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Measuring ramp use in guinea pigs (*Cavia porcellus*)

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To investigate the utility of ramps as enrichment and as a method for establishing demand for commodities, the latency to climb a ramp of increasing slope to obtain food was measured in four guinea pigs. The average height where guinea pigs failed to climb was 29.1 cm (slope 14.2 degrees). In addition, the increasing slope altered climbing behavior; when climbing speed was tested using the same slope for all trials within a single session, the guinea pigs maintained their climbing speed as the gradient increased across sessions. In comparison, when the slope was increased with each successful climb within a session, climbing speed was not maintained. Installing the maximum slope climbed can promote increased exercise and foraging but avoid physical harm or barriers to resources. Furthermore, these results indicate that climbing, a simple behavior with measurable differences as a function of slope and thus, effort, could be used as a method for testing the demand for commodities, such as food type or enrichment items, to be included in the husbandry of guinea pigs to improve welfare of the small cavy.

Key words: guinea pig, ramp, exercise, enrichment, demand

Small mammals, such as guinea pigs (*Cavia porcellus*), are common companion animals living in 32,000 households in New Zealand (CANZ, 2020). However, their behavioral and dietary needs are commonly misunderstood, leading to inadequacies in the captive environment. These environments can provide safety from predators, veterinary care and a food supply, but sometimes fail to satisfy species-specific health and behavioral needs, especially those relating to nutrition, housing, and the social environment (Dawkins, 2004; Grazian, 2015). In a New Zealand survey, 21.1% (60/330) of owners house their guinea pigs in enclosures of <1 m^2 (Cameron et al., 2022) which is smaller than the recommendation provided by the New Zealand RSPCA of >1.0 m^2 for two guinea pigs (RNZSPCA, 2021). In addition, a UK survey found guinea pigs commonly experiencing inadequate diets, inappropriate enclosure sizes, and a lack of opportunities for social interaction with conspecifics (Harrup & Rooney, 2020). Such deficits in the husbandry conditions of guinea pigs may contribute to prolonged periods of inactivity, weight gain, and the development of related health issues and psychological disorders, severely impacting their welfare (Rooney et al., 2014).

Traditional methods for preventing or targeting weight gain in companion animals include increased exercise in the form of walking or play, as well as a veterinary-dictated feeding regime (Bland et al., 2010). An alternative method is to increase the activity required to gain access to food, for example, by providing food in a way that promotes foraging-related behavior, which can also act as a form of enrichment (German, 2006). The scattering of food stuffs for captive wild animals is a common practice in many zoos worldwide (e.g., Newberry, 1995), and the provision of food toys, or even simply moving the food bowl around the house can increase activity in kenneled dogs (*Canis lupis familiaris*; Schipper et al., 2008) or other companion animals living in small spaces, such as apartments (German, 2006). Providing such opportunities for guinea pigs is usually achieved by the scattering of food stuffs in the enclosure and providing a medium, such as straw or hay, for the animals to manipulate (Harrup & Rooney, 2020). Cameron et al. (2022) found nearly 27.5% (84/306) of owners offered foraging opportunities in the form of edible toys, hay or straw, or treats in puzzle devices. This method increases the activity required to gain access to food as a form of enrichment, which provided as an adjunct to increasing enclosure size, can inhibit the development of certain behavioral problems and weight gain (German, 2006).

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The RNZSPCA (2021) has recommended that owners can increase the size and complexity of indoor cage systems for guinea pigs by adding a second level, accessed by a ramp. This addition would require the guinea pigs to climb a ramp resulting in a greater effort being made through exercise to gain access to resources on the second level, such as food or manipulatable materials. There is at present no research to guide owners in the appropriate angle of the ramps for use in their guinea pig enclosure. Online "folk wisdom" suggests a slope of no more than 30 degrees (e.g., theguineapigforum.co.uk), however, this has no empirical basis. Considering that guinea pigs are not morphologically designed to climb in the same way as rats and have lost the ability to manipulate objects with their paws (Barbera et al., 2019), it is important to understand what an appropriate slope would be to effectively increase exercise and foraging opportunities without causing either physical or psychological stress by making resources less attainable. Thus, the use of ramps (and the additional extra space) may therefore provide an easily implemented opportunity for guinea pigs to expend energy to obtain food—but there is still the question of how to safely implement ramps in enclosures.

