UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO
POSGRADO EN CIENCIAS BIOLÓGICAS
INSTITUTO DE INVESTIGACIONES BIOMÉDICAS
ECOLOGÍA

ELECCIÓN DE CANTIDAD Y TAMAÑO DE PRESAS EN GATO DOMÉSTICO (*Felis silvestris catus*)

TESIS

POR ARTÍCULO CIENTÍFICO

REVISITING MORE OR LESS: INFLUENCE OF NUMEROSITY AND SIZE ON PREY CHOICE IN THE DOMESTIC CAT

QUE PARA OPTAR POR EL GRADO DE:

MAESTRA EN CIENCIAS BIOLÓGICAS

PRESENTA:

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Ciudad de México. Octubre 2019

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OFICIO CPCB/1054/2019

Asunto : Oficio de Jurado para Examen de Grado.

M. en C. Ivonne Ramírez Wence
Directora General de Administración Escolar, UNAM.
P r e s e n t e

Me permito informar a usted que en la reunión ordinaria del Comité Académico del Posgrado en Ciencias Biológicas, celebrada el día 26 de agosto del 2019 se aprobó el siguiente jurado para el examen de grado de MAESTRA EN CIENCIAS BIOLÓGICAS en el campo de conocimiento de Ecología del (la) alumno(a) CHACHA OLALDE JIMENA con número de cuenta 302861154 por la modalidad de graduac ión de tesis por artículo científico, con la tesis titulada : "Elección de cantidad y tamaño de presas en gato doméstico *(Fe/is silvestris catus)"*, producto del proyecto realizado en la maestria que lleva por titulo "Elección de cantidad y tamaño de presas en gato doméstico *(Fe/is Si/vestris* catus)" ambos realizados bajo la dirección de la Dra. Robyn Elizabeth Hudson, quedando integrado de la siguiente manera:

Presidente:	DR. CARLOS RAFAEL CORDERO MACEDO
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Suplente:	DRA. MORELIA CAMACHO CERVANTES

Sin otro particular, me es grato enviarle un cordial saludo.

A T E N T A M E N T E
"POR MI RAZA HABLARA EL ESPÍRITU"
Ciudad Universitaria, Cd. Mx., a 1 de octubre de 2019

DR. ADOLFO GERARDO NAVARRO SIGÜENZA
COORDINADOR DEL PROGRAMA

POSGRADO EN CIENCIAS BIOLOGICAS
COORDINACIÓN

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AGRADECIMIENTOS PERSONALES

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A los dueños de los gatos que participaron en los experimentos. Gracias por abrirnos sus puertas y tenernos la confianza de observar a sus gatos.

Gracias a mi familia y amigos por siempre acompañarme e inspirarme.

ÍNDICE

RESUMEN

La discriminación cuantitativa tiene valor adaptativo para una gran variedad de especies animales en un amplio rango de contextos. En estudios previos se ha entrenado a gatos domésticos para que discriminen entre diferentes números de puntos y también se ha demostrado que pueden elegir espontáneamente entre diferentes números y tamaños de porciones de alimento. En el presente estudio investigamos la discriminación cuantitativa del gato doméstico en un contexto naturalista de potencial depredación y elección espontánea de presas mediante dos experimentos en los que participaron 24 gatos adultos. En el Experimento 1 le presentamos a cada gato dos opciones simultaneas con diferentes números de presas vivas (1 ratón blanco vs 3 ratones blancos), y en el Experimento 2 con dos opciones simultaneas de presas vivas de diferentes tamaños (1 ratón blanco vs 1 rata blanca). Los experimentos se realizaron en una sesión semanal durante 6 semanas y repetimos cada experimento 6 veces con cada individuo (2 veces por sesión); la mitad de los gatos inició con el Experimento 1 y después el Experimento 2 y la otra mitad a la inversa. En el Experimento 1 los gatos eligieron con mayor frecuencia el mayor número de presas (3 ratones) y en el Experimento 2 eligieron con mayor frecuencia la presa de menor tamaño (1 ratón). Los gatos mostraron diferencias individuales que fueron repetibles en su elección y en las conductas registradas durante las pruebas. Concluimos que los gatos domésticos discriminan espontáneamente entre diferentes números y tamaños de presas potenciales y que hacen una elección de valor adaptativo para un carnívoro obligado que es también un cazador solitario. Además, muestran complejos niveles de análisis costo-beneficio en este contexto, lo que nos hace cuestionar la noción de que más es necesariamente mejor.

