Supplementary Information

Supplementary Materials and Methods

Infrared marker placement

The spacings between the markers were measured as they were placed, to facilitate later analysis. The markers were affixed using adhesive dots (Removable Dots, Glue Dots ® Adhesive, Germantown, WI, USA) attached to stickers (Color Coding Labels, Jot ™, Greenbrier Intl Inc., Chesapeake, VA, USA), which were then placed on the snake to increase visual contrast. We also marked a dot of white paint (Basics Acrylic, Liquitex ®, Cincinnati, OH, USA) caudally to each of the markers, to enable replacement of the marker at the same location if it fell off.

Gap size calculations

The size of the gap in each trial was calculated using the locations of the origin and target markers, using the averages of their values throughout a trial. These positions were then adjusted by the relative offset from the true branch end, defined as the center point of the top surface at the end of the PVC. The absolute gap size was calculated as the Euclidean distance from the target end to the origin end.

In eight trials, the position of one of the branch markers was not properly recorded, either because the marker fell off or was occluded. In these cases, the gap size was inferred to be the size of the gap in the other replicate trials conducted at that gap distance that day; if a replicate was not available, the size of the gap was set to that measured using a measuring tape on the day of the experiment.

Across all trials, the average error between the intended gap size (compared to that calculated using the 3D data) was 1.6% (min: 0.02, max: 14). The average error between the binned gap size (the gap size rounded to the nearest 5% SVL) used for statistical analysis and the gap size calculated using the 3D data was 1.3% (min: 0.01, max: 4.8). In absolute terms these values corresponded to 0.68 cm (min: 0.01cm, max: 3.7 cm) and 0.73 cm (min: 5.5e-3 cm and 2.2 cm), respectively.

Distinguishing between cantilevers and non-cantilevers

For most trials, the distinction between cantilever and non-cantilever behaviors was obvious. Ambiguous cases were adjudicated as follows:

- Trials in which the snake deviated from a straight line path (e.g., formed a loop or an arch) but then did not initiate any sort of lunging, jumping, or arching movement, and instead returned to a roughly straight body posture before continuing steadily across the gap, were classified as cantilever.
- Trials in which the snake moved in a relatively straight line path until its head was vertically above the target, and then seemed to release tension in order to "drop" onto the target, were classified as cantilever.
- Trials in which the snake moved in a relatively straight line path until nearing the target branch, and then initiated a very small upward and outward (lunge-like) movement toward the target to land, were classified as non-cantilever.

Calculation of moving and landing velocities

In some trials, the snake paused for long periods before continuing across the gap, artificially depressing the total average speed. Therefore, we defined an average head speed using only frames in which the snake was moving toward the target branch. To determine this average speed, the data were filtered to exclude frames where the X velocity component of the head was less than 0.025 m/s. This criterion was selected by comparing the 3D motion capture data to the corresponding video for three sections of data: one in which the snake was moving very slowly, and two in which the snake was entirely still (Fig. S3).

Random effects structure

The random effects structure was determined for each model by comparing a random slopes and intercepts vs. a random intercept-only model with the same fixed effects tructure, fit by REML. The Akaike information criteria (AIC) was calculated for each model, nd for the model set under consideration, $\Delta_i \ = {}_i \ -$ was determined for each odel *i* in the set. Following Burnham and Anderson (Burnham and Anderson, 2004), $\Delta_i \ <$ is considered to provide strong support for the less complex model *i*, 4 < Δ_i < 7 provides oderate support for the less complex model *i,* and if Δ_i > 10, there is no support for the less complex model *i* over the minimal AIC model. If the random slopes model was singular, we used the intercept-only model without comparing the AIC.

Missing and excluded data

Overall, we recorded 289 gap-crossing events from seven snakes. 64 of these events were not included in the analyzed data because they were used to establish methods, familiarize the snakes with the setup, or encourage the snake to cross a larger gap by presenting smaller gaps. However, in three cases (snake #94, gap = 30% SVL; snake 90, gap = 35% and 40%), measurement error led to unintended gap sizes being presented.

Data from an additional 15 trials from one snake were removed because the snake was later found to have been gravid. In 23 other trials, the snake did not complete a crossing event. In these cases, generally the snake either jumped off-target or repeatedly turned back to the origin (a refusal) (Fig. S4). Finally, five trials had to be excluded because the quality of the motion capture data was too poor to analyze or the file was corrupted. In total, 182 trials from six snakes were used for analysis.

For three trials, loop depth could not be calculated because the origin marker was not recorded properly by the motion-capture system. Additionally, in seven trials, as part of attempting to coax the snake across the branch, the snake was held near the target until it began to initiate a loop, and then moved back to the origin. Because the snake was being held during the transition frame for these trials, they are excluded from the torque and postural analyses. The torque analysis and head position at transition analysis also exclude the three trials where the origin marker was missing, and one trial in which the head position was missing from the transition frame. Finally, the overshoot analysis excludes five trials in which the target marker was not recorded.

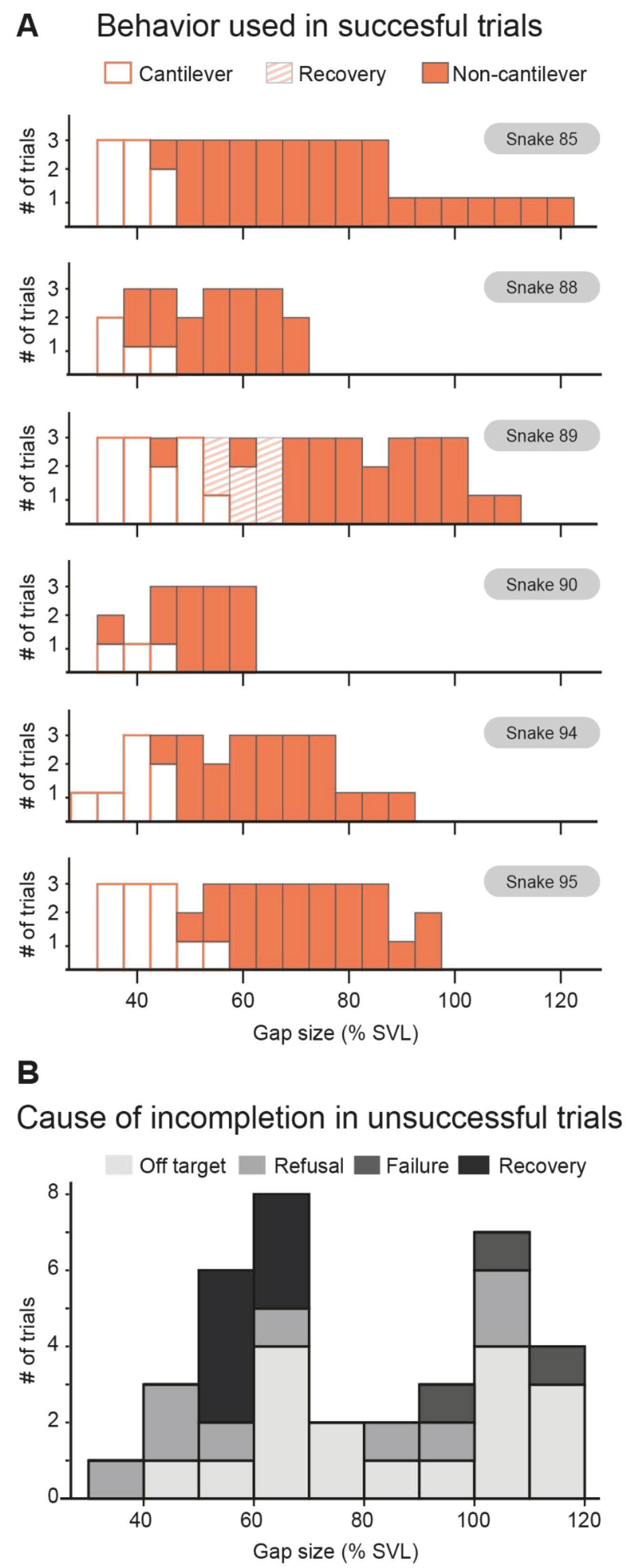

Fig. S1. Behavior and gap size. Top: Each subplot contains a plot of the number of instances of each behavior used by gap size for a given individual. Fewer total crosses are present for the largest gap sizes due to the snake's unwillingness to cross large gaps. Bottom: A summary of each trial, by gap size (% SVL), in which the snake did not successfully reach the target. Off-target trials were those in which the snake's movements appeared to be directed toward a non-target destination, as judged by where the snake was looking at the time of departure. Refusals are those in which the snake did not depart the origin. Failures are those in which the snake did not reach the target despite seemingly attempting to reach it. Recovery trials are those where the snake failed a first attempt, but succeeded on a subsequent attempt within the same crossing bout.

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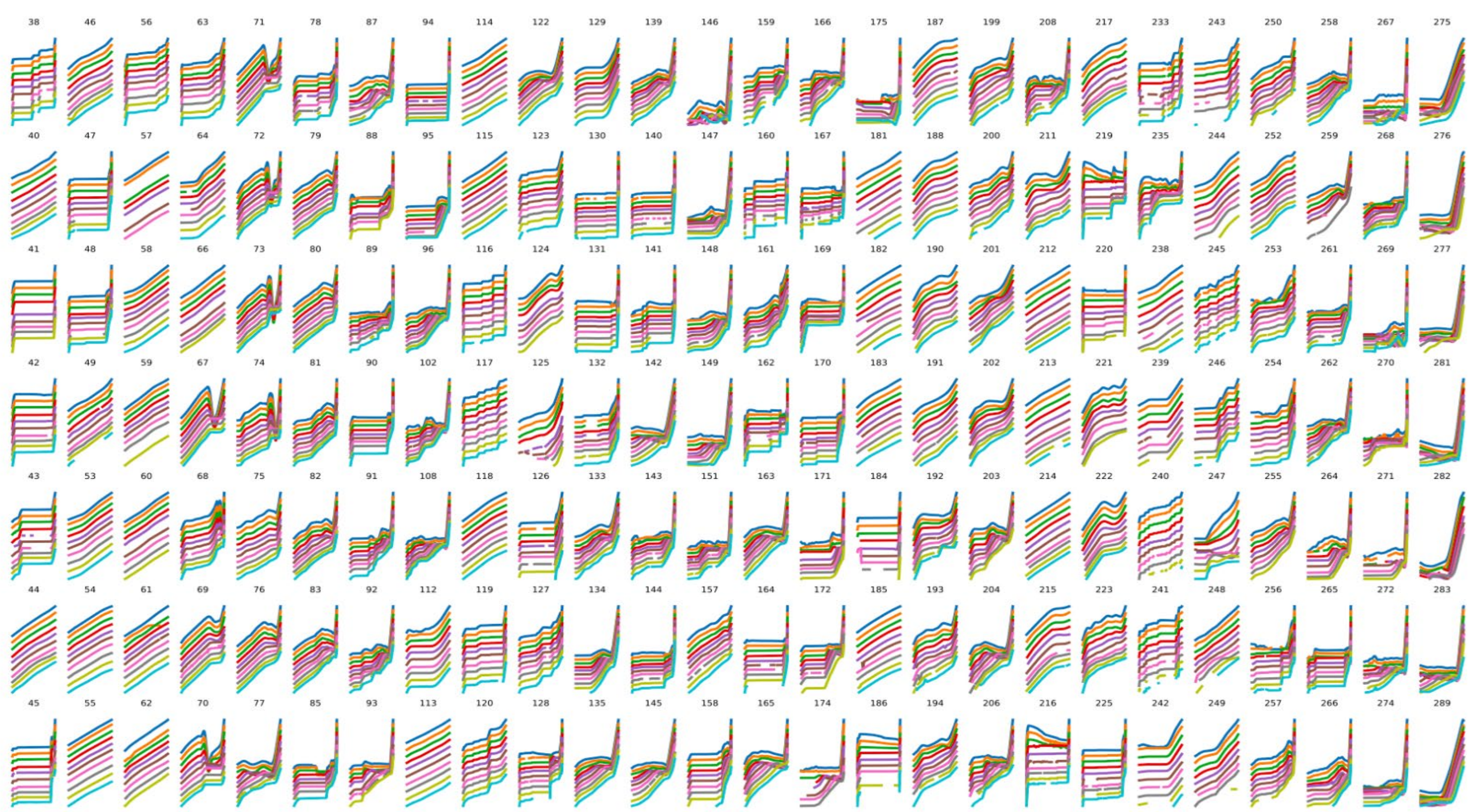

Fig. S2. Interpolated position data. Each subplot in this figure contains the X position trajectories (vertical axis) against time (horizontal axis) for all markers on the snake in that trial after interpolation of small sections of missing data. Trials in which a marker was missing for all or part of the trial can be noted by white space in the line; gaps of greater than 0.2 seconds were not interpolated. Subplot titles reflect trial numbers.

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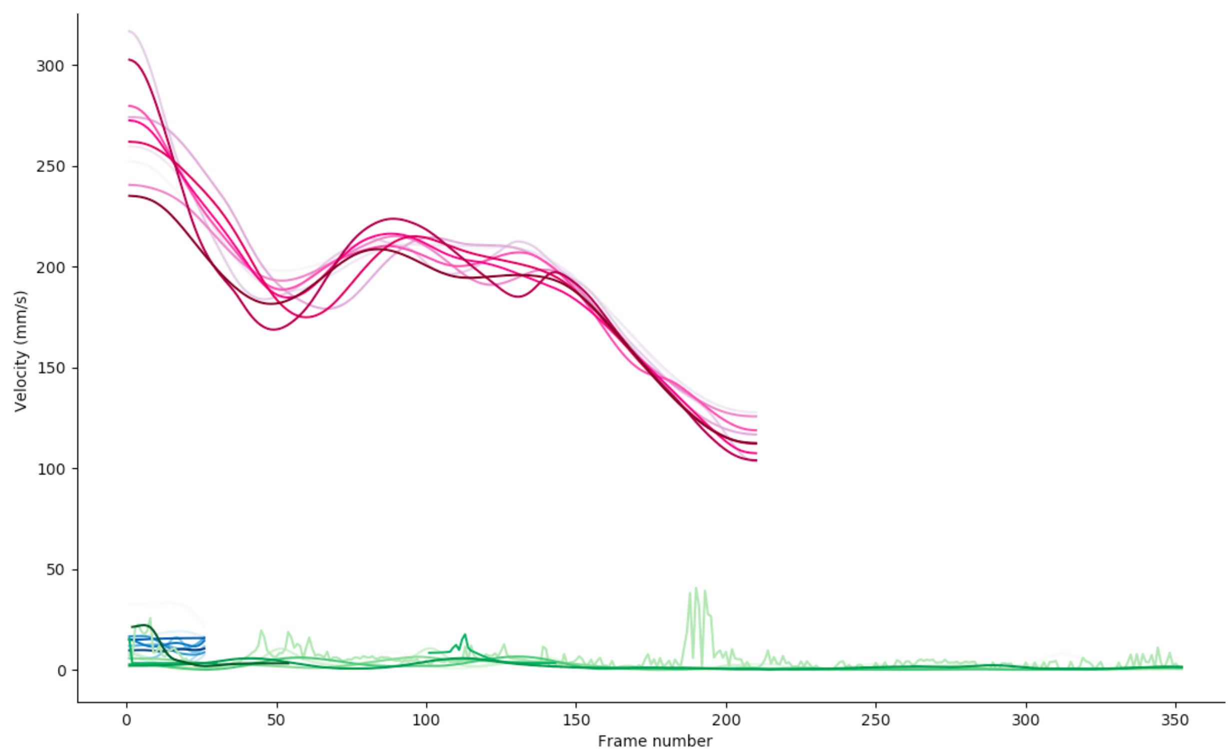

Fig. S3. Establishing threshold for moving velocities. Pink lines show raw speed data for all 10 markers during a trial period in which the snake was consistently moving, according to video data. Green and blue lines show 10 markers of data during which the snake appeared to be still, according to the video data. In each case, the darkest line represents the head. The comparisons presented here were used to set the cut-off speeds for determining sections of data where the snake was still: 0.025 m/s was used as the cutoff.

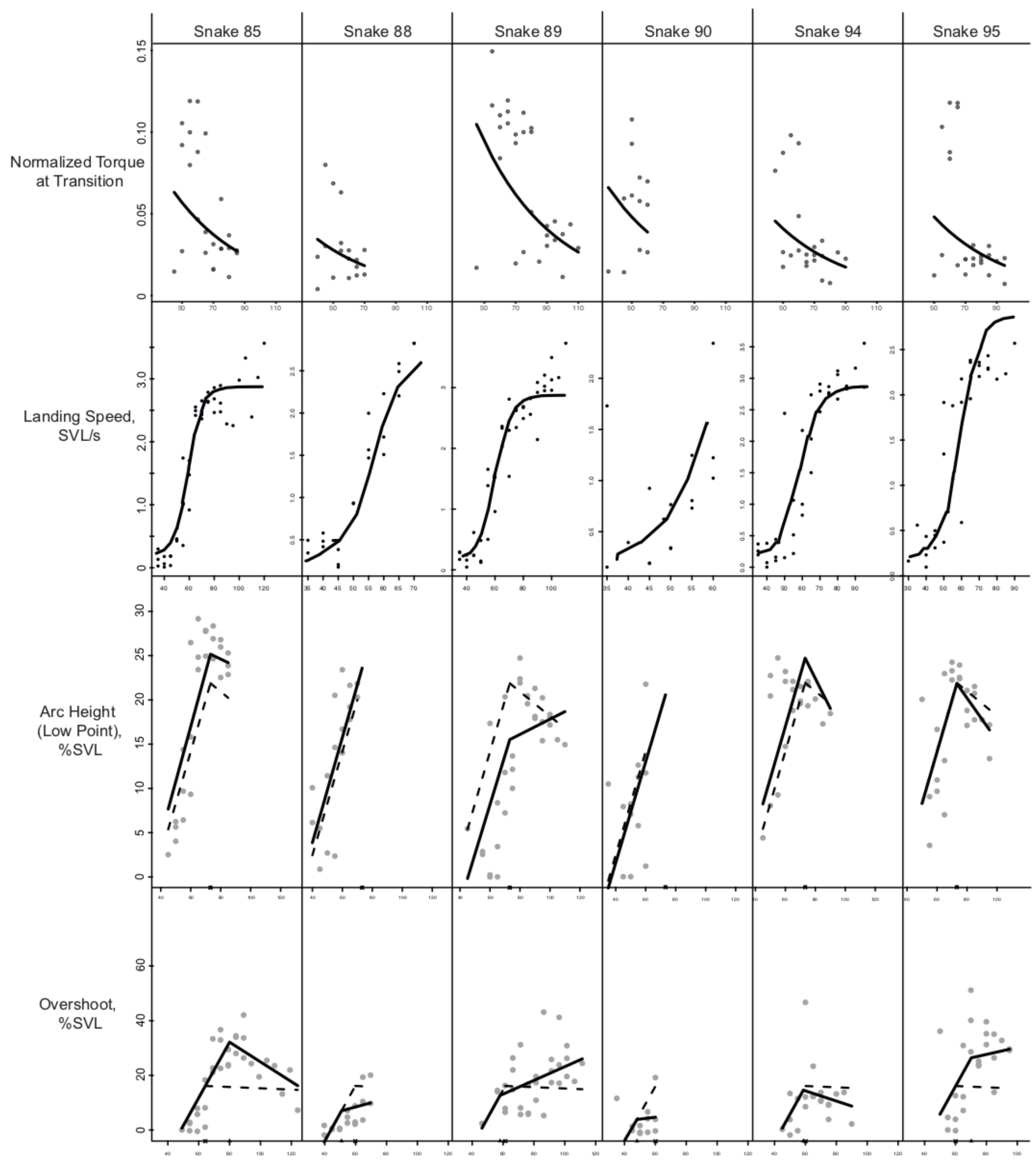

Fig. S4. Variation in specific kinematic metrics between individuals. Results of a mixed effects model for four analyses (normalized torque measured at the transition point, landing head speed, arc height at the low point, and overshoot) against gap size are presented, showing variation between individual snakes. For breakpoint analyses (bottom two rows), the dotted lines represent the population estimate, while the solid line represents the estimate for the given individual.

Table S1: Maximum torques recorded for each snake during cantilever and non-cantilever movements

ID	Behavioral category	Gap size at which largest transition torque value recorded (%SVL)	Largest transition torque (Nm)	Largest gap size for which a transition torque was recorded (%SVL)	Corresponding transition torque (Nm)
85	Cantilever	45.0	0.04	-	-
	Non-cantilever	54.4	0.04	85.8	0.01
88	Cantilever	45.4	0.09	-	-
	Non-cantilever	43.3	0.08	72.3	0.01
89	Cantilever	55.1	0.07	-	-
	Non-cantilever	55.1	0.07	109.1	0.01
90	Cantilever	42.7	0.04	-	-
	Non-cantilever	49.1	0.04	58.7	0.02
94	Cantilever	45.5	0.11	-	-
	Non-cantilever	55.6	0.10	89.4	0.02
95	Cantilever	53.2	0.03		
	Non-cantilever	58.6	0.03	96.6	1.6e-3

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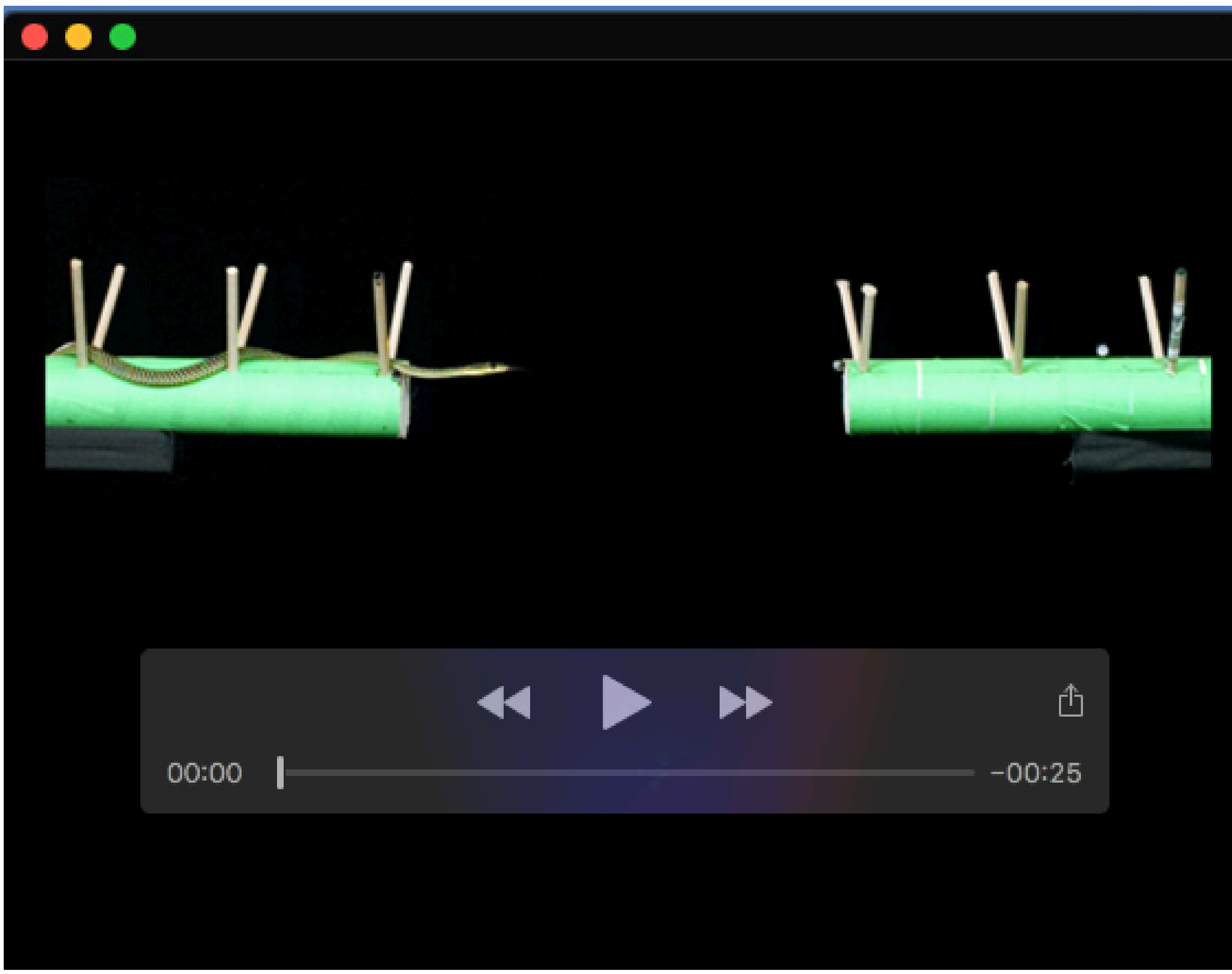
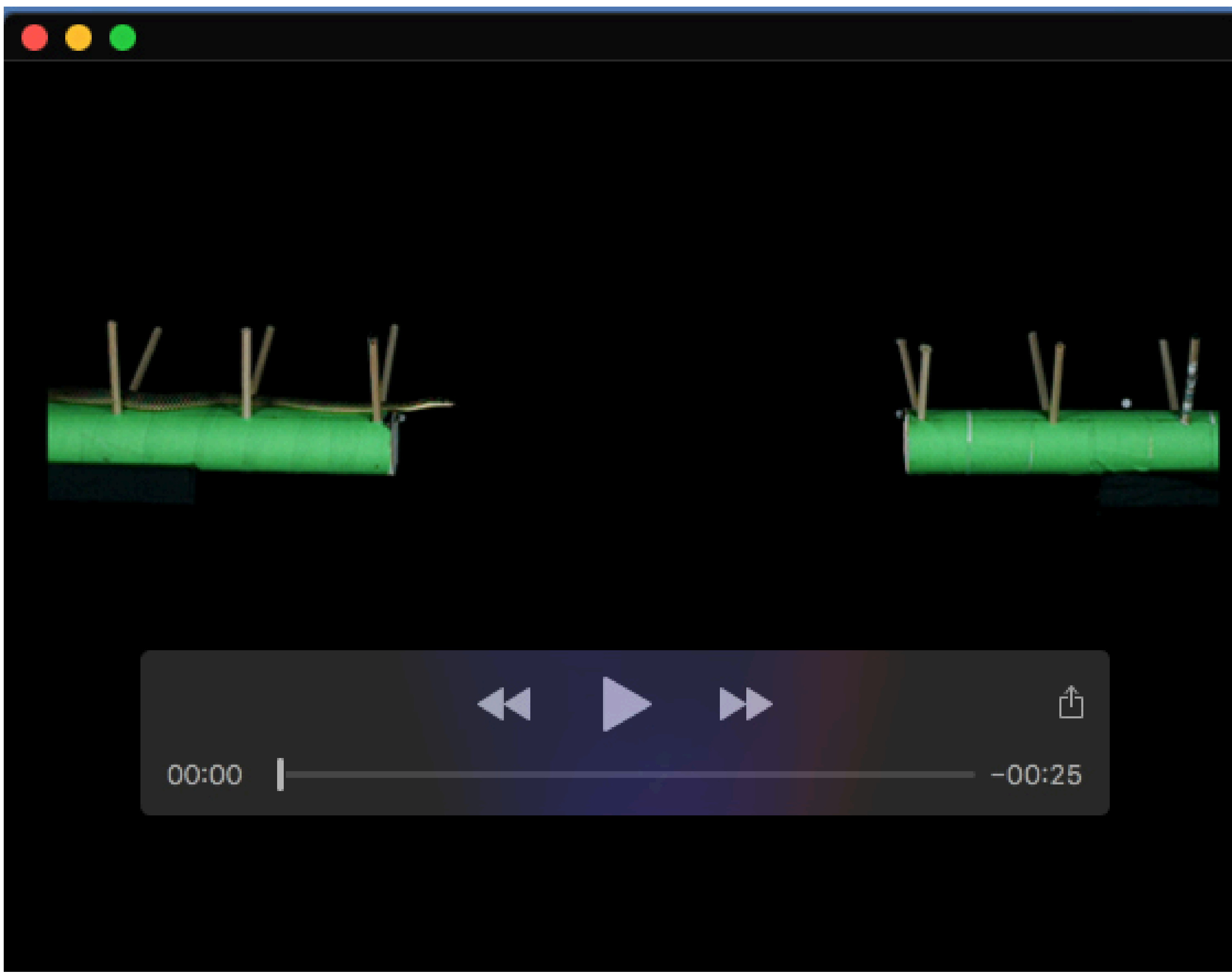
Table S2. Comparisons between J-loop crosses and J-loop launches. "Prep" and "Vert" refer to the preparation time (from snake entering the gap to beginning of first downward movement) and vertical acceleration time (from start of upward acceleration until movement becomes more horizontal than vertical, respectively. "Max" and "L" refer, respectively, to maximum and landing speeds in both Z (vertical) and X (horizontal) directions. "Dist" refers to the distance traveled horizontally by the head from the origin to the position at landing, and "Height" refers to the maximum vertical height of the head above the origin. Data were compared using a Mann Whitney U test, and the only significant difference between J-loop launches and crosses was in the distance traveled.

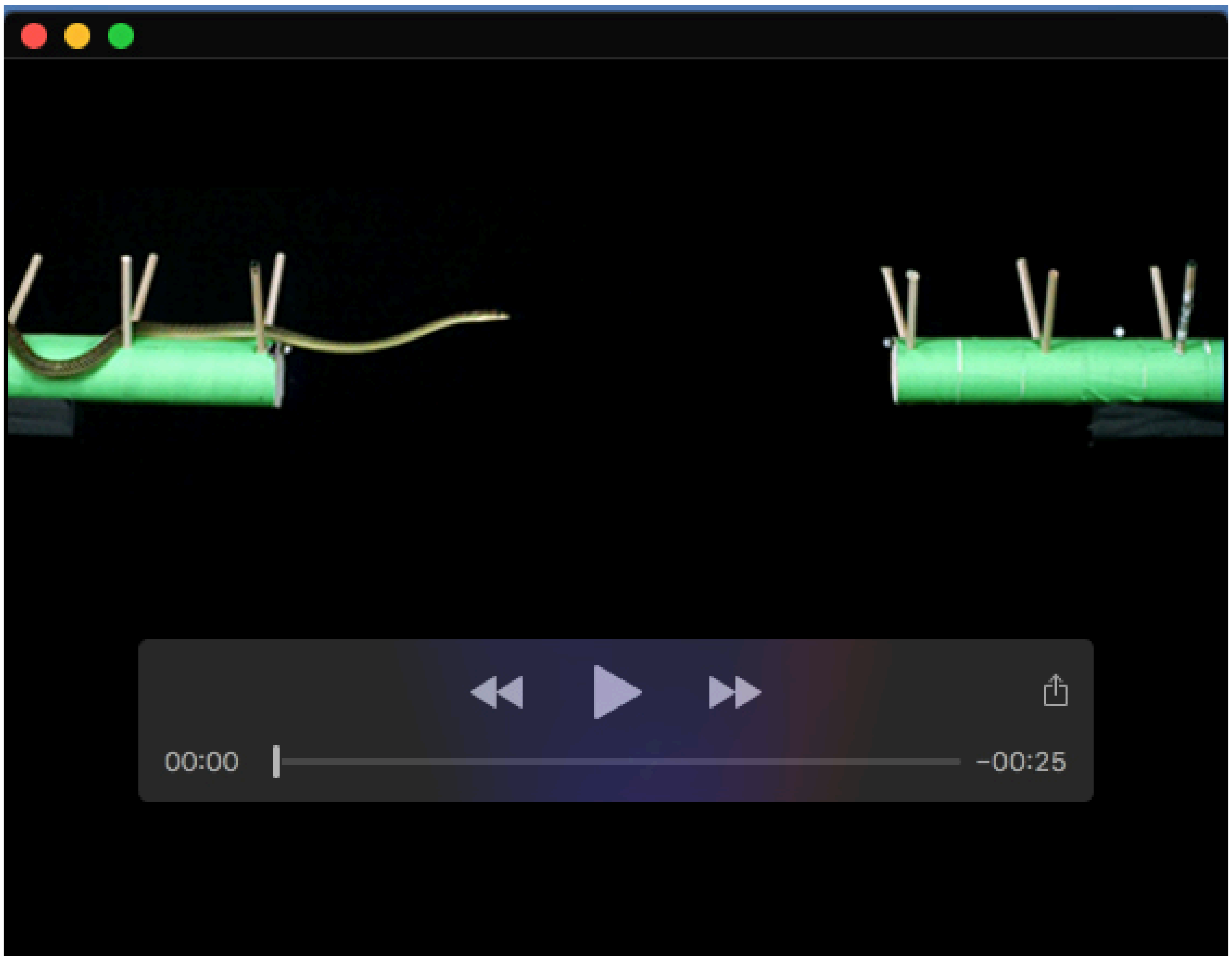
			SVL/s				SVL	
	Prep (s)	**Vert (s)**	**Max Z**	**Max X**	**LZ**	**LX**	**Dist**	**Height**
J loop launches (Socha, 2006)								
Median	1.82	0.32	2.64	2.92	-2.64	2.01	0.97	0.25
N	10	11	11	11	11	11	11	11
Data from this study								
Median	2.82	0.36	2.09	2.66	-1.99	2.40	1.27	0.33
N	3	3	3	3	3	3	3	3
Statistical comparison - Mann Whitney U Test								
Ua	21	23	3	11	25	19	33	24
Ub	9	10	30	22	8	14	0	9
f	0.7	0.70	0.09	0.33	0.75	0.58	1	0.73
0.05 crit value	3	3	3	3	3	3	3	3
Is U < Crit?	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	**Reject Null**	Fail to Reject
Null hypothesis: for randomly selected values X and Y from two populations, the probability of X being greater than Y is equal to the probability of Y being greater than X.								



Movie 1.



Movie 2.



Movie 3.