Should I stay or should I go: Vigor of arm reaching movements during foraging

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INTRODUCTION

Research in patch foraging decisions is generally concerned with when an animal should exit a patch after gaining some reward. However, the question of how to select travel vigor to further optimize foraging performance is considered by few [1]. In a previous study [2], we extended a classical normative framework, the Marginal Value Theorem (MVT) [3], to predict how optimal travel durations varied when environment utility was manipulated by changing harvest difficulty in a visual foraging task. In the current study, we further investigate the modulation of optimal travel durations, in human arm reaching movements, as the effort associated with travel in an environment changes.

METHODS

Model: The extended MVT model proposed in [2] predicted that movement vigor was modulated to optimize the global utility rate of foraging in an environment (Figure 1a). In addition, it also shows that if effort of either harvesting or travelling in an environment was higher, i.e., global utility rate was low, the vigor of movements decreased (Figure 1b).

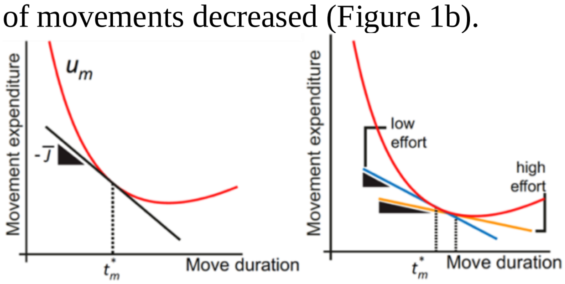

Figure 1: Extended MVT model predictions. a) movement vigor tm is modulated to optimize the global environment utility. b) high effort environment leads to slower movements. Figure adapted from [2].

To test this, we designed a protocol that emulates the classic patch foraging task design in which subjects had to perform arm reaches while holding the handle of a robotic manipulandum that was affixed with a grip force sensor (InMotion2; Interactive Motion Technologies; Figure 2).

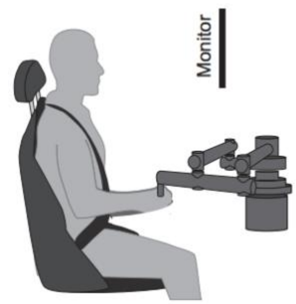

Figure 1: Subject holds the robot handle and performs task in front of monitor screen which displays game

Experiment: Subjects (n=10) would control a cursor on screen, as seen in Figure 3a & b. Subjects had to move the cursor into the red "patch" and apply a required constant grip force of 30N in the patch to start collecting reward or "berries". These berries were dispensed by means of an audiovisual stimulus, with a small orange circle flashing in the patch accompanied by a beeping sound, at a depleting rate with respect to time. The score was updated with the number of berries collected in a patch.

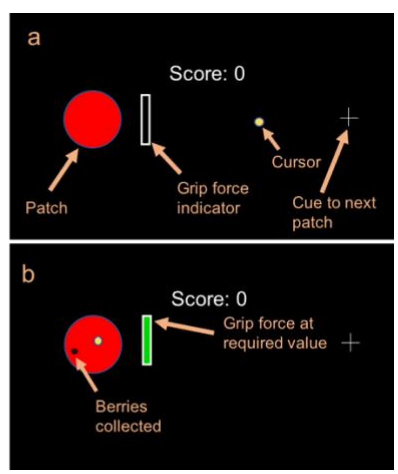

Figure 2: Game screen with main components annotated in tan.

a) When the game starts, the subject needs to move the cursor inside the patch to harvest berries.

b) Indicated berries being collected by the subject when force reaches required level.

Subjects were free to move on to the next (newly replenished) patch at any time, the location of which was cued by a plus sign. While moving to a new patch subjects experienced added mass, simulated by acceleration-dependent forces, that modulated travel effort. The experiment session was conducted in two main blocks of 200 trials one with high travel effort (added mass = 3.5kg) and the other with lower travel effort (added mass = 0kg). Of the 200 trials in each environment, 40 trials were designated as probe trials (grouped together in sub-blocks of 10) with intermediate travel effort (added mass=2kg). Probe trials ensured comparison across movements with the same effort requirement to elicit vigor modulation due to just the global utility rate of an environment.

RESULTS AND DISCUSSION

The empirical results revealed that there was a significant main effect of global utility rate of the environment on the vigor of movements, both for peak velocity ($p<0.001$) and travel duration ($p<0.001$), as seen in Figures (3a) & (4a). This showed that subjects responded to an increase in added mass by reducing their speeds, in accordance with previous findings regarding effort costs in arm reaches [4]. More importantly, we looked at the effect of environment effort levels on probe trials separately from the non-probe trials. Interestingly, we found that movement vigor in probe trials belonging to the low effort environment was higher than in the high effort environment (Figure (4b); t-test reveals $p < 0.01$). This result of the effect of environment on probe trials revealed a similar trend in travel duration, though not significant, (Figure (5b); t-test $p = 0.06$).

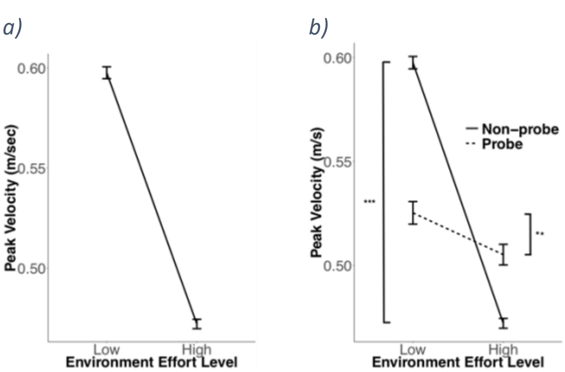

Figure 3: a) Peak velocity in arm reach with respect to environment levels averaged across all subjects. b) Peak velocity displayed separately for probe and non-probe trials

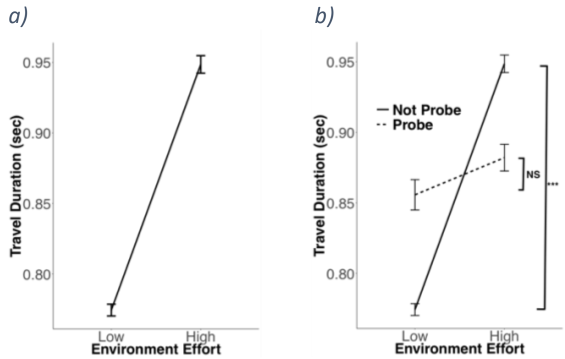

Figure 4: a) Travel duration in arm reach is plotted with respect to environment effort level averaged across all levels. b) Travel duration displayed separately for probe or non-probe trials

CONCLUSION

In this study, we investigated the role of movement effort of foraging decisions and the extension of Marginal Value Theorem, presented in our previous work [2]. We found that movements with identical effort requirements had lower vigor in environments with higher global utility rate than those in environments with lower global utility rate.

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