ABSTRACT

Quantity discrimination is of adaptive relevance in a wide range of contexts and across a wide range of animal species. Trained domestic cats can discriminate between different numbers of dots, and we have shown that they also spontaneously choose between different numbers and sizes of food balls. In the present study we performed two experiments with 24 adult cats to investigate spontaneous quantity discrimination in the more naturalistic context of potential predation. In Experiment 1 we presented each cat with the simultaneous choice between a different number of live prey (1 white mouse vs. 3 white mice), and in Experiment 2 with the simultaneous choice between live prey of different size (1 white mouse vs. 1 white rat). We repeated each experiment six times across six weeks, testing half the cats first in Experiment 1 and then in Experiment 2, and the other half in the reverse order. In Experiment 1 the cats more often chose the larger number of small prey (3 mice), and in Experiment 2 more often the small size prey (a mouse). They also showed repeatable individual differences in the choices they made and in the performance of associated predation-like behaviours. We conclude that domestic cats spontaneously discriminate between the number and size of potential prey in a way that can be interpreted as adaptive for a lone-hunting, obligate carnivore, and show complex levels of cost-benefit analysis, calling into question the notion that bigger is necessarily better.

1. INTRODUCCIÓN

1.1 Discriminación cuantitativa

Los animales se enfrentan diariamente a situaciones en las que deben hacer discriminaciones de cantidades discretas y continuas en un amplio rango de contextos como la adquisición de alimento, la estimación de la fuerza de oponentes en encuentros agresivos, la evasión de depredadores, y la elección de grupos con la proporción de sexos más ventajosa para aparearse (Agrillo & Bisazza 2014; Benson-Amram et al. 2018). La discriminación cuantitativa es importante en la toma de decisiones y puede contribuir al aumento de la adecuación de los individuos, por lo que debería ser favorecida por la selección natural (Nieder 2018; Skorupski et al. 2018). Numerosos estudios han mostrado que un gran número de especies además de humanos tienen la capacidad de discriminar entre diferentes números y tamaños (revisado por Agrillo & Bisazza 2014). Por ejemplo, el gorgojo del arroz dedica más tiempo a cortejar y aparearse con una hembra conforme aumenta el número de machos en el grupo (Flay et al. 2009), el pez mosquito es capaz de elegir el grupo social más grande solamente tomando en cuenta información numérica (Dadda et al. 2009), salamandras rojas eligen la mayor cantidad de moscas de la fruta (Uller et al. 2003), ranas arborícolas eligen microhábitat discriminando cantidades continuas y discretas de pasto (Lucon-Xiccato et al. 2018), la focha americana cuenta sus propios huevos y rechaza los ajenos, evitando parasitismo (Lyon 2003), grupos de leonas adultas evalúan situaciones de conflicto basadas en la cantidad de rugidos que escuchan en el grupo de oponentes (McComb et al. 1994).

La numerosidad puede ser evaluada desde varias perspectivas, como la superficie total de área, la cantidad discreta, el volumen ocupado o la densidad en que se arregla. Se han planteado dos mecanismos principales mediante los cuáles los animales pueden discriminar cantidades. Uno es el

modelo del objeto acumulado con el que se representan cantidades pequeñas (hasta 3 o 4) exactas y en el que cada objeto de un conjunto es representado con un símbolo, y el otro es el sistema numérico aproximado que representa cantidades mayores y quizá también pequeñas de una manera aproximada, de magnitud continua, no precisa (Benson-Amram et al. 2018). Además, diferencias inter e intra-específicas en la discriminación cuantitativa reflejan la manera en que las especies han evolucionado y cómo se adaptan cognitivamente a diferentes nichos ecológicos y estilos de vida (Sunquist & Sunquist 1989; Mettke‑Hofmann 2014; Nieder 2018).