It is difficult to measure animal needs. In laboratories, the expenditure of effort can be utilized experimentally to gain an understanding of animals' preferences for different commodities. Animals are commonly offered some of their daily ration within experimental sessions for expending effort, such as by pressing levers. These are known as *demand* experiments, where the effort required of an animal to obtain a resource is systematically increased (Hursh et al., 2013). For example, Cameron et al. (2015; 2016) offered a variety of foods to captive brushtail possums (*Trichosurus vulpecula*) contingent on their responding on two levers that required different numbers of presses to gain the food. Although lever pressing is not a typical behavior for the species, it is a proxy for foraging enrichment as it involves effort to gain access to differentially valued food and allows for control over delivery of a commodity to accurately measure the limits of behavior.

Paradigms that manipulate effort to gain a reward rely on the completion of a behavior under conditions where one dimension is altered to increase the work or effort the animal must exert to gain the reinforcer (Pinkston, 2021; Pinkston & Libman, 2017). For example, rabbits (*Oryctolagus cuniculus*) were given the opportunity to gain access to food, social contact, a platform, or an empty cage by pushing open increasingly heavy doors (Seaman et al., 2008). The rabbits put forth the most effort to gain access to food compared to the other options. Pinkston (2021) relates that the operant behavior in completing the task might change as a result of an increasing response effort required to complete the task, and performing the task might become aversive, resulting in eventual termination of behavior when the effort requirement is too great. For example, the behavior to complete the task is performed more slowly as the effort requirement increases, until failure—both aspects of which are demonstrated well by the demand model.

Recently, point-to-point movement has been used to measure the demand for resources in dogs (*Canis lupus familiaris*) by measuring the time to move down a runway to obtain different food commodities (Cameron et al. 2019; 2021). The dogs moved faster to obtain their most preferred food compared to either their least preferred food or a sample of their staple diet. At present, no suitable demand paradigms for guinea pigs exist, or those that do require extensive training and are time-consuming, such as clicker training. Point-to point movement on the ramp may be an easily applied paradigm to test for commodity value without requiring extensive training in a response behavior such as lever pressing, allowing for measurement of the value of different commodities to that animal. For instance, if an animal works harder for one commodity compared to another, evidenced by climbing a steeper ramp, this can be interpreted as the animal placing higher value on that commodity. Establishing the demand for different commodities such as food type or enrichment items to be included within an enclosure has potential for increased welfare of the pet cavy.

In the current study, the aims were to 1) investigate ramp use in guinea pigs, and 2) measure the viability of climbing ramps as a method for studying demand in guinea pigs. It was hypothesized that with an increase in the slope of the ramp, and thus the effort required to access the food, the guinea pigs' latency to climb would increase. The maximum slope each guinea pig would climb before failure to climb the next slope was recorded as the breakpoint, and a demand analysis was conducted to assess the effect of the slope on the latencies to obtain the food.

Method

Subjects

Four female guinea pigs participated in the experiment (Daffy, Thor, Loki and Della), housed separately in the Unitec Animal Husbandry and Behavior Centre (Unitec Institute of Technology, Auckland, NZ) for the duration of the experiment. In each enclosure there were places to hide such as a cardboard box or hide, and hay for burrowing. The age of the guinea pigs was unknown as they were foster guinea pigs from a rescue centre but were estimated to be adults of 3-4 years old. The average weight was 1108.8 grams (SD = 64.5 grams). Each enclosure had substrate of polar fleece, wood shavings, and a constant supply of hay held above the substrate for eating.

