Faculty of Science

Category discrimination in a species of rodent

Perceptual concept learning in the *Octodon degus*

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ABSTRACT
Forming concepts or categories is, according to some researchers, a fundamental way of organizing earlier experiences. By forming categories, animals are able to be quicker in their responses towards novel food, prey and predators. This *perceptual concept learning* is thought to function as a vital part of an animal's understanding and capability to learn from, and predict, its environment. For instance, when a small rodent like the degu (*Octodon degus*) encounters a large flying animal (e.g. an owl) it would prove more effective to transfer earlier experience about other large flying animals (e.g. hawks) instead of behaving as if encountering a completely novel stimulus.

This study tests the hypothesis that the degus subjected to the experiment are capable of forming perceptual concepts, and that this ability extends to non-natural categories (i.e. objects not found in the natural habitat of the wild degu). In this case, by being able to discriminate triangles from other geometric shapes. Four adult degus were initiated in the experiment and trained using positive reinforcement. Two individuals were finally passed on to testing. The test was divided into four main sessions and consisted in choosing (by biting or scratching) the triangle out of sets of two or three geometric shapes. To rule out mere associative learning, the degus were trained and tested using different colors, materials and sizes.

The results show that, at least, one of the tested individuals was able to discriminate triangles from other geometric shapes, and thus to form a perceptual concept. The results also suggest that the ability to form perceptual categories in the tested degus goes beyond a limited "natural" set of categories.

ABSTRAKT
Att bilda koncept eller kategorier är enligt en del forskare, ett grundläggande sätt att sortera tidigare erfarenheter. Genom att bilda kategorier kan djur vara snabbare i sina responser gentemot nya typer av föda, byten och rovdjur. Denna så kallade perceptuella koncept-inlärning är därför tänkt att fungera som en nödvändig komponent i ett djurs förståelse och förmåga att lära från, och förutsäga, sin omgivning. När t ex en liten gnagare, som degun, stöter på ett stort flygande djur (som en uggla) vore det mer effektivt att överföra tidigare erfarenheter om andra stora flygande djur (som hökar) istället för att bete sig som om det rörde sig om ett helt ny och isolerad upplevelse.

I den här studien prövas hypotesen att degun är kapabel att bilda sig perceptuella koncept, och att denna förmåga sträcker sig till artificiella kategorier (dvs. sådana saker som inte förekommer i den vilda deguns habitat), i det här fallet, genom att kunna skilja på trianglar och andra geometriska former. Fyra vuxna deguer initierades i studien och tränades genom positiv förstärkning. Två individer ingick slutligen i försöket. Försökssituationen var indelad i fyra huvudsakliga sessioner och bestod i att degun skulle välja (genom att gnaga eller krafsa på) triangeln i set om två eller tre geometriska former. För att utesluta förekomst av ren associativ inlärning, tränades och testades deguerna på flera olika färger, material och storlekar.

Resultaten visar att åtminstone en av deguerna som testades kunde skilja på trianglar och andra geometriska former, och därmed bilda sig ett perceptuellt koncept. Resultaten pekar också på att förmågan att bilda perceptuella kategorier hos de testade deguerna rör sig utanför en begränsad och fixerad uppsättning ”naturliga” kategorier.

KEY WORDS: Degu; Degus; Concept formation; Concept learning; Perceptual concept learning; Category formation; Category learning.

INTRODUCTION

Forming concepts or categories is, according to some researchers, a fundamental way of organizing earlier experiences. By forming categories, animals can be quicker in their responses towards novel food, prey and predators. One type of category learning is called *perceptual concept learning* (see Zentall et al., 2008) and is thought to function as a vital part of an animal's understanding and capability to learn from, and predict, its environment (Zentall et al., 2008). The ability to form concepts or categories of perceptual stimuli makes it possible to transfer and generalize new stimuli to past experience. For instance, when a small rodent like the degu (*Octodon degus*) encounters a large flying animal (e.g. an owl) it would prove more effective to transfer earlier experience about other large flying animals (e.g. hawks). In this case by fleeing down a burrow instead of behaving as if encountering a completely novel stimulus. Experiments indicating category formation in animals include dogs (Kaminski, et al., 2004; Pilley & Reid, 2011), dolphins (Herman, Pack & Wood, 1994), parrots (Pepperberg, 1983; Pepperberg, 1987) and pigeons (Bhatt et al., 1988), among others.

Although the ability to form mental categories of perceptual stimuli, like vision or sound, has been shown in many studies of animal cognition, the subject is not wholly uncontroversial. Some researchers (Premack, 1976) maintain that indications of category formation might, in most cases, be ascribed to classical conditioning (Pearce, 2008). Another issue regarding concept formation is whether the ability to form categories should be ascribed to some limited function restricted to natural categories or to a more "open" way of organizing new stimuli into learned categories. All of the mentioned studies suggest that the ability to form concepts is a rather open cognitive function, flexible enough to enable the animals to form categories that they would not seem naturally adapted to (like verbs, human phonemes, geometric shapes etc.).

Animals subject to experiments in the field of comparative cognition have traditionally been primates, and more recently corvids (Shettleworth, 2009). In recent years though, two published studies of the degu have attracted interest: one being the first observation of tool use in a non-primate and non-bird (Okanoya et al., 2008), and the other an observation of spontaneous construction of "Chinese boxes" (Tokimoto & Okanoya, 2004). In light of these, rather spectacular, findings it would be of interest to test the degu's ability to form mental concepts.

The degu is an active, social and semi-burrow dwelling rodent native to central Chile (Woods & Boraker, 1975). It lives in small family groups, with occasional larger gatherings into colonies (Woods & Boraker, 1975). The diurnal degu is equipped with good vision, and is able to notice the urine of con-specifics based on reflection of UV-light and also has UV-reflecting fur on its belly (Chávez et al., 2003). However, like most other land-dwelling placental mammals, the degu has dichromatic vision (Jacobs et al., 2003) making it unable to discriminate between similar shades of red and green.

This study aims to test the hypothesis that the degu is able to form perceptual concepts. Here in the form of a certain geometric shape – the triangle. The following prediction is tested:

- The degu is able to discriminate triangles from other geometric shapes.

Because of the small sample size used, the study is to be regarded as a pilot experiment.

MATERIALS & METHODS

General:

The test was designed to determine whether the degus were able to choose a novel triangle from a random set of geometric shapes. The shapes were simultaneously presented and placed in a randomly selected order (left-middle-right).

Animals:

Four experimentally naïve adult female degus were initiated in the experiment. They will henceforth be referred to as individuals A, B, C and D. Their age ranged from 1 to 2 years old, with A being the oldest and B the youngest. Individuals A and B are mother and daughter whilst C and D are probably siblings. They were kept in an enriched wire cage (L:80 x W:75 x H:161 cm). The cage contained four hay-racks, one wooden nest, one cardboard nest, nesting material, two water cups, two sand baths and comprised of two plastic floors and a third floor made of fabric. The temperature varied from 19 to 21°C and the night-day-cycle varied with the set and rise of the sun. All four degus have unknown backgrounds. Degus C and D were picked up at a veterinary clinic and A and B adopted from a temporary home. They have been kept together since 3 months prior to training. At arrival, all four degus had injured tails (Vanderlip & Earle-Bridges, 2001), which was more pronounced in degu C and D (i.e. shorter), and they were distinctively more reserved than the other two. The degus were not subjected to food deprivation during the training period, instead they had free access to hay and were also fed a small amount of pellets each day. Individual A suffered from weight loss during a few days of the training period and was therefore fed a larger amount of pellets 1-2 times daily.