Dos formas en las que se ha evaluado la discriminación cuantitativa en diferentes especies son la de elección espontánea y por entrenamiento. En las pruebas de elección espontánea, a los sujetos de estudio se les da a elegir entre dos estímulos biológicamente relevantes que difieren en numerosidad o volumen; en las pruebas por entrenamiento, a los individuos se les enseña a elegir uno de dos estímulos neutros de diferente numerosidad o volumen mediante su asociación con una recompensa. Por lo general, si se emplea una forma de evaluación espontánea, se busca conocer la motivación natural de los individuos para discriminar cuantitativamente en un contexto particular, mientras que si se emplea una evaluación por entrenamiento se puede identificar el mecanismo mediante el que los individuos discriminan entre cantidades y sus límites perceptuales y cognitivos, ya que se busca controlar todas las variables que pueden ser tomadas en cuenta en la toma de decisiones (Agrillo & Bisazza 2014).

1.2 Depredación

La conducta de depredación brinda una buena oportunidad para evaluar la discriminación cuantitativa. Tomar decisiones apropiadas en este contexto es de relevancia adaptativa debido a que los depredadores emplean una cantidad de tiempo considerable a rastrear o acechar a sus presas, además de

evaluar el balance entre un posible riesgo de heridas provocadas por la presa contra la adquisición nutricional (Werner & Hall 1974; Cooper et al. 2007; Panteleeva et al. 2013; Mettke-Hofmann 2014).

Estudios previos en los que se puso a prueba la discriminación cuantitativa en anfibios con presas vivas, respaldan la teoría de que los individuos deben maximizar la ingesta de alimento de acuerdo al tiempo y energía invertidos en ello, y así, dada la oportunidad, elegir la mayor cantidad y tamaño de presa (Uller et al. 2003; Krusche et al. 2010; Stancher et al. 2015). Sin embargo, los resultados fueron diferentes en un estudio en el que la presa era potencialmente peligrosa. Panteleeva et al. (2013) colocaron a ratones rayados de campo (*Apodemus agrarius*) en parches de forrajeo simulados que contenían diferentes cantidades de hormigas comestibles, pero agresivas. Los ratones eligieron los parches que contenían menos hormigas con mayor frecuencia, presumiblemente para reducir el riesgo de heridas y cuando se les colocó en parches con una mayor cantidad de hormigas, mostraron conductas aversivas y una menor cantidad de hormigas consumidas. Esto sugiere que evaluar los riesgos y las recompensas en tareas particulares puede influir en la manera en que los individuos toman decisiones.

1.3 El gato doméstico como modelo de estudio

El gato doméstico (*Felis silvestris catus*) es una especie de mamífero adecuada para evaluar la discriminación cuantitativa (Pisa & Agrillo 2009; Bánszegi et al. 2016) y la potencial relación de ésta con una manera adaptativa de toma de decisiones. Es una especie animal que se encuentra en abundancia, de fácil mantenimiento y manejo en experimentos conductuales, aún en condiciones semi-naturales, lo que provee la oportunidad de estudiar la conducta de depredación de un carnívoro obligado (Bradshaw et al. 1996). Aunque generalmente se considera al gato como un animal social facultativo (Crowell-Davis et al. 2004; Bradshaw 2006; Spotte 2014), es un cazador solitario (Bradshaw 2006; Stella & Buffington

2013; Spotte 2014). En la naturaleza, los gatos ferales usualmente cazan presas pequeñas (< 50 g; Pearre Jr. & Maass 1998; Biró et al. 2005) independientemente de la edad y el sexo de la presa (Christian 1975; Liberg 1984; Childs 1986; Biró et al. 2005). Y, en ambiente doméstico, los gatos usualmente comen numerosas porciones de alimento comercial de tamaño pequeño (5 a 8 gr) a lo largo del día, en vez de pocas porciones de gran tamaño (Tobie et al. 2015), lo que nos permite evaluarlo de forma continua sin necesidad de privarlo de alimento en busca de motivación.

1.4 Antecedentes

En un experimento previo, Pisa & Agrillo (2009) demostraron que los gatos domésticos adultos pueden ser entrenados para discriminar entre diferentes números de puntos y elegir el de mayor número, y después Bánszegi et al. (2016), con dos experimentos mostraron que también pueden discriminar entre diferentes números y tamaños de porciones de alimento (Fig. 1).