On experiment days, the subjects were not fed their morning pellet ration (15 g Camtech®). Guinea pigs received either carrot or fresh greens such as grass, meadow grass (*Poa annua*), clover (*Trifolium repens*), and dandelion (*Taraxacum officinale*) as reinforcers, with supplementary food to make up their daily ration offered after the experiment at 2 pm, made up to consist of 15 g pellets, 15 g vegetables (e.g., carrot, beans, tomato) and 20 g of fresh greens. Ethics approval was given by the AgResearch Ethics committee (approval number 14480).

Each guinea pig was weighed in the morning as part of a regular husbandry routine which included checking physical health and body condition.

Apparatus

The ramp was custom-built (17 cm wide × 120 cm in length) made from untreated plywood and painted with non-toxic paint (Fig. 1). There were ladder-like rungs 2 mm deep on the ramp to provide grip. There were *start* and *finish* boxes (17 cm × 30 cm length) attached at each end, which remained horizontal as the elevation of the ramp increased and were lined with newspaper during the experiment. Two U-shaped pieces of conduit were aligned at the finish end of the ramp with holes 2.5 cm apart. When the ramp was raised, two long bolts passed through holes of the same height and held the finish box securely. There were safety latches on the boxes to keep them flat at the different heights (Fig. 1). The ramp was placed on a table and was stable.

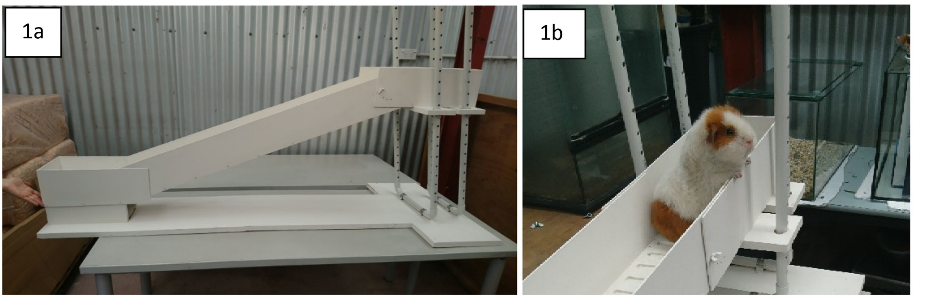
Procedure

Prior to the experiment, a paired stimulus preference assessment was conducted to determine a reinforcer for use in the experiment. This consisted of presenting small samples of greens, carrots, and pellets in pairs to each guinea pig during a single session. There were 12 trials within a session, where each food was paired with every other food on both the right and left side of a plate placed in front of the guinea pig. The food the animal consumed was recorded out of each pair. The choices were rank ordered according to how many times each food was chosen to determine a rank order. The food chosen most often was used as a reinforcer for that guinea pig (see Cameron et al., 2013). Thor and Loki chose greens over other foods and Della and Daffy chose carrots, thus these were provided as reinforcers for reaching the top of the ramp.

The guinea pigs were first habituated to the ramp in short sessions of approximately 5 minutes where they were fed their preferred food. They were offered their entire ration of preferred food and any portion uneaten was given after the session during the afternoon feed in their enclosure. Training began when the guinea pig was placed on the ramp in the horizontal (height 0, slope 0 degrees) position with small portions of their reinforcers spread along the ramp to shape the behavior of moving along the entirety of the ramp. When the guinea pigs started to move as soon as they were placed in the start box, food was placed close to, then only in the finish box. Training was complete when the guinea pig moved to the finish box as soon as they were placed in the start box five times and continued moving. During training, it was observed that the guinea pigs tended to stop in the ramp after five trials. Therefore, this was determined as an appropriate number of trials for a session to see maintained movement in the ramp.

Figure 1

1a. The Custom-Built Ramp Held at a Height of 30 cm with 14.5 Degree Slope. 1b. Della in the Ramp



A trial consisted of movement between the start and finish boxes. Each guinea pig's daily ration of the food was weighed and placed in the finish box. After placement in the start box the guinea pig would start moving. A trial started when the body of the guinea pig moved from the start box to the ramp, indicated by passing a line on the outside of the ramp. The trial ended when the body of the guinea pig had passed another line indicating the end of the ramp and the finish box. Each climb was reinforced with 20 s access to the guinea pig's preferred food. After the session was finished, the remaining food was weighed and put aside to be given at the afternoon feeding time.

