illustrate this potential problem. If a radiologist is looking for metastases of a cancer, we want him or her to find all of them. It would be obviously wrong to adopt a strategy of terminating search when the yield from the current patient drops below the average yield. Still, there must be rules, implicit or otherwise, that govern when it is time to move to the next patient. If those rules are influenced by deep-seated MVT tendencies, we

This project was completed for the course Introduction to Cognitive Science at IIT Kanpur, Semester 1, 2014-15.

can imagine that MVT behavior could be a source of search failures.

II. Experiment 1

A. Methods

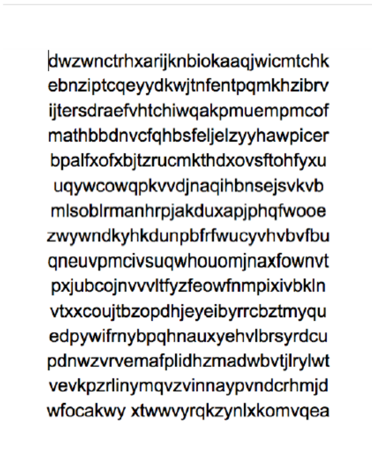

Fig. *The participants were asked to search for the letter s amongst all the letters pres*

30 participants were shown a single search scene (one image) and were told to search for the letter s amongst other letters. A blue circle appeared around identified targets to avoid them from interfering in further searches. One point was awarded for each correctly identified target. The participants had to go through six search scenes (with 3 levels of target densities 5%, 10% and 15%) individually one after the other finding as many targets possible within two minutes.

Mouse click was used to note the time

- before first target was found and how it varies with change in target distribution.
- after last target was found and observer moves to next search scene, and its variation with change in target distribution.

Stimuli were presented on laptops with a 15-in screen using PsychoPy software.

B. Results

While conducting the experiments one design flaw was noticed which should be rectified in further trials. It was noticed that participants tended to search for the letters in a line by line top to bottom fashion which would not be good to replicate a natural visual search scenario where a search may not be systematic. A possible solution for this would be to incorporate moving targets or to arrange the letters in a haphazard manner and not linearly. The results are still in accordance with the MVT because the factors deciding the leaving time are the acquisition rate which is not affected by the fact that whether the search is in systematic fashion or not.

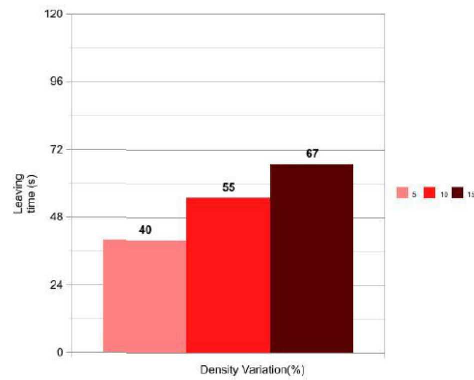

Fig. *As expected from the MVT people follow the opimal foraging model and linger on to a search scene for more time when the target density is more*

In accordance with the MVT participants tended to remain in a search scene when the target density was higher which resulted in a higher click rate.

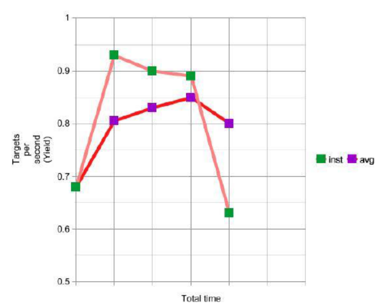

Fig. *The participants left the current search area after the instantaneous yield dropped below the average yield..*

As predicted by the MVT participants tended to leave the search scene as their instantaneous yield fell below the average yield. The hit rate was 68%.

III. Experiment 2

A. Methods

Experiment 1 shows that, when told to pick as many good berries as possible, observers adopt behavior predicted by MVT. As discussed earlier, this could be a problem if observers need to find all of the targets, maximizing hit rate and/or accuracy, rather than rate of acquisition. In Experiment 2,The methods were essentially the same as for Experiment 1 with the following changes. Participants were now told that they were supposed to select all targets in a search scene before moving on to the next search scene. Any unmarked targets would result in a penalty of 0.5 points

B. Results

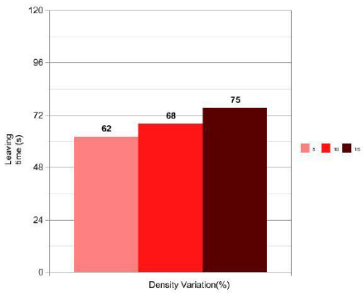

Fig. *When participants are directed to find all targets the leaving time increases, also the time difference between densities decreases appreciably.*

In this experiment we see a deviation from the MVT, the leaving time increases across the target distribution. Another important fact being that the difference in leaving time decrease as compared to Experiment 1. This is explained by participants following instructions to search for all possible targets before moving on to the next search scene.

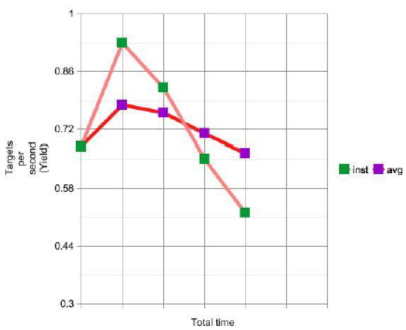

Fig. *Participants persisted with the search scene even after the instantaneous rate dropped below the average rate. But for not long.*

Participants tended to continue searching well after their instantaneous yield had fallen below the average yield. The hit rate increased from 68% to 83%.

IV. Conclusion

The results show that patch-leaving behavior in human visual search tasks is a strongly rule-governed behavior. When searching through a world of roughly uniform, depletable resources, patch-leaving behavior is consistent with the expectations of the MVT. As observers select items from the current patch, those items become rarer and take longer to pick. As a result, the rate of yield from the patch drops. At some point, the rate drops below the average rate for the task, and at about that point, our observers tend to move to the next patch. The behavior is appropriately influenced by the experimental conditions. Observers stay longer and pick to a higer yield when the target density is more.

If observers were searching for signs of cancer or security threats, they did not, as we might wish, eliminate false negative (miss) errors, but they did move in the appropriate direction. As noted in the discussion of Experiment 2, the response to instructions reveals something of a circularity in using OFT to explain patch-leaving times. If we ask observers to be exhaustive, we are asking them to reduce their average rate of return in the effort to find that last target. Their patch-leaving time will be later, but it does not seem quite right to say that the lower average rate actually caused the later leaving time.

Did we evolve to be optimal? In the context of our very artificial tasks, it must be acknowledged that we certainly did not evolve to forage for the letter ”s” on computer screens, even if the experimenter tells the observer to maximize yield or to exhaustively search. The observers optimal behavior might be to complete the odd task with as little effort and as much speed as possible. Seen in those somewhat depressing terms, it may be considered a pleasant surprise that the results of these experiments are as orderly as they are and that the MVT serves as a useful description of the results of several of these experiments. These experiments have observers foraging in a realm of uniform, infinite resources. This leaves other large areas unexplored. For example, suppose that there are multiple target types in the same patch.

In sum, humans engage in a great deal of visual foraging behavior. That behavior seems obviously rulegoverned. The results of the six experiments reported here show that our observers changed rules depending on the specific conditions of the foraging task. It seems likely that we share the basis for our foraging decisions with other animals and it seems likely that there will be situations in our civilized world where those ancient rules are at odds with our modern desires.

Acknowledgment

The author would like to thank Prof. Amithabha Mukerjee *Dept. Of Computer Sciences, IIT Kanpur* for his kind help and guidance during this project.

References

[1] Elazary, L., Itti, L. (2010). *A Bayesian model for efficient visual search and recognition.* Vision Research, 50(14), 1338-1352, doi:10.1016/j.visres. 2010.01.002.

[2] Charnov, E. L. (1976). *Optimal foraging, the marginal value theorem.* Theoretical Population Biology, 9, 129136.

[3] Wolfe .*When is it time to move to the next raspberry bush? Foraging rules in human visual search,* Journal of Vision (2013) 13(3):10, 117

[4] Drew, T. (n.d.). *The Invisible Gorilla Strikes Again: Sustained Inattentional Blindness in Expert Observers.* Association for Psychological Science.