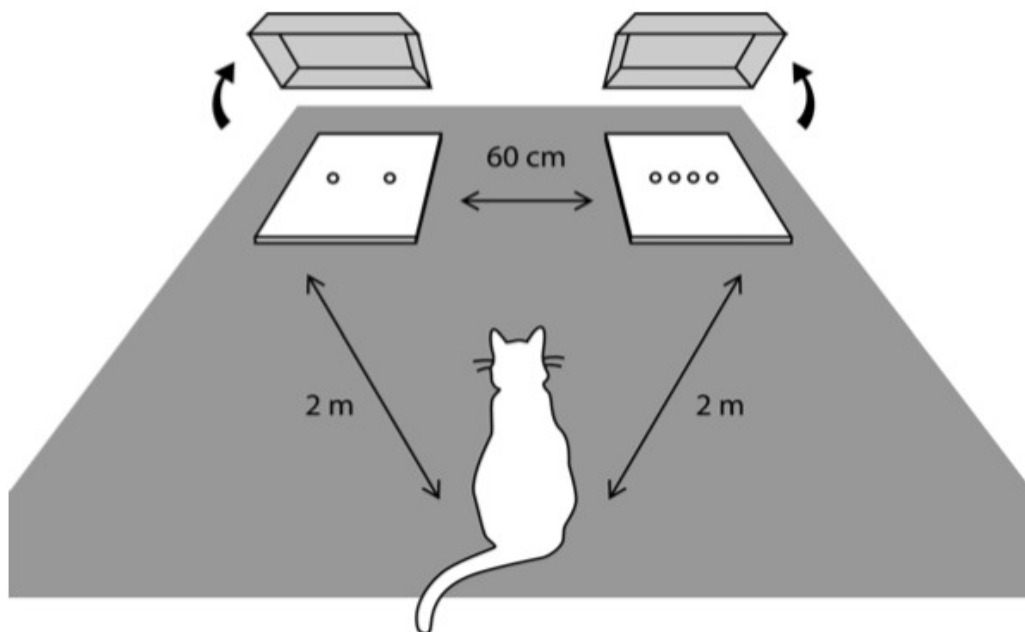**Fig. 1.** Vista esquemática de la prueba tomado de Bánszegi et al. (2016). Vista esquemática de la prueba. Los estímulos se presentaron en dos láminas de plástico a 60 cm de distancia entre ellas, y se cubrieron con cajas opacas. Los dueños ubicaron a los gatos en una posición central a 2 m de distancia de frente a las láminas y se les permitió acercarse después de que el experimentador levantara las cajas.

En ese estudio, en el primer experimento los gatos eligieron espontáneamente el número más grande de porciones de alimento, pero en el segundo experimento, eligieron la porción de alimento más pequeña cuando la porción más grande excedía cierto tamaño (Fig. 2).
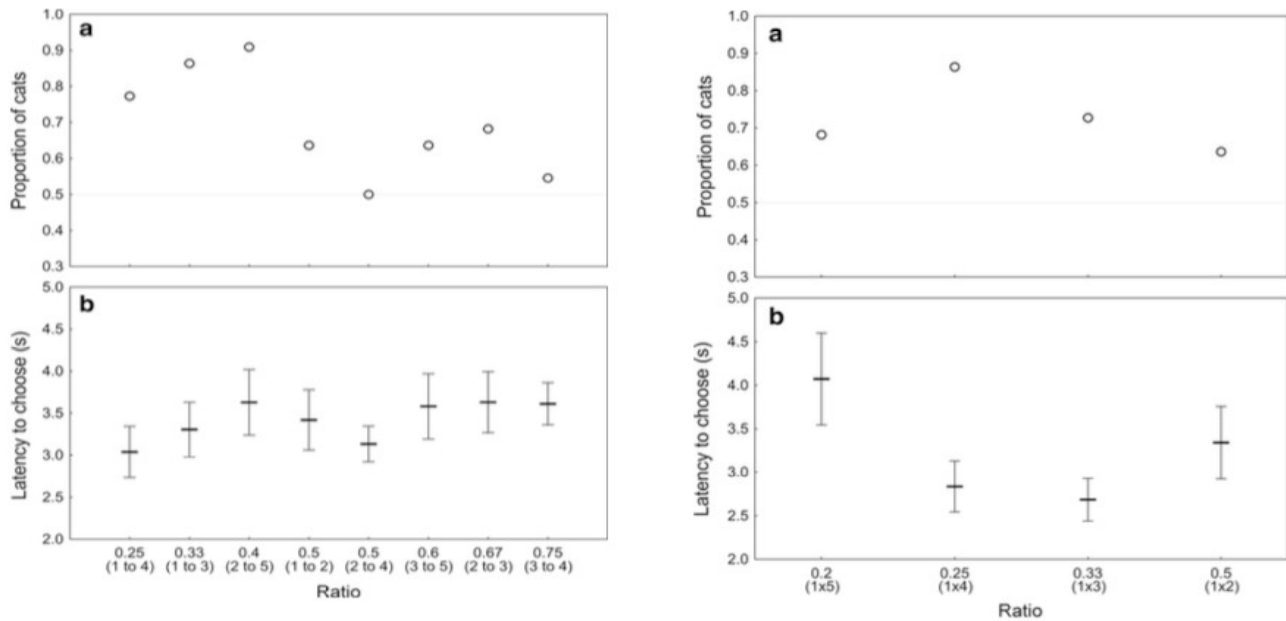