Training:

Triangles, differing in size, material and color, were used as the conditioned stimuli. The materials used were paper, cardboard and wellpapp. The unconditioned stimulus (i.e. the reward) comprised of one chip of rolled oats. The training area consisted of a separate room with small wooden table placed with one of its shorter ends against a white plaster wall. The geometric shapes were set up on the wall with Blu-Tack (an adhesive material). Training consisted of approximately 15 minutes, 5-7 times a week for a period of 21 days. The method used for training was a simple kind of positive reinforcement (Pearce, 2008). Each session comprised of about 20-30 trials and each degu was trained individually. The degus were taught to mark their choice of geometric shape by putting their paws on, scratching or biting one of the shapes. This, to avoid the difficulties of noting the chosen shape by mere head direction or sniffing. The ability to mark the chosen shape in a proper way functioned as a basal criterion for further training. A clicker was used to ease the conditioning procedure (ibid.). Each training session was divided into several trials. Each trial started with the degu being put down on the short end farthest from the wall. The start of a trial was marked with a verbal command. Regardless of whether the degu had managed to mark the triangle or not, the individual was lifted up a few seconds between every new trial. During this short period of time, the triplet of geometric shapes was rearranged.

The training comprised of five phases:

A: The first phase consisted of habituating the degus to the noise of the clicker and to associate the clicks with reward. All four individuals managed to learn this in one session of about 10 minutes. However, one individual in particular, C, showed signs of being uncomfortable with the high clicks. This could be observed by a simultaneous startle response upon clicking.

B: The next step of the training procedure consisted of habituating the degus to the training table. This was done in one trial consisting of approximately 15 minutes.

C: The initial step of the conditioning consisted of establishing an association between triangles and reward. All but individual C managed to learn this in one session of approximately 15 minutes. Individual C had to be additionally trained.

D: In the next sessions the degus were conditioned to touch, scratch or bite the triangle to get a reward. This to ensure a less dubious way of marking, e.g. by sniffing or head direction. Individual C did not manage to learn this as fast as the other three, and due to time limitations, she was removed from further training and the experiment.

E: The fifth and last phase of training consisted of placing the triangle along with two squares in different sets of order (Fig. 1). The reason to put only squares along with the triangle at this point was to ensure that the degus learnt the difference between these, relatively, similar "pointy" shapes, before moving on to test triplets containing circles. This step lasted for 12 days. The whole training period was finished after 21 days, a total of 16 hours and 12 minutes, including a total of 1945 trials (estimated 2/minute). Because of increasing signs of stress upon training, individual D, was removed from further training and testing.

Figure 1: Degu A marks the triangle by scratching, hears the "click", and heads for her reward.

Test:

The test comprised of choosing triangles out of sets of (two or three) novel geometric shapes made of colored paper or a thicker cardboard (only used for test 2). These were placed in a random order from left-middle-right. The order was altered before each trial. The shapes used during the test were different both in being newly made and by color from the ones used during the training period. This, not only to function as novel *visual* stimuli, but also to prevent *olfactory* association. A new set of shapes was used for each session and each individual degu. The geometric shapes used during testing comprised of triangles, squares and circles. These were arranged to make up four different test session (where the first and fourth were made up of two sub-sessions). The test was carried out in the same room and on the same table as the training.

To see whether the degus chose the triangle more often, the frequency of marked geometric shape for each session is presented as bar charts (Fig.6-10). Because of the small number of tested animals, Chi2-tests were conducted for the results of each individual separately.

Test 1: Comprised of two sub-session of 15 trials each (30 trials in total). Each degu was tested on a novel triplet (not used and new color) each session and sub-session.
The first test was aimed to test the degus' ability to discriminate between two different shapes (Fig. 2).

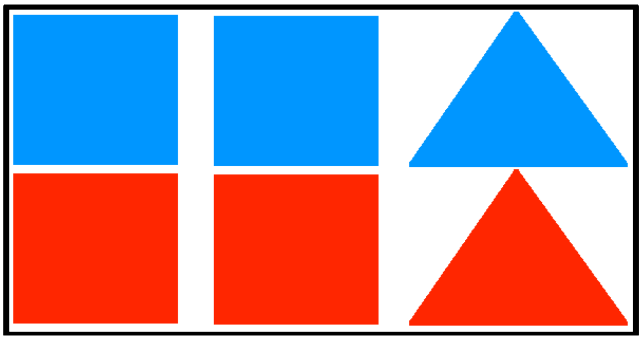

Figure 2. The two triplets of shapes used in the two sub-sessions of test 1.

Test 2: The second test comprised of one session of 15 trials. It aimed to rule out the possibility of a mere associative learning (Fig. 3).

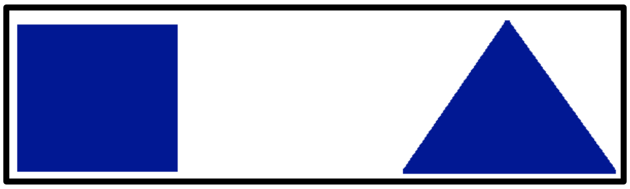

Figure 3. The two shapes used for test 2.

Test 3: The aim of the third test-session was to test the degus' ability to choose between three different geometric shapes (Fig. 4). The session consisted of 15 trials.

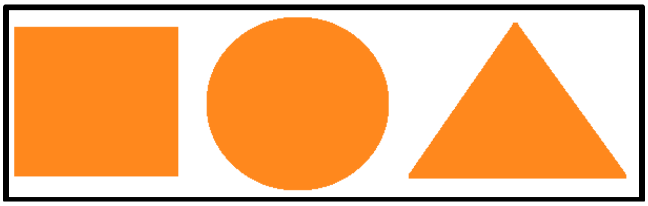

Figure 4. The triplet of shapes used for test 3.

Test 4: The fourth test comprised of two sub-sessions with 10 trials in each.
These sessions aimed to test the degus' ability to discriminate between shapes regardless of size (Fig. 5).

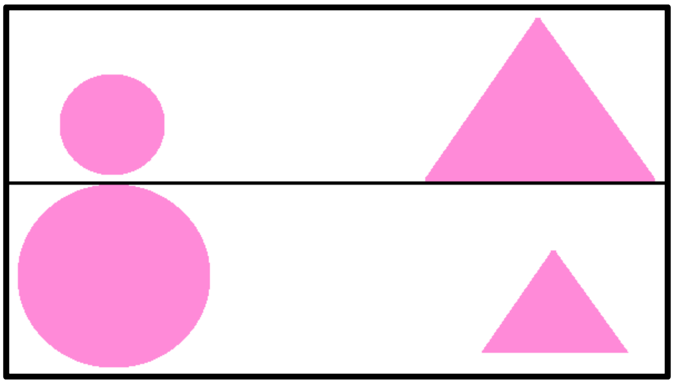

Figure 5. The two set ups of shapes used in the two sub-sessions of test 4.

RESULTS

Are degus A and B able to discriminate triangles from other geometric shapes?
The results are shown in the following figures:

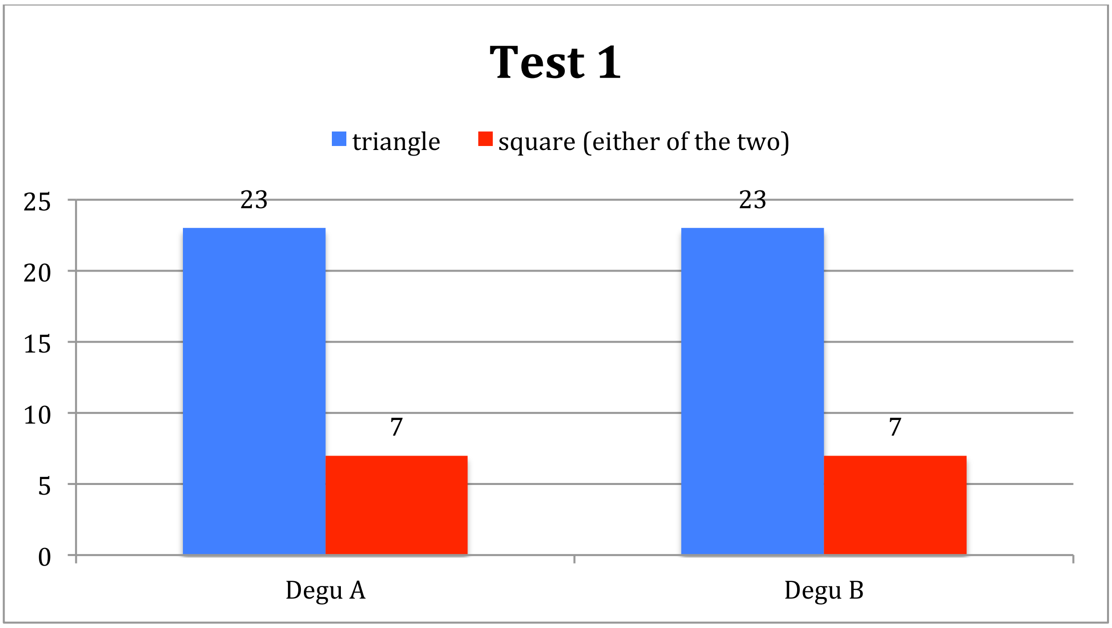

Figure 6. Frequency of chosen geometric shapes in test 1.

In test 1 (Fig. 6) the bar chart depicts the frequency of the squares as one bar. However, they did in fact constitute two separate choices. Because of this, and because of non-existent data on individual squares, the Chi2-test was conducted using the least favorable frequency (3,5). The results for these sessions were highly significant: Chi2 = 25,4 with df = 2, p < 0,001, which shows that both degus managed to discriminate the triangle when presented with two squares. Both degus initially chose the correct shape, i.e the triangle.

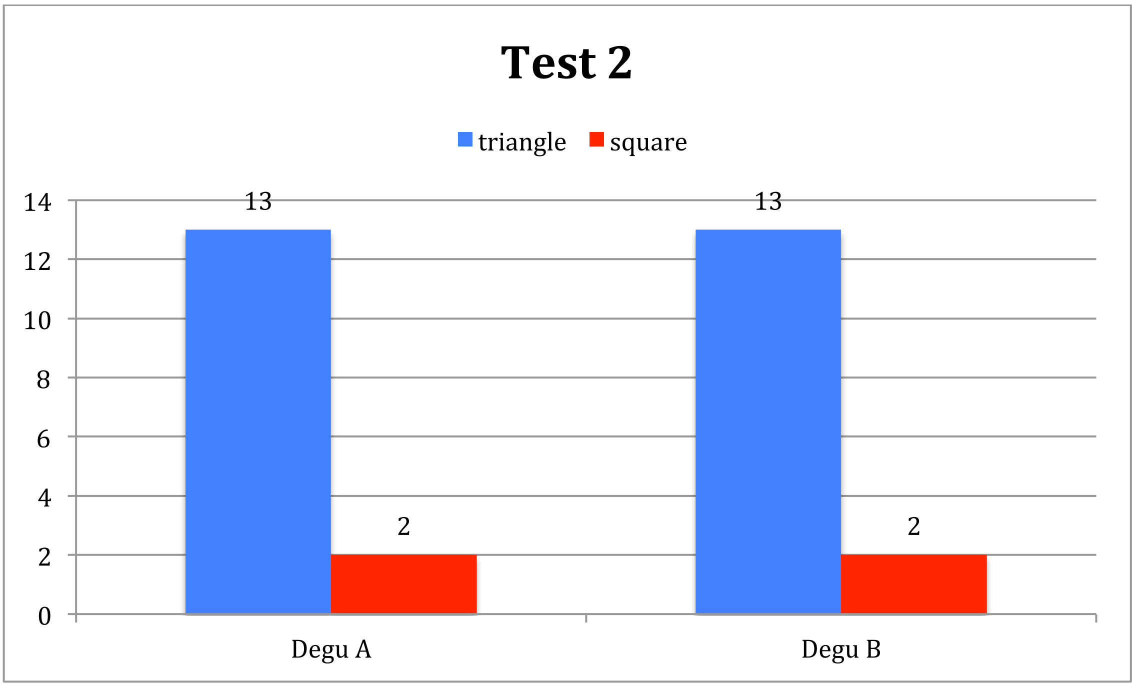

Figure 7. Frequency of chosen geometric shapes in test 2.

Similarly, in test 2, the results suggest that the degus were able to choose the triangle when presented in sets with only *one* of each geometric shape. The results for these sessions were significant: Chi2 = 8.1 with df = 1, $p < 0.01$. As in test 1, both degus chose the triangle on their initial trial.

