

Transition by head-on collision: Mechanically mediated maneuvers in cockroaches and small robots

Response to Reviewer Comments

Comments to the editor:

We see the reviewers now have attained consensus on all criteria for publication. We thank them. As requested, we constructively addressed the few remaining concerns in a revised manuscript [rsif-2017-0664], most requiring a single word/ sentence change.

We hope the manuscript is now acceptable for publication in Proceedings of the Royal Society Interface.

Response to the reviewer comments:

We thank all reviewers for their useful feedback towards improving the quality of our current manuscript. We have incorporated suggestions, improved the writing, and attached a detailed point-by-point response to the comments.

Referee 1:

Overall, the manuscript is much improved and I recommend it for publication. A few additional notes:

Figure 3: I really do think figures A and B should be combined. This would improve the clarity, save space, and address reviewer #2's concern that 1kg is approximate: by clearly showing the intersection of the lines the readers will be able to decide for themselves if 1kg is appropriate.

Response: We appreciate the reviewer's suggestion towards improving the clarity of Figure 3. We tried our best to combine the figures as suggested, but found that it became cluttered, perhaps leading to more confusion. Therefore, we have retained the figures in the current form.

Pg 5, line 11: I believe that the sentence would read better as follows: Exceptional performance is often considered to be elegant and free of 'errors' or missteps.

Revised as requested: The text now reads "Exceptional performance is often considered to be elegant and free of 'errors' or missteps."

Pg 6, line 14: 'its exoskeleton' should probably be 'their exoskeletons' to agree with the subject.

Revised as requested: The text has been corrected to read "their exoskeleton"

Pg 7, line 29: the explanation of sample size is better but still could be improved. I would suggest changing line 29 to “out of 11 ‘additional’ animals”. From the additional pool of 11 animals, 4 were selected for each of the following treatments: lighting, distance, substrate, blind, and clipped antennas. I assume this means that some of the animals were reused for multiple modification trials? I further assume that animals that were blinded were not subsequently returned to the pool of 11 animals. All of these details really could be clarified with some simple modifications to the text.

Revised as requested: We have added more details in the text that clarifies the reviewer’s concern and describes the experimental protocol clearly.

The text now reads “From the additional pool of 11 animals, 4 were randomly selected for each of the following treatments: lighting, visual input, wall preview distance, and running substrate. Experiments with blinded animals to test the effect of visual input were performed last and those animals were not returned to the pool for further experimentation”

pg 10, line 52: all of the studies mentioned here relate to 1) animals much bigger than 1kg and 2) animals falling out of the sky at speeds much faster than they can run. Therefore this sentence does not directly support your derivation of the Haldane limit defined by graph 3. I do think it is important to include but I would move it after the sentence that ends with “flying, falling, parachuting, and jumping” where it is much more relevant and will not confuse the reader who does not follow up on the references.

Revised as requested: The text is reordered as suggested.

pg 13, line 9: this sentence is confusing. It should be reworded for clarity eliminating some of the nested clauses and providing a clearer subject of the sentence.

Revised as requested: The text is reworded to read, “Thus, animals with body sizes below the “Haldane Limit”, estimated to be about one kg, gain access to a variety of alternate, effective strategies that ensure successful performance”.

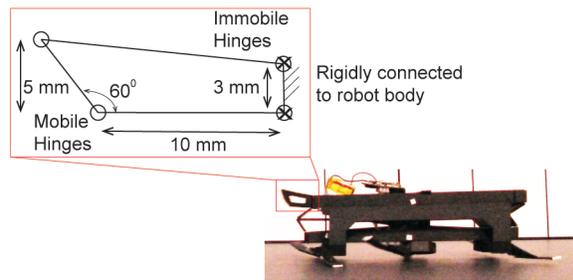
Referee: 2

Comments to the Author

The reviewer appreciates the comprehensive and detailed responses. By and large, the responses and revisions address most of the previous concerns. However, there are still a few points that the reviewer believes merit further attention:

1. The supplementary figure showing the nose of the DASH robot is a nice addition. However, the picture is blurry and not particularly informative. It would be better if there were a good, clear picture of the actual robot to match up with the design drawing. It may also be helpful to the bioinspired robotics community in general to provide a sentence or two either in text or caption about the materials used for the nose piece.

Revised as requested: A new high-resolution image of the robot was added to supplementary figure S2.



Information about the materials used for the construction of the nose has been added to the text in the methods section.

2. Regarding the response to comment 12 clarifying the cubic model and scaling laws, the authors should clarify both the purpose of the scaling and the limitations with it. For example, it would be helpful to include the following statement (or similar) from the authors' response states. "Our main intention here is to capture the scaling trends of mechanical properties and explain intuitively what small sizes are advantageous for energy dissipations during collisions"

Additionally, it should be clear that the scaling law applies only to head on collisions, not a vertical drop, for instance. Perhaps this point is already made obvious since the authors only study head-on collisions?

Revised as requested: Echoing the reviewer's sentiments, we have the following text in Section 3.3, "Thus, this plot serves as indicator of the approximate size scales (below the Haldane limit) where mechanics and material properties can potentially influence obstacle avoidance behavior."

3. In response to point 9, the authors reply: "Second, the decay time (T_d) could not be determined since the behavior was considered as a single shot collision and not a damped vibration, for ease of analysis. "

This seems at odds with the statement on page 10 lines 4-6:

"Using COR-damping ratio relationship [23], we estimate the damping ratio for a typical head-first transition ($COR = 0.22$) as $\xi = 0.479$."

A value of zeta < 1 would indicate an underdamped vibration case. A "single shot collision" as an impulse to the system would be expected to cause underdamped vibrations.

How can these statements be reconciled? It is understood that this mechanical modeling is meant as a guide to build a robot, but in terms of the larger assertion of the Haldane limit, this point really ought to further be clarified.

Similarly, the response notes that: "From Figure 1, we notice that the typical time between the antenna contact to head impact was about 20 ms (estimate of maximum damping time)..."

It is agreed that Fig 1 shows ~ 20 ms between antennal contact to head impact. It is further agreed that the head impact zone time is also ~ 20 ms. However, what is not established is that the head impact zone time sets an upper bound on the maximum damping time. Verifying this claim is important to establish the mechanical model was properly applied for both using the Haldane limit as a (somewhat) general guideline for robot design.

Revised as requested: We agree with the reviewer's comments. The confusion was created at our end due to the semantics in defining decay time.

As previously noted in the paper, the mean damping coefficient, ξ , was 0.479. The measured mean natural frequency (ω) was 377.96 rad/s. Thus, assuming second order spring-mass-damper dynamics, the corresponding damped natural frequency (ω_d) would be 333.62 rad/s. Their respective time periods, natural and damped are 16.6 ms and 18.8 ms. These oscillation periods are less than the fastest known neural response times (~35-40 ms) for escape behaviors, supporting our claims of energy dissipation. The same has been reported in Section 3.3.

As noted by the reviewer, this is the first step towards quantifying collision dynamics in such small animal systems. In the future, we intend to measure the same with higher resolutions both temporally and spatially, which will lead to more accurate modeling - currently outside the scope of this paper.