Fig. 2. Resultados tomados de Bánszegi et al. 2016. Izquierda: a) proporción de gatos en el Experimento 1 que eligieron la cantidad más grande de porciones de alimento, b) latencia para elegir en segundos como función de la razón entre el número de porciones en cada arreglo. Derecha: a) proporción de gatos en el Experimento 2 que eligieron la porción más grande de alimento, b) latencia para elegir en segundos como función de la razón entre tamaños volumétricos.

En una situación más natural Biben (1979) usó ratones y ratas vivas de diferentes tamaños para evaluar la probabilidad de depredación del gato doméstico en relación a su estado de saciedad y al tamaño de la presa. Los resultados mostraron que si el tamaño de la presa aumenta, o el hambre decrece, la incidencia de depredación decrecía, lo que indicaba que el estado motivacional del gato y su juicio del riesgo tienen parte en su toma de decisiones.

El objetivo del presente estudio fue extender lo encontrado en el estudio previo de discriminación de cantidad y tamaño en la elección de alimento en el gato (Bánszegi et al. 2016)

poniendo a prueba a los gatos en un contexto más natural de potencial depredación. Otro de los objetivos fue investigar la posible presencia de diferencias individuales en los patrones de conducta y en la elección, y aumentar la información que pueda ser comparable a los resultados de estudios similares en el gato y otros vertebrados que son depredadores y en los que también se usaron presas vivas (Biben 1979; Avery & Krebs 1984; Uller et al. 2003; Krusche et al. 2010; Panteleeva et al. 2013; Stancher et al. 2015). Estos reportes previos sugieren que el uso de presas vivas en contextos de toma de decisiones para los depredadores es altamente motivante, presumiblemente porque refleja las condiciones naturales en las que los sujetos de estudio naturalmente vivirían, lo que detona la conducta de depredación. En dos experimentos diferentes les presentamos a gatos adultos 1) diferentes números de presas del mismo tamaño (1 ratón blanco vs. 3 ratones blancos), y 2) dos presas de diferente tamaño (un ratón blanco vs. una rata blanca). Pusimos a prueba la elección de cada gato varias veces para evaluar si había diferencias individuales repetitivas en su elección y en las conductas asociadas (cf. Mendl & Harcourt 2000; Hudson et al. 2015; Urrutia et al. 2019).

2. ARTÍCULO ENVIADO PARA PUBLICACIÓN A *Animal Cognition* (en revisión)

More or less revisited: influence of numerosity and size on prey choice in the domestic cat

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Abstract

Quantity discrimination is of adaptive relevance in a wide range of contexts and across a wide range of species. Trained domestic cats can discriminate between different numbers of dots, and we have shown that they also spontaneously choose between different numbers and sizes of food balls. In the present study we performed two experiments with 24 adult cats to investigate spontaneous quantity discrimination in the more naturalistic context of potential predation. In Experiment 1 we presented each cat with the simultaneous choice between a different number of live prey (1 white mouse vs. 3 white mice), and in Experiment 2 with the simultaneous choice between live prey of different size (1 white mouse vs. 1 white rat). We repeated each experiment six times across six weeks, testing half the cats first in Experiment 1 and then in Experiment 2, and the other half in the reverse order. In Experiment 1 the cats more often chose the larger number of small prey (3 mice), and in Experiment 2 more often the small size prey (a mouse). They also showed repeatable individual differences in the choices they made and in the performance of associated predation-like behaviours. We conclude that domestic cats spontaneously discriminate between the number and size of potential prey in a way that can be interpreted as adaptive for a lone-hunting, obligate carnivore, and show complex levels of risk-reward analysis, calling into question the notion that bigger is necessarily better.

Keywords: Cognition · Quantity discrimination · Spontaneous responding · Ecological relevance · Risk/reward · Individual differences

Introduction

Animals engage in daily quantitative judgements in contexts such as food intake, quantitative estimation of opponent strength in aggressive encounters and predator avoidance (Agrillo and Bisazza 2014; Benson-Amram et al. 2018). As such discrimination can contribute importantly to making decisions enhancing individual fitness, it should be favoured by natural selection (Nieder 2018; Skorupski et al. 2018). Several studies have shown that a wide range of species – from invertebrates to humans – are capable of discriminating between different numbers and sizes (review by Agrillo and Bisazza 2014). Moreover, species-specific differences in quantity discrimination can reflect the way in which species are cognitively adapted to different ecological niches (Sunquist and Sunquist 1989; Nieder 2018).

Predatory behaviour provides a good opportunity to evaluate quantity discrimination. Appropriate decision making in this context is of adaptive significance due to the often considerable time invested in tracking prey or to waiting in ambush and to the possible risk of injury versus nutritional gain (Werner and Hall 1974; Cooper et al. 2007; Panteleeva et al. 2013). Previous studies with amphibians tested with live prey support the theory that individuals should maximize food intake according to time and energy invested, and so if given the opportunity, should choose the larger quantity and size of prey (Uller et al. 2003; Krusche et al. 2010; Stancher et al. 2015). However, a study with a prey species that can be potentially dangerous gave different results. Panteleeva et al. (2013) presented different quantities of edible, but quite aggressive red ants to simulate foraging patches to striped field mice (Apodemus agrarius). The mice chose the patches containing fewer ants more often, presumably to reduce the risk of injury. This suggests that weighing up the risk and rewards of particular choices can influence how individuals make decisions.

The domestic cat (Felis silvestris catus) is a useful mammalian species to test quantity discrimination (Pisa and Agrillo 2009; Bánszegi et al. 2016) and the potential relation of this to adaptive decision-making. It is easy to maintain and to handle in behavioural experiments, even under semi-natural conditions, providing the opportunity to assess the predatory behaviour of an obligate carnivore

(Bradshaw et al. 1996). Although the cat is generally considered to be a facultative social animal (Crowell-Davis et al. 2004; Bradshaw 2006; Spotte 2014), it is a lone hunter (Bradshaw 2006; Stella and Buffington 2013; Spotte 2014). In nature, feral cats usually hunt small prey (< 50 g; Pearre Jr. and Maass 1998; Biró et al. 2005) irrespective of the prey's age or sex (Christian 1975; Liberg 1984; Childs 1986; Biró et al. 2005), and under domestic conditions pet cats usually eat many small (5 to 8 g) portions of commercial food throughout the day rather than a few large portions (Tobie et al. 2015).

In a previous experiment, Pisa and Agrillo (2009) demonstrated that adult domestic cats can be trained to discriminate between different numbers of dots, and later Bánszegi et al. (2016) showed that they also discriminate between different numbers and sizes of food items. In that study, in a first experiment cats spontaneously chose the larger number of food items, but in a second experiment, they chose the smaller food item if the larger item exceeded a certain size. In a more naturalistic situation Biben (1979) used live mice and rats of different sizes to evaluate the probability of killing by domestic cats in relation to satiety and to prey size. The results showed that as prey size increased, or hunger decreased, the incidence of killing decreased, thus indicating that the cats' motivational state and judgement of risk played a part in their decision-making.

The aim of the present study was to extend the findings of our previous study of numerosity and size discrimination in the cat (Bánszegi et al. 2016) by testing animals in a more naturalistic context of simulated predation. It was also our aim to investigate possible individual differences in patterns of behaviour and choice, and to increase the comparability of our results with those of similar studies in the cat and other vertebrates, also using live prey (Biben 1979; Avery and Krebs 1984; Uller et al. 2003; Krusche et al. 2010; Panteleeva et al. 2013; Stancher et al. 2015). Previous reports suggest that the use of live prey in decision-making contexts is highly motivating, presumably because it reflects an everyday reality with which the animals are adapted to deal, and thus readily triggers predatory behaviour. In two different experiments we presented adult cats 1) with different numbers of same-size prey (1 white mouse vