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Authors(s)	Lopresti-Goodman, Stacy M., Turvey, Michael T., Frank, Till D.
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Negative Hysteresis in Affordance Experiments

Stacy M. Lopresti-Goodman[1], & T. D. Frank[2]

[1]Marymount University, Arlington, VA, 22207,
[2]CESPA, University of Connecticut, Storrs, CT, 06269.

To perceive an *affordance* is to perceive what the current layout of surfaces *affords* with respect to one's body size and action capabilities (Gibson, 1979). Affordance experiments have demonstrated that the shift from one mode of behavior to another exhibits the features typical of a self-organized dynamic system (Fitzpatrick et al., 1994; Richardson et al., 2007; van der Kamp et al., 1998), where stable patterns of behavior emerge from the lawful interaction between components of the animal-environment-task system.

For example, the boundary between graspable-with-one-and-two-hands differs experimentally when the object-to-hand-ratio (e.g. pi-number, α) is scaled in an ascending and descending manner: There is hysteresis ($\Delta\alpha$). When the critical value of α for ascending trials (α_{c2}) is larger than that for descending trials (α_{c1}), *positive hysteresis* has occurred. This is typically found in experiments where perception is indexed by selective action (e.g. actually grasping objects) (Lopresti-Goodman et al., 2009; Richardson et al., 2007). When $\alpha_{c1} > \alpha_{c2}$, *negative hysteresis* (e.g. *enhanced contrast*) has occurred, and is typically found when perception is indexed by selective verbal classification (e.g. "two-hands") (Fitzpatrick et al., 1994; Hirose & Nishio, 2001; Richardson et al., 2007). When $\alpha_{c1} = \alpha_{c2}$, a critical point has occurred.

Frank et al. (2009) developed a dynamical model, the Grasping Transition (GT) model, for affordance transitions. The different types of grasping modes represent the system's stable states and may be considered order parameters (ξ) of the dynamic system. The order parameters ξ_1 and ξ_2 represent the generalized amplitudes of the one- and two-hand grasping modes, respectively. $\xi_1 > 0$, $\xi_2 = 0$ defines the one-hand mode, $\xi_2 > 0$, $\xi_1 = 0$ defines the two-hand mode. Then, the grasping behavior is determined by the time evolution of ξ_1 and ξ_2:

$$\dot{\xi}_1 = \lambda_1\xi_1 - g\xi_2^2\xi_1 - \xi_1^3, \text{ and } \dot{\xi}_2 = \lambda_2\xi_2 - g\xi_1^2\xi_2 - \xi_2^3. \quad (1)$$

λ_1 and λ_2 are the one- and two-hand so called "attention" parameters (Haken, 1991), respectively, corresponding to ξ_1 and ξ_2. α acts as a control parameter. By Eq. (12) in Frank et al. (2009), λ_1 and λ_2 relate linearly to α where β determines the overall size of λ like $\lambda_1 = \beta(1 - \alpha)$ and $\lambda_2 = \lambda_{2,0} + \beta\alpha$.

Parameter values for g in Eq. (1) can be derived from experimental observations of α_{c1} and α_{c2}. Eq. (13) of Frank et al. (2009) yields

$$g = (1 - \alpha_{c1})/(1 - \alpha_{c2}). \quad (2)$$

g represents the strength of the interaction between the two grasping modes, as well as to the stability of the attractors and the hysteresis size ($\Delta\alpha$). This experiment investigated what changes in g are responsible for the hysteresis differences observed in selective action and verbal classification experiments.

Experiment 1

Experiment 1 investigated differences in grasping dynamics where the perception of graspability was indexed by selective action, hereafter referred to as the "action" condition, and when perception is indexed by verbal classification, hereafter referred to as the "perception" condition.

Method

Thirty-two University of Connecticut students participated as partial fulfilment of a course requirement.

Two sets of narrow wooden planks, 2 cm high and 6.5 cm wide, ranging in length from 4.5 to 24.5 cm, in 0.5 cm increments, were used as the objects. These planks were painted black with their ends red. Participants were instructed that they were only permitted to grasp the objects by their red ends (lengthwise).

Each individual participated in two task conditions (action and perception) with three plank presentation sequence trials blocked within each condition (ascending, random and descending), for a total of 6 trials per participant. For each trial, the participant was presented with an experimental object, one at a time, on a small table. For the action trials, participants were asked to grasp, lift, and move the objects from location 1 marked on the table, to location 2, which was marked 30 cm to the right of location 1. For the perception trials, participants kept their eyes closed until the object was placed in location 1. They were then instructed to open their eyes and indicate verbally whether they would use one hand or two hands if asked to grasp and move each object to location 2.

The experiment was a 2 (task: perception, action) × 3 (sequence: ascending, random and descending) within subject design. α_{c2} was calculated as the plank length at which a participant physically transitioned (action) or verbally indicated (perception) they would transition from one- to two-hand grasping (vice versa for α_{c1}), divided by their hand-span. These values were substituted into Eq. (2) to calculate g values for both task conditions.

