String-mediated Inertial Force-based Haptic Perception of Disk Diameter

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Introduction

Rotational inertia is the force required for acceleration about a rotational axis. Prior research in haptic perception indicates that information provided by the three moments of inertia about the three principle axes of an object can be utilized to make accurate judgments of object properties (Carello & Turvey, 2004).

Physical-mathematical analysis predicts that some object properties may be recoverable from even a single moment of inertia (Cabe, 2010).

We adopted a similar method to investigate haptic perception of disk diameter using information provided solely through the moment of inertia. Participants perceived varying disk diameters by rotating a shaft using strings attached to their forefingers.

We predicted that participants would be able to accurately and reliably perceive disk diameters, using moment of inertia information. Findings in support of these predictions suggest that rotational inertia and the inertia tensor are sufficient for perceiving spatial properties of objects.

Apparatus and Stimuli

Stimuli. Five aluminum disks (12, 14, 16, 18, and 20 cm diameter, .32 cm thick). The disk masses were 96, 126, 169, 215, and 257g (see below).

Apparatus. The photographs to the right display the apparatus from the participant's view (top), the apparatus from the experimenter's view (middle), and the apparatus before the addition of a screen (bottom).

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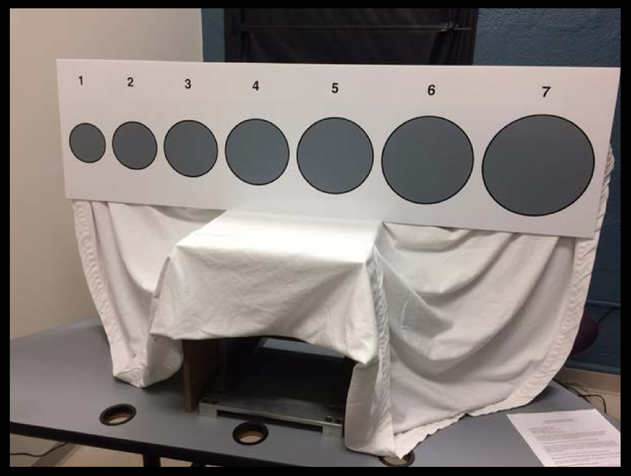
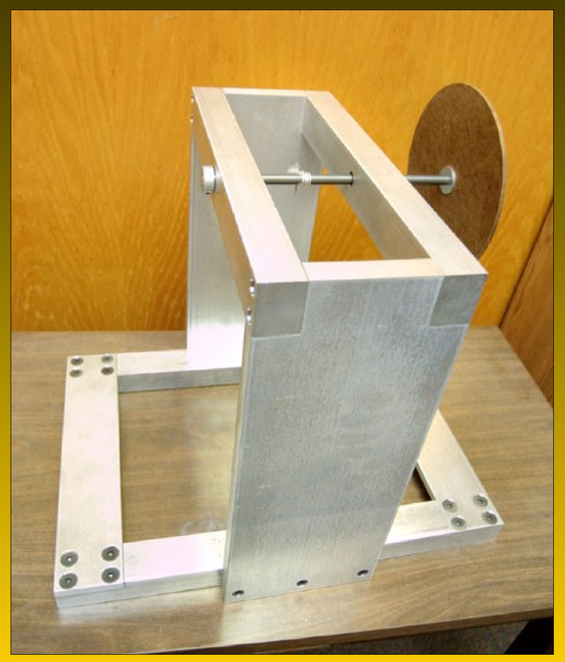
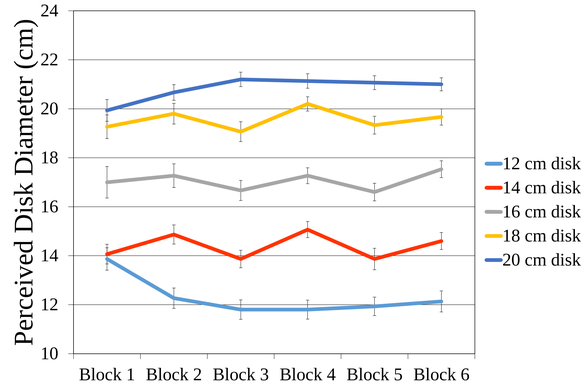




Experiment 1

Participants (N = 30) bidirectionally rotated visually-occluded disks using index fingers operating a string wrapped around the shaft connected to the disk.

While rotating the disk, they attempted to identify the disk's diameter, by choosing one of seven circles displayed visually.



ANOVA. An initial 5 (disk diameters) x 6 (trial blocks) ANOVA showed a strong main effect for diameter, $F(4, 116) = 470.00$, $p < .0001$, $\eta^2_{part} = .94$, but a non-significant main effect for blocks, $F(5, 145) = 1.29$, $p = .27$. The interaction was significant, $F(20, 580)$, $= 1.94$, $p < .0001$, $\eta^2_{part} = .09$. Repeating the ANOVA, with the first trial block omitted (on the basis that it was a familiarization block), gave the same strong main effect for disk diameter, the same non-significant main effect for block, and now a non-significant interaction.

Pairwise comparisons, using judgments averaged over blocks for each participant, yielded significant differences between all 10 pairs, all Bonferonni-corrected $t(29) > 8.37$, all $p < .001$, all Cohen's $d > 1.5$.

References

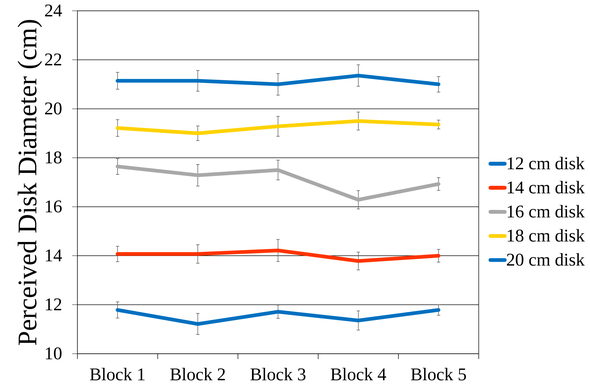
Cabe, P. A. (2010). Sufficiency of longitudinal moment of inertia for haptic cylinder length judgments. *Journal of Experimental Psychology: Human Perception and Performance, 36(2),* 373-394. doi:10.1037/a0018395

Carello, C., & Turvey, M. T. (2004). Physics and Psychology of the Muscle Sense. *Current Directions in Psychological Science, 13(1),* 25-28. doi:10.1111/j.0963-7214.2004.01301007.x

Experiment 2

Participants (N = 28) were administered the same methodology as Experiment 1, with the exception being they wore earplugs to reduce potential acoustic information from the apparatus.

The first 5 trials were a familiarization block.



ANOVA. An initial 5 (disk diameters) x 5 (trial blocks) ANOVA showed a strong main effect for diameter, $F(4, 108) = 553.33$, $p < .0001$, $\eta^2_{part} = .95$, but a non-significant main effect for blocks, $F(4, 108) = 0.45$, $p = .77$. The interaction was not significant, $F(16, 432) = 0.96$, $p = .50$.

Pairwise comparisons, using judgments averaged over blocks for each participant, yielded significant differences between all 10 pairs, all Bonferonni-corrected $t(27) > 9.50$, all $p < .001$, all Cohen's $d > 1.8$.

Discussion

Participants made reliable and accurate disk diameter judgments with or without access to acoustic information from the apparatus.

Findings are consistent with the interpretation that moment of inertia informed disk diameter judgments.

Disk diameter, disk mass, and disk moment of inertia were confounded, however, by using disks of one material and constant thickness. Separating the effects of these variables will be the objective of future experiments.