Electronic Supplementary Material (ESI) for Soft Matter.
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How to capture active Marangoni surfers

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Supplementary Material

1 Trapping pentanol infused particles

For an isolated pentanol infused paper disk, the quantity d_{ROI} is also calculated. To reiterate, it is defined as the euclidean distance between the particle's current position and the Region of Influence (ROI) of the pump. It is explicitly defined below:-

$$d_{ROI}(t) = |\vec{x}(t) - \vec{x_0}|$$

where $\vec{x_0}$ is a constant point in the pump's ROI.

The evolution of d_{ROI} as a function of time (Figure 1(a)) points towards the swimmer spending more time near the ROI of the pump when the pump is 'ON' (marked by cyan highlights). Hence an isolated *pentanol infused* paper disk is also captured by the pump's action.
To further verify the confinement of the ensemble near the region of influence of the pump, we plot the ensemble average of the inter-particle distance as a function of time (denoted as $< d >$). The time evolution of $< d >$ is presented in Figure 1(b) (blue). The state of the perturbation is plotted in the same figure highlighted in cyan color. One can observe that when the perturbation is in 'ON' state, $< d >$ is markedly reduced. The value of $< d >$ increases again when the pump is switched off and the particles are free to move around in the petri-dish. In addition, the ensemble average distance from the ROI ($< d_{ROI} >$) is plotted (Figure 1(b) (red)). It shows a similar trend as $< d >$.

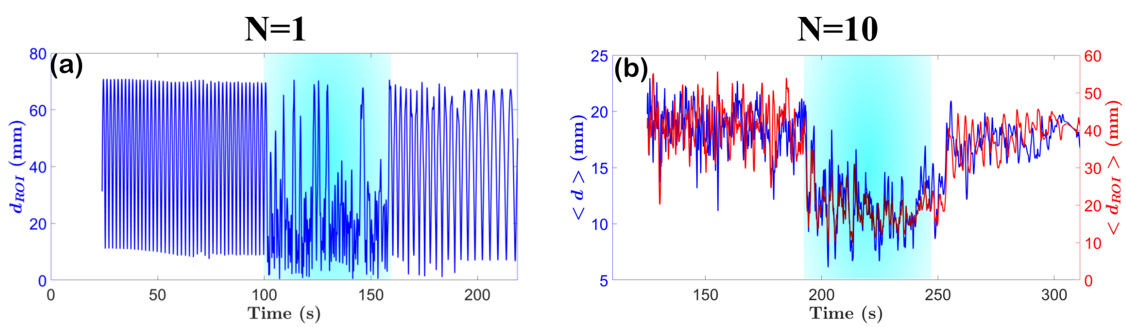

Figure 1: ***Pentanol infused disks are captured by the effect of the perturbation:*** (a) Time evolution of d_{ROI} (blue) along with the pump state (cyan highlights). (b) Time evolution of $< d >$ (blue) and $< d_{ROI} >$ (red) along with the pump state (cyan highlights indicate 'ON' state).

2 Comparison of particles for different fuel types:

We compared the speed of the particles infused with Camphor solution with those infused with 1-Pentanol. As can be seen in Figure 2, the speeds of the particles infused with 1-Pentanol were, on an average, higher than those of camphor infused disks regardless of the number of swimmers in the petri-dish. It is evident that in an ensemble, due to an abundance of collisions among the paper disks, the median speed of the pentanol swimmers is not drastically larger than that of camphor infused

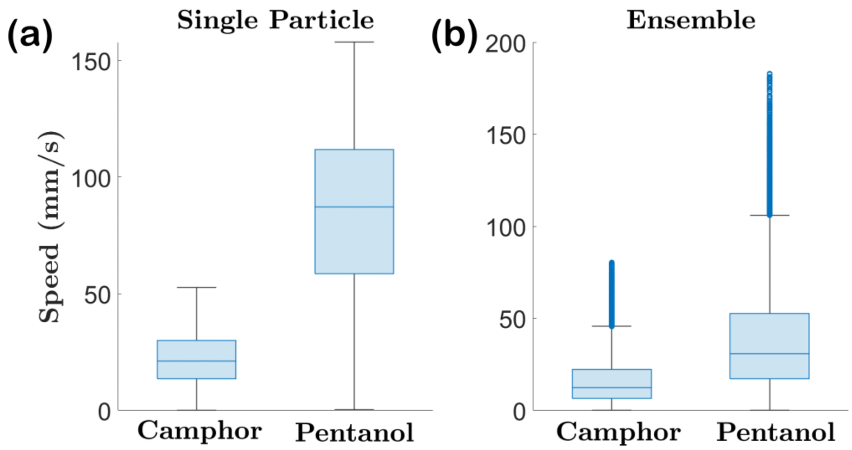

Figure 2: ***Pentanol infused disks have faster dynamics:*** The speed of paper disks is markedly higher when pentanol is used to infuse them, both for (a) an isolated swimmer and for (b) an ensemble. The top and bottom edges of each box represent upper and lower quartile respectively. The outliers are data points more than 1.5 Interquartile range away from the median.

swimmers. Nonetheless, the maximum speeds of the Pentanol infused swimmers is almost double of the maximum speeds from camphor infused swimmers in an ensemble.

We believe this enhanced speed of 1-pentanol infused particles can cause the trapping observed from the perturbation to be of relatively inferior quality when compared to their camphor infused counterparts. To check for this, we present below a comparison of the metric d_{ROI} for both types of fuels (camphor and 1-pentanol) and the two different population sizes ($N = 1$ and $N = 10$) taken. For $N = 10$, the ensemble average value $< d_{ROI} >$ is plotted. It is evident from Figure 3(a,c) that the trapping is relatively inferior for the single pentanol infused disk, when compared to its camphor counterpart. The pentanol infused disk is able to escape the ROI to perform large excursions, possibly due to its high speed dynamics. Interestingly, the performance of the trapping protocol is similar for the ensemble scenario across types of fuel (Figure 3(b,d)). This might be due to the arrested speeds of the 1-pentanol fueled ensemble due to steric interactions and too much lowering of surface tension by multiple active agents.

3 Further analysis of passive particles' response to the perturbation

Upon calculation of the metric d_{ROI} for the passive isolated particle (Figure 4(a), it was observed that the metric has no consistent response during the epochs when the pump is switched on (cyan highlights). In the first epoch of the perturbation switching on, d_{ROI} decreases, while in the second such 'ON' epoch, d_{ROI} increases to a significantly large value. Therefore, it can be inferred that the isolated passive particle does not experience any systematic force towards or away from the ROI of the air pump. When we plot the average inter-particle distance of the ensemble ($< d >$) as a function of time, $< d >$ is found to decrease to a particular value and then saturate. This is due to the "Cheerios effect" [1] attraction experienced by the passive paper disk. In addition, the ensemble average distance from the ROI ($< d_{ROI} >$) is plotted (Figure 4(b) (red)). It does not seem to increase or decrease systematically when the perturbation is ON. It decreases in the first epoch of perturbation and increases in the next one. This further strengthens our hypothesis that the attractive effect observed for

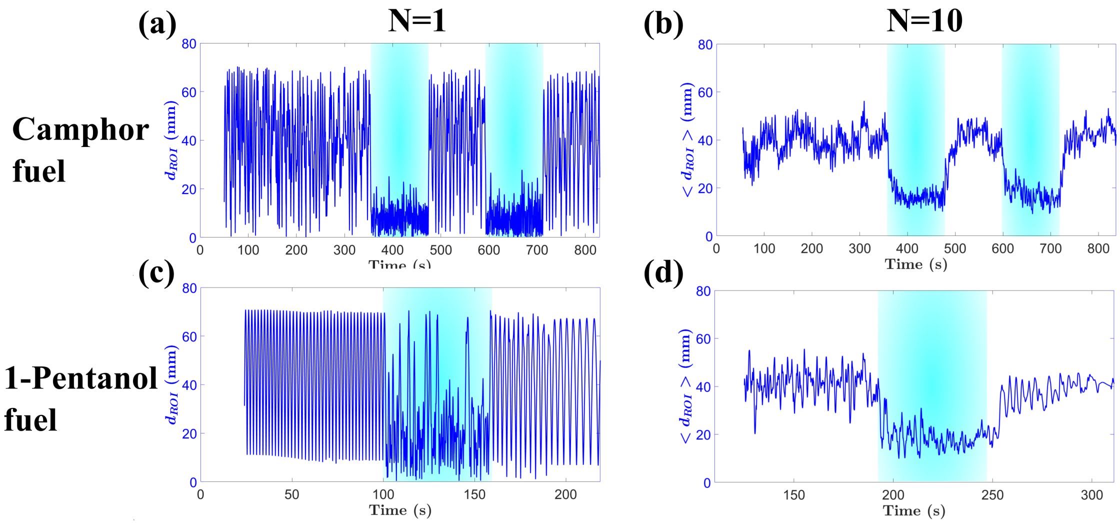

Figure 3: ***Performance comparison across fuel and population:*** Trapping performance comparison of a single camphor infused (a) and pentanol infused (c) disk. Similar comparison for the ensemble scenario of camphor infused (b) and 1-pentanol (d) disks.

1-pentanol and camphor cases stems from the interplay of surface-tension-gradient fueled activity and the air-flow from the pump.

References

[1] D. Vella and L. Mahadevan, The “cheerios effect”, American journal of physics **73**, 817 (2005).

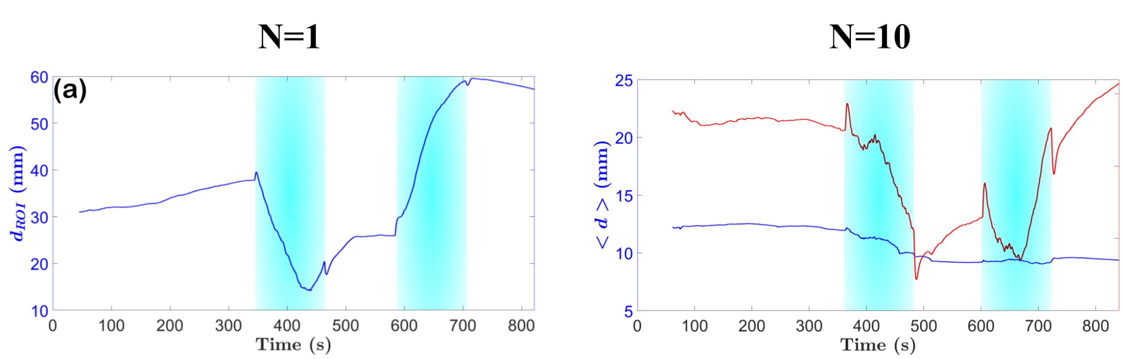

Figure 4: ***Passive ensembles fail to be captured:*** (a) Time evolution of d_{ROI} (blue) along with the pump state (cyan highlights) for a single *passive* particle. (b) Time evolution of $< d >$ (blue) along with the pump state (cyan highlights indicate ‘ON’ state) for a *passive* ensemble of paper disks.