Species-specific whisker morphology affects tactile interactions*

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Abstract— **Bio-inspired robotic whisker touch sensors exist, although the shape of the whisker is often overlooked, despite it affecting whisker mechanics and resulting whisker movements. We demonstrate here in three Carnivora species that whisker shape affects tactile interactions. We recommend that whisker shape needs to be designed specifically for a task, and suggest that this is a good area for future research.**

I. Introduction

Whiskers, like fingertips, are an important sensing modality in animals and inspire biomimetic tactile sensors for robotics [1]. Whiskers can be easily replaced, and the sensor (or follicle) is at a distance from the tactile interactions, which reduces sensor wear. However, whisker shape (morphology) affects whisker mechanics and movement [2], so the shape of the whisker needs to be considered in robotic tactile sensor design. The biggest variation in animal whisker shape is found in the Carnivora [2]. We investigated whisker shape in three Carnivora species to better understand the effect of whisker shape on tactile signals.

II. Methods

Harbour seal, European otter and ferrets were chosen due to their differences in whisker shape and substrate preference (aquatic, semi-aquatic and terrestrial, respectively). Mystacial whiskers were plucked from a specimen of each species (n=61, 43, 40 whiskers, respectively) and scanned on a 2D scanner. Whisker length, base width and taper were estimated as per [2]. One caudo-ventral whisker from each species was held within an artificial follicle – TacTip sensor [1]. A 1 mm square-textured grating was moved over the whisker (17 mm/s) and the whisker was filmed with a high-speed video camera (800 fps, 1 s). Four points on the whisker were manually tracked as per [3] (Fig. 1a). Bezier curves were automatically plotted through the four points to estimate whisker curvature (mm^{-1}) at the whisker base, mid and tip. Curvature amplitude (amount of bending) was calculated from the curvature traces (Fig 1b).

III. Results

All whiskers were slender, tapered hairs (Fig. 1b). Harbour seal whiskers were undulating, whereas the others were smooth (Fig. 1b). Both the otter and harbour seal had thick, short whiskers, with high taper values. The ferret had slim, long whiskers, which moved more against the surface, both at the tip and the base (Fig. 1b). One example trace can be seen for each species in Fig. 1b.

TABLE I. SUMMARY DATA TABLE

	Whisker morphology (mean)			Movement summaries	
	Length	***Width***	***Taper***	***Base Amp***	***Tip Amp***
Seal	22.9	0.009	-0.008	0.45	0.67
Otter	15.8	0.011	-0.008	0.53	1.05
Ferret	27.0	0.004	-0.002	0.68	1.46

IV. Discussion

Harbour seal and otter whiskers moved less against the surface; both are thicker, stiffer and more resistant to bending. For underwater robotics, a stiffer, thicker whisker might be useful to resist the movement of viscous water [2]. For terrestrial tactile robotics, we would recommend a smooth, slender whisker - since the ferret whisker moved easily against a textured surface. We need to investigate more species whisker shapes interacting with different surfaces, in order to design better whisker-inspired sensors.

References

[1] N. Lepora, M. Pearson, and L. Cramphorn. "TacWhiskers: Biomimetic optical tactile whiskered robots." *International Conference on Intelligent Robots and Systems (IROS)*. 2018. IEEE

[2] G. Dougill, E. Starostin, A. Milne, G. van der Heijden, V. Goss, and R. Grant. "Ecomorphology reveals Euler spiral of mammalian whiskers." *Journal of morphology*, 2020, vol. 281, pp.1271-1279.

[3] B. Hewitt, M.H. Yap, and R. Grant, Manual whisker annotator (mwa): A modular open-source tool. *JORS*, 2016, vol. 4.

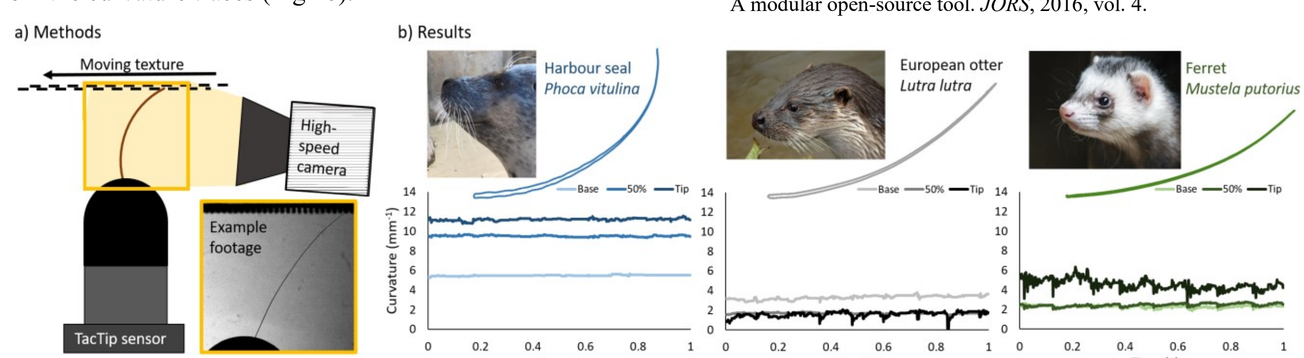

Figure 1. a) Seal, otter and ferret whiskers were held in a Tactip sensor, moved over a squared grating, filmed and tracked. b) Results show that the ferret whisker was thinner and moved more than the otter and seal whiskers.

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