The experiment consisted of a series of five trials per day where the height of the ramp was increased by 3 cm from the session before. This is referred to as a *continuous effort condition* (CEC), because the effort required by the animal to climb the ramp was altered but the response to earn a reinforcer remained at a single climb. The guinea pig was given 5 min to complete the trial, or if the guinea pig failed to move at all for 90 s (often due to defecation) it was removed for 2 min as the ramp was wiped clean and the newspaper replaced if required. The trial was repeated. If the guinea pig failed to complete two trials of the same slope, the session for that day was terminated. The same slope was repeated the following day and the experiment concluded if the guinea pig failed to complete another two trials.

An additional condition was completed after the CEC schedule condition. Within this condition, the height of the ramp was increased by 3 cm after each successive climb within a session. We have termed this schedule a *progressive effort condition* (PEC). The PEC was in effect for three sessions. These trials continued until the guinea pig failed to complete two consecutive trials at the same height within the session.

A video camera was set up approximately 1 m away from the ramp and at an angle where the guinea pig's movement past the lines indicating the beginning and end of the ramp was visible. The time to complete the climb was determined by analyzing the video recordings.

Data and Statistical Analysis

The last successful height and slope climbed for each guinea pig in the CEC and PEC conditions were recorded as the break point, and the time to complete each climb was recorded. This was tabulated in Excel™ and statistics (paired *t*-test) were calculated on the break points between conditions using SPSS™.

$$\mathrm{Log}(Q) = \log\left(Q_0\right) + k\left(\mathrm{e}^{-\alpha Q_0 \mathrm{C}} - 1\right) \qquad (1)$$

The exponential model of demand was used to assess the demand for food as ramp height increased. The model was fitted to the trial (climb) completion time as a function of ramp height using nonlinear least squares regression (Hursh & Silberberg, 2008; see Eq. 6). The parameter, C, is the latency at each ramp height. Initial demand (height ramp is 0) is represented by Q_0 and is the y-intercept on the graph. The parameter alpha, α, is a measure of the rate of change in elasticity as ramp height increases. If this value is large it indicates that the guinea pig is taking longer to climb the ramp as a function of ramp height. Both *a* and Q_0 are allowed to vary and are estimated by the regression. The parameter *k* is the range of latencies used to accurately predict the best-fit line using the SOLVER application in Excel. As the range of *k* is large due the differences between guinea pigs climbing the ramp, this value was allowed to vary for individual animals (Cameron et al., 2015).

Results

Across guinea pigs, the break point ranged from height 8 - 13 for the CEC schedule and between height 4 - 12 for the PEC schedule. For individual guinea pigs, the discrepancy between breakpoints under the CEC and PEC schedules was mostly within five heights (Table 1). Across all guinea pigs, the average height reached for the CEC condition was height number 9.75 which was 29.25 cm high and provided a slope of 14.1 degrees, and height number 9 which was 27 cm high and provided a slope of 13.1 degrees for the PEC condition. There were no significant differences between the break points of the PEC and CEC conditions (t [3] = 0.26, p = .811, d = .13).

Overall, the model fitted the data well with VACs of greater than 99% (SE = .0012 - .029; Table 2). In Figures 2 and 3, the trial completion times for each ramp height (with standard error bars) and the best-fit line as derived using Equation 1 and nonlinear least-squares regression are shown. It was expected that as height increased under the CEC and PEC schedules the guinea pigs would slow their ascent indicated by larger *rate of change* or α values. There were significantly higher α values under PEC schedule (M = 0.0036, SD = 0.00081) compared to the CEC schedule (M = 0.0012, SD = 0.0012; t [3] = 4.04, p = .027, d = 2.33). Generally, the guinea pigs maintained or increased their speed as height increased under the CEC schedule, showing inelastic demand for the food, but showed more elastic demand (or slower climbing as height increased) to gain food under the PEC schedule.

The initial demand, that is, latency at height zero, indicates no differences between the CEC and PEC schedules (t [3] = 0.57, p = .611, d = 0.28). According to Table 2, however, initial demand was higher under the PEC schedule for three out of four guinea pigs, indicating that they took longer to climb the ramp at height 0 under the CEC schedule compared to the PEC schedule.

Discussion

This experiment confirmed that guinea pigs can be trained to climb a ramp of increasing slopes to obtain a valued food. Across animals and conditions, there was consistency in the break points. The guinea pigs were faster to climb the ramp when the slope was unchanged within a session (CEC condition), compared to when the slope increased each trial (PEC condition). Furthermore, the demand equation (Hursh & Silberberg, 2008) fitted the data well and described the demand

Table 1

Table of Break Points (Height and Slope at Failure to Climb) for Each Condition

GP	Progression	Break Point	Height (cm)	Slope (degrees)
1 Daffy	CEC	8	24	11.54
	PEC	12	36	17.5
2 Della	CEC	13	39	19.0
	PEC	4	12	5.7
3 Loki	CEC	9	27	13.0
	PEC	11	33	16.0
4 Thor	CEC	9	27	13.0
	PEC	9	27	13.0
Average	CEC	9.75	29.25	14.1
	PEC	9	27	13.0

Note. CEC = continuous effort condition – same height each trial within a session; and PEC = progressive effort condition – increased slope each trial within a session.

Table 2

Parameters as Derived from Equation 1 Fitted Using Nonlinear Least Squares Regression (Eq. 6; Hursh & Silberberg, 2008)

GP	Condition	a	Q_0 Log units (in seconds)	k (in log units)	VAC (%)	SE	df
1 Daffy	CEC	0.0027	0.75 (5.67)	0.469	99.93	0.0011	6
	PEC	0.0045	0.77 (5.90)	0.659	99.86	0.0292	10
2 Della	CEC	0.0016	0.66 (4.61)	0.439	99.90	0.0095	10
	PEC	0.0027	0.66 (4.61)	0.214	99.96	0.0020	2
3 Loki	CEC	0.00003	1.11 (12.81)	0.587	99.98	0.0655	7
	PEC	0.0033	1.46 (29.12)	0.807	99.98	0.0447	7
4 Thor	CEC	0.0004	0.86 (7.24)	0.737	99.90	0.0095	7
	PEC	0.0041	1.44 (27.28)	0.644	99.96	0.0020	7
Average	CEC	0.00007	0.86 (7.24)	0.600	99.95	0.0812	9
	PEC	0.0117	1.24 (17.5)	0.333	99.96	0.0265	9

Note. α, rate of change of elasticity, Q_0, (derived) initial latency (intensity of demand for no effort) in log units and in parentheses the value is given in seconds, k (range of the dependent variable) in log units, the variance accounted for by the model as a percentage, standard error of y and the degrees of freedom.

for food as the response effort required to climb the slope increased.

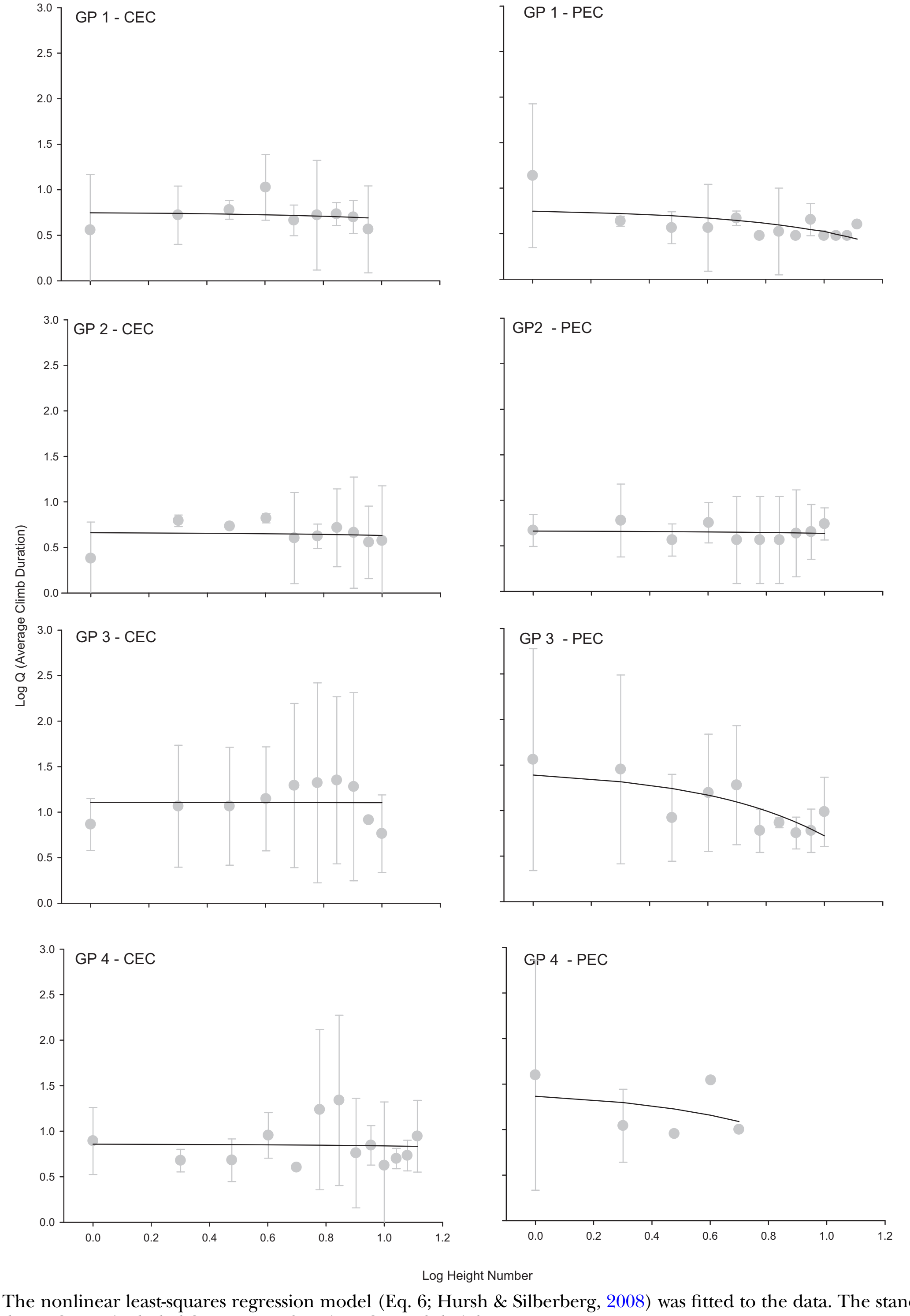
In the current experiment, the guinea pigs maintained similar speeds in moving up the ramp as elevation increased, but all failed to climb at a height greater than 27 cm and slope of 13.0 degrees in both conditions. It is likely that this height and slope represents the upper limit of slopes that guinea pigs will climb to gain food. We also hypothesize that climbing was affected by natural guinea pig foraging behavior and speculate that failure to climb greater slopes may be because, at a greater height and slope, the guinea pigs no longer see the food at the top of the ramp from their position at the bottom.

Guinea pigs in the wild live in burrows or vegetative shelters in groups of approximately 10 animals. However, they generally forage out in the open (Adrian et al., 2005; Cassini & Galante, 1992). As a small prey animal, the guinea pig may be exposed during foraging. Guinea pigs and other herbivores must thus ensure survival by adopting behaviors to mitigate risk from predation (Mcarthur et al., 2014), such as choosing safer food patches and minimizing the time spent at the patch (Brown et al., 1999). In gerbils (*Gerbillus andersoni allenbyi*), when sightlines to predators (from the air or ground) are obscured, the animals spend less time foraging and more time assessing risk, such as looking for possible predators (Embar et al., 2011). In addition, visual assessment of food patches of different shapes affected the position of mice (*Peromyscus polionotus*) in the patch while foraging (Orrock & Danielson, 2005). It is not documented specifically in guinea pigs, but research in foraging of rodents shows that they identify potential risks and allocate behavior to obtaining food based on what they can identify as safe, although cavies forage in groups, with larger groups travelling greater distances from the den (Cassini, 1991). Attributing risk mitigation behaviors to guinea pigs as both a rodent and prey species suggests that in our experiment, the food at the end of the ramp may have been obscured at the greater slopes due to the view from the horizontal start to finish boxes. In turn, this may have caused the guinea pigs to perceive risk and stay in the start box and not proceed up the ramp. Furthermore, in the experiment the guinea pig travelled up the ramp alone. Although the guinea pigs received food at the top of the ramp after every climb, learning this may not have been enough to overcome their inability to assess risk by sighting the food and climb the ramp. As the first paper to speculate that visual confirmation of food availability might be important for guinea pigs in demand experiments, we suggest that this factor be considered in future experimentation.

Considering the first aim of our study, the utility of ramps in enclosures of pets to increase the opportunity for exercise, the authors could find no literature related to the benefits of including ramps in cages except for the recommendation by the New Zealand RSPCA (RNZSPA, 2021) for multilevel cages to increase space. There was no empirical basis for the suggestion of a ramp of no more

Figure 2

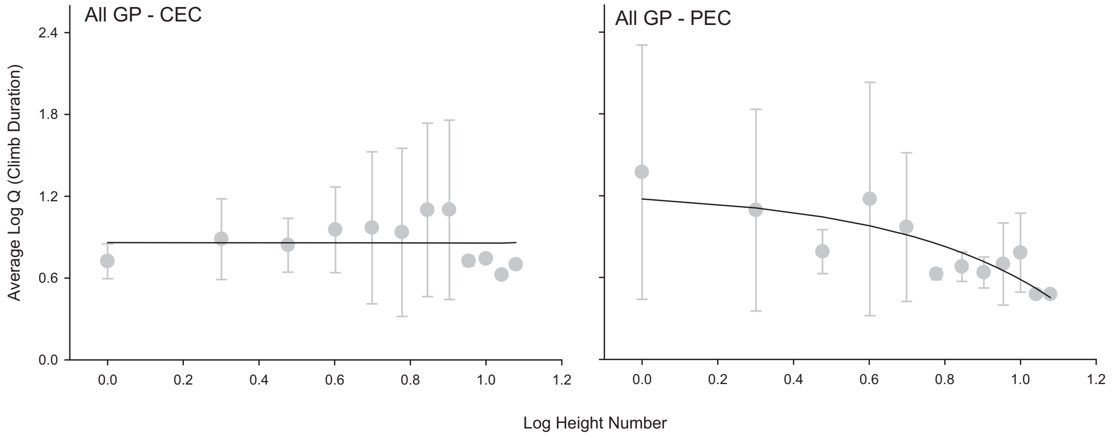
Average Log Q of the Climb Duration as a Function of Log Height Number for Each Condition for Guinea Pigs 1-4



Note. The nonlinear least-squares regression model (Eq. 6; Hursh & Silberberg, 2008) was fitted to the data. The standard error bars of y are included for average durations for each height.

Figure 3

Average Log Q of the Climb Duration as a Function of Log Height Number



Note. The standard error bars of the mean are included for average consumption values when at least three animals contributed. The VAC and SE of the function as per the nonlinear least-squares regression model (Eq. 6; Hursh & Silberberg, 2008).

than 30 degrees (e.g., theguineapigforum.co.uk), which is double the gradient that we observed the guinea pigs consistently failing to climb when rewarded with valued food items. It is important that guinea pig owners are encouraged to promote exercise and foraging opportunities for their cavies, as well as to increase the size of enclosures. However, it is important that these efforts do not also have unintended negative consequences. Based on the results of our study, if owners were to follow the suggested slope of up to 30 degrees, the ramp may act as a barrier to resources on the enclosure's second level, as guinea pigs may not be willing to consistently climb the ramp. Furthermore, in the very sparse literature on foraging in guinea pigs, the animals tend to live and forage in flat areas, such as along railway lines and fields (Cassini & Galante, 1992). Climbing such a ramp may therefore contribute to physical harm, considering that guinea pigs do not have the paw structure to grasp rungs or grooves on a steep ramp (Barbera et al., 2019).

The second aim of the study was to measure the suitability of ramp climbing as a method to measure demand for commodities, as theoretically, the time to complete the climb as slope increases may be lower for more valued commodities. To trial the use of ramp climbing, the food for each guinea pig remained the same in the experiment, with time to complete the climb measured as only the slope was increased. It was predicted that as the ramp increased in height and slope, the time to complete the climb would also increase. Under the CEC condition (the same height and slope in a session of five trials) the guinea pigs defended the increase in height by climbing the ramp with little difference in completion time. Under the PEC condition, however, where height increased each trial within a session, the time to complete the climb increased as height increased. This increase may have been due to fatigue, with the guinea pigs completing as many trips up the ramp as possible before failure, resulting in more trips within a session than in the CEC condition. However, the increase in time to complete the climb in the PEC condition compared to the CEC condition might also reflect the frequent changes in slope in the PEC condition, rather than the number of trials. For example, Cameron et al. (2016) found that possums showed higher break points, but elastic and slower rates of responding when the response requirement doubled each trial, compared to smaller break points and inelastic, higher rates of responding when the response requirement increased by five responses each trial. The authors concluded that the size of the "jump" each trial affected the pattern of responding by the possums. Similarly, the guinea pigs in the current study showed sensitivity to the change in elevation between the CEC and PEC conditions, with more consistent and inelastic patterns of behavior in the CEC condition versus the PEC condition.

There were limitations to the interpretation of our data, such as the sample size. Due to the nature of the Unitec Small Animal Unit, where animals are housed for students to practice handling, only four guinea pigs were onsite and available for testing at the time of the experiment. Thus, a replication of the experiment with a larger sample size is planned in order to test our hypothesis that an instinctual survival mechanism affected movement up the ramp. Moreover, in the current study the PEC condition was conducted post-hoc after the CEC condition for all subjects. We would therefore also aim to counterbalance the CEC and PEC conditions in future experiments. Additionally, we would also aim to increase the number of ECE trials within a session, as guinea pigs were clearly capable of completing more than five in a session.

Measuring demand for different foods and commodities for animals can indicate valued options for inclusion in an animal's environment or for use as a reinforcer. In future, the use of slope as a measure of effort could therefore be used to measure preferences for guinea pigs. However, a method, such as the use of an angled mirror above the food, or the presence of a conspecific at the top of the ramp needs to be trialled to mitigate confounding the assessment of demand. These additions may ensure continued climbing of the ramp to reach a true failure point, which is necessary in order to compare the effort a guinea pig will exert to obtain a valued commodity.

In conclusion, the results confirmed that guinea pigs are able to climb ramps of heights up to 30 cm high at a slope of nearly 14 degrees to obtain food and will also defend the increase in slope by increasing their speed. Additionally, a potentially confounding effect of foraging behavior, whereby guinea pigs may aim to minimize the risks associated with foraging in the open or alone, may need to be controlled for when designing future experiments. Overall, the study evidenced that ramps can be used to measure demand for commodities in guinea pigs. Through such an application, insight can be gained into the resources on which guinea pigs place high value and should therefore be included in enclosures to increase housing capacity and exercise and foraging opportunities to enhance cavy welfare.

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