Results and Discussion

Given the results of previous perception and action affordance experiments (Richardson et al., 2007), we expected moderate positive hysteresis ($\alpha_{c2} > \alpha_{c1}$; $\Delta\alpha > 0$) in the action trials and expected negative hysteresis ($\alpha_{c1} > \alpha_{c2}$; $\Delta\alpha < 0$) in the perception trials. A Univariate ANOVA on the $\Delta\alpha$ values revealed significant differences between the two conditions, $F(1, 31) = 54.08$, $p < .001$, $\eta^2 = 0.64$, with very moderate positive hysteresis, or a critical point, occurring in the action trials ($M_{\Delta\alpha} = 0.01 \pm 0.05$) and negative hysteresis occurring in the perception trials ($M_{\Delta\alpha} = -0.12 \pm 0.10$).

A Repeated Measures ANOVA revealed that the average g value for the action trials ($M = 1.03 \pm 0.15$) was significantly larger than that for the perception trials ($M = 0.71 \pm 0.25$), $F(1, 31) = 48.51$, $p < .001$, $\eta^2 = 0.61$. This suggests that negative hysteresis in the perception trials is the result of decreased interaction of the grasping modes, and decreased stability of their attractors, relative to the modes and attractors in the action condition. It is possible that the differences in dynamics in the perception trials are the result of a lack of feedback about grasping abilities which is obtained while grasping the objects.

Experiment 2

Experiment 2 investigated whether the GT Model could capture the affordance dynamics in an experiment investigating the perception of maximum sit-on-ability. Given this is an investigation of perception, we expected negative hysteresis and expected $g < 1$ due to a decreased interaction between the sit-on-able (ξ_1) and not-sit-on-able (ξ_2) modes.

Method

Twelve participants from the University of Connecticut participated as partial fulfillment for a course requirement.

The experimental apparatus was a 61 cm wide × 136.5 cm high wooden stand with a 2 × 42 × 61 cm wooden seat attached to the front that had a range of mobility of 25 to 100 cm. The seat pan was manually adjusted by the experimenter who was hidden from the participants' view. Participants asked the experimenter to "stop" moving the seat when it reached what was judged to be the maximum height they could sit on without lifting their feet off of the ground.

Individuals participated in 12 trials where the seat pan slowly moved from the ground up (ascending trials) and 12 trials where the seat pan moved from the top of the apparatus down (descending trials), the order of which alternated. α_c was calculated for each trial as the seat height in cm judged to be the maximum height that afforded sitting on, divided by the participant's leg length in cm. The mean α_{c2} and α_{c1} values were calculated as the average α_{c2} and α_{c1} values for all 12 ascending and 12 descending trials, respectively. These values were substituted into Eq. (2) to calculate the g value for this experiment.

Results and Discussion

Given the results of previous experiments investigating the perception of maximum sit-on-ability (Hirose & Nishio, 2001), we expected negative hysteresis ($\alpha_{c1} > \alpha_{c2}$; $\Delta\alpha < 0$). A Repeated Measures ANOVA on the mean α_c values revealed that α_{c1} ($M = 0.87 \pm 0.05$) was significantly larger than α_{c2} ($M = 0.80 \pm 0.05$), $F(1, 11) = 103.67$, $p < .001$, $\eta^2 = 0.90$, suggesting that negative hysteresis occurred ($M_{\Delta\alpha} = -0.07 \pm 0.02$).

Given our expectation of negative hysteresis, we anticipated $g < 1$, which might indicate a weak interaction between, and stability of, the ξ_1 and ξ_2 modes. Our analysis revealed that this was the case ($M_g = 0.63 \pm 0.17$).

Interestingly, a qualitative analysis reveals that the *g* value for maximum sit-on-ability was similar to that found in the perception condition of Experiment 1, which may suggest an invariance of the *g* parameter dynamics for perception experiments.

Conclusion

As expected, negative hysteresis was observed in both of our perception experiments. The evaluation of the GT model suggests that the negative hysteresis effects observed were the result of weaker interactions between, and a weaker stability of, the two behavioral modes (e.g. $g < 1$). It is possible that the lack of active exploration of the environment in our perception conditions is what led to the weaker interactions and stabilities observed.

References

Fitzpatrick, P., Carello, C., Schmidt, R. C., & Corey, D. (1994). Haptic and visual perception of an affordance for upright posture. *Ecological Psychology, 6(4),* 265-287.

Frank, T. D., Richardson, M. J., Lopresti-Goodman, S. M., & Turvey, M. T. (2009). Order parameter dynamics of body-scaled hysteresis and mode transitions in grasping behavior. *Journal of Biological Physics, 35,* 127-147.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Haken, H. (1991). *Synergetic computers and cognition.* Springer: Berlin.

Hirose, N., & Nishio, A. (2001). The process of adaptation to perceiving new action capabilities. *Ecological Psychology, 13(1)*, 49-69.

Lopresti-Goodman, S. M., Richardson, M. J., Baron, R. M., Carello, C., & Marsh, K. L. (2009). Task constraints and affordance boundaries. *Motor Control, 13*, 69-83.

Richardson, M. J., Marsh, K.L., & Baron, R. M. (2007). Judging and actualizing intrapersonal and interpersonal affordances. *Journal of Experimental Psychology: Human Perception and Performance, 33*, 845-859.

Van der Kamp, J., Savelsbergh, G. J. P., & Davis, W. E. (1998). Body-scaled ratio as a control parameter for prehension in 5- to 9-year-old children. *Developmental Psychobiology, 33(4),* 351-361.