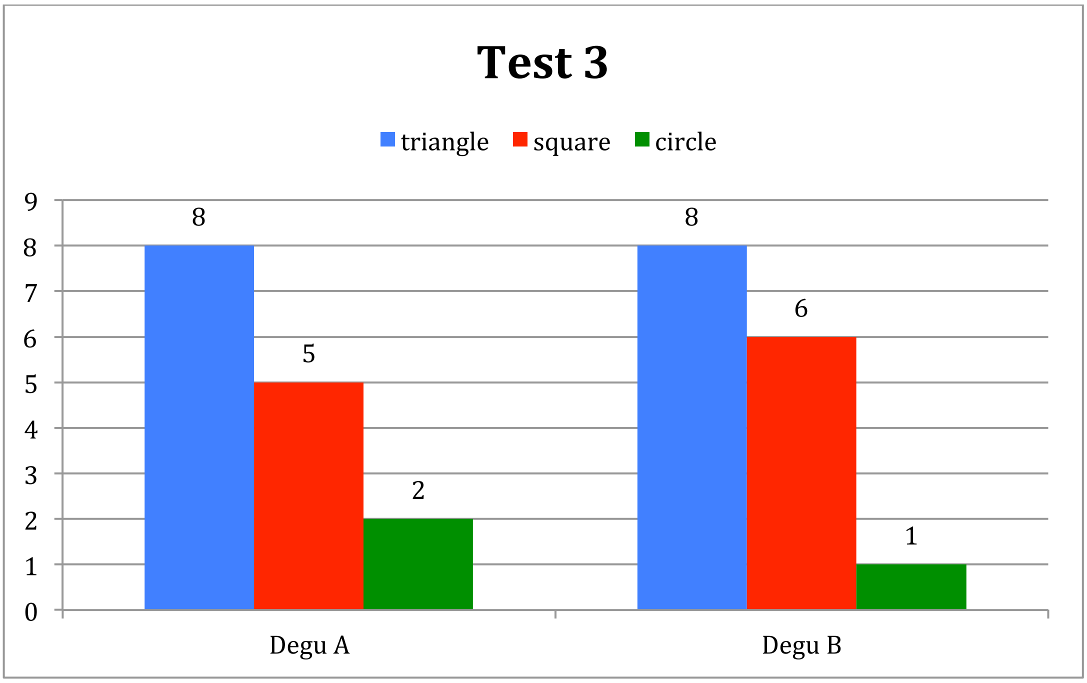

Figure 8. Frequency of chosen geometric shapes in test 3.

Further, degus A and B were not able to discriminate triangles when accompanied with both a square and a circle (Fig. 8): Chi2 = 3.6 and 5.2 with df = 2, $p > 0.05$. This was thus one of the two main focuses of test 4 (Fig. 9 & 10). Another inquiry was to test the possibility that the significant results of test 1 (Fig. 6) and 2 (Fig. 7) were due to size-association.

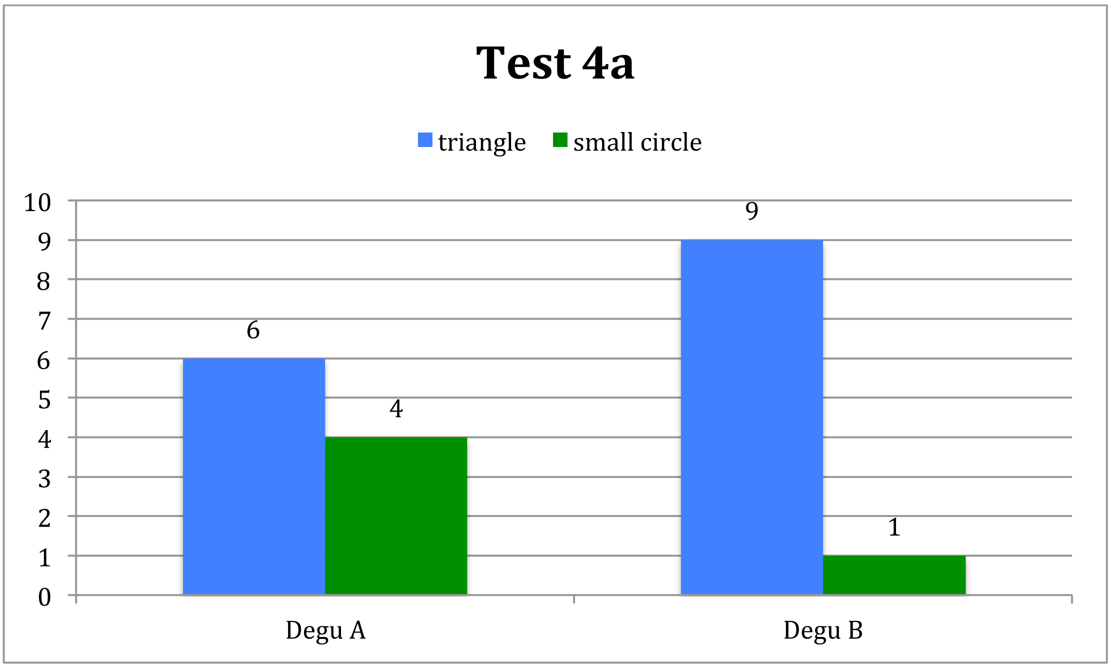

Figure 9. Frequency of chosen geometric shapes in test 4a.

The results for the first session of test 4 were not significant for degu A: Chi2 = 0.4 with df = 1, $p > 0.05$, but significant for degu B: Chi2 = 6.4 with df = 1, $p < 0.05$.

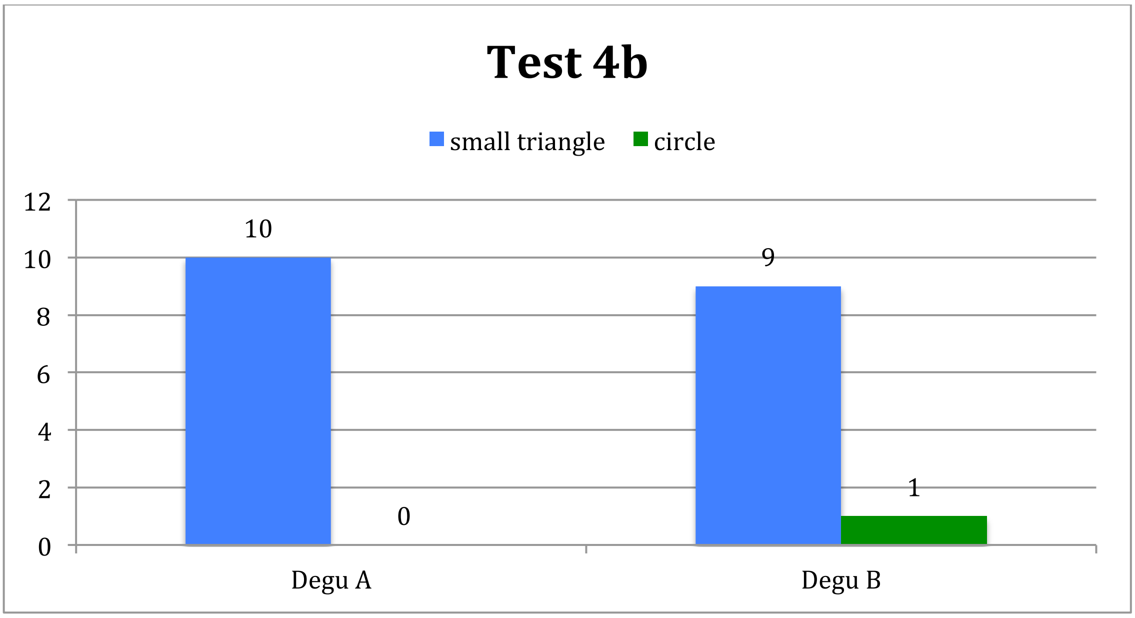

Figure 10. Frequency of chosen geometric shapes in test 4b.

The results for the second session of test 4 were significant for degu A: Chi2 = 10 with df = 1, $p < 0.01$, as well as for degu B: Chi2 = 6.4 with df = 1, $p < 0.05$.

DISCUSSION

Are degu A and B able to learn conceptually?

There seems to be a number of factors favoring a positive answer: The results for test 1 speak against the possibility of associative learning. This, both because the triplets were newly made for each session and because no color-cues were possible. However, because the triplets in both sub-sessions always contained *two* squares as opposed to *one* triangle, one might rise the question that the discriminatory ability could have been based on mere quantitative-association, i.e. that the shape of the lesser number was associated with reward. If there actually is a discriminatory ability connected to the triangular shape, as suggested in Fig. 6, one would thus expect the degus to be able to choose the triangle even when there is no quantitative difference between the presented shapes. This was thus the aim of test 2, and the significant results rule out the possibility that the results for test 1 were the consequence of quantitative-association.

How should one interpret and explain the results of test 3 (Fig. 8)? Do they speak against the discriminatory ability of the degus? Because of the highly significant results of earlier tests, a more elaborate theory appears to be needed to explain the discordance of these results, than mere coincidence or inability. The results for test 3 show that the degus mainly confused the triangle with the square. Moreover, this was the first test where degus A and B both initially chose the wrong shape. What could have made this setup so different from earlier ones that neither degu managed a significant result? The obvious answer appears to be the introduction of the circle. There seems to be one probable explanation why the inclusion of a circle might infer in such a dramatic way with the discriminatory ability of the animals: the circular shape of the circle decreases the *contrast* between the shapes of the triangle and the square, so that these two rather "pointy" geometric shapes appear to be more similar.

To investigate such a theory, one needs to make up a session containing circles and triangles. This was the aim of test 4. The total surface area of the squares used in the experiment was larger than the surface area of the triangles. Can the degus have simply learned to choose the shape with the smallest surface area? The results for tests 4a and 4b (Fig. 9 and 10) speak against such an explanation. At least degu B managed to discriminate the triangle regardless of whether the accompanied circle was larger or smaller. Also, the results suggest that the poor results of test 3 (Fig. 8) were due to an effect of lessened contrast rather than an actual inability to discriminate triangles from squares. The poorer results of degu A in test 4a (Fig. 9) might be due to perseveration (Everall, 1935) to a chosen strategy. During the training period the tendency to stick to a shape, even though it did not generate any reward, was seen on a number of occasions for all four degus. This behavior was accompanied with signs of frustration, like biting or scratching the shapes more frequently. The fact that degu B, in fact, managed to discriminate the triangle from the circle in test 4b speaks in favor of such an explanation.

The results as a whole bore out the prediction: the degus (at least degu B and less convincingly degu A) managed to discriminate triangles from other geometric shapes, and this regardless of color, size or the two materials used. Because this was learned in a fashion where the mere triangular shape was the lowest common denominator associated with the food reward, one might quite confidently put forward the interpretation that the results were due to perceptual concept learning. The triangle was thus likely learned as a visual category, making it possible for the degus to sort out irrelevant visual stimuli like color, size and material.

Also, the results suggest that the degus' ability to form such concepts is not limited to "natural" objects, like plants, predators or social categories. Geometric shapes are most likely not part of the natural habitat of the degu, and thus form a rather artificial set of stimuli. Even so, the results indicate that the cognitive ability to form perceptual concepts is not limited to such natural categories (as indicated by former studies of category learning like Kaminski et al., 2004; Bhatt et al., 1988). Instead, it appears to be a rather open and flexible function allowing the animal to actively adapt to its environment.

Further, more extensive, study, both regarding the number of animals and the types of tests conducted, would likely provide more relevant results. This, both regarding the species as a whole, but also to test a wider range of conceptual abilities and to test non-visual stimuli. For instance, perceptual categories based on auditive stimuli, have successfully been taught to animals like chinchillas (Kuhl & Miller, 1975), and dogs (Kaminski, et al., 2004; Pilley & Reid, 2011).

CONCLUSION

In conclusion, the results indicate that degu B, and less convincingly, degu A, managed to form a perceptual concept of triangles. This, in contrast to mere stimulus-association. Also, like prior experiments the results suggest that concept formation might be an "open" cognitive function. This in contrast to being hard wired to a limited "natural" set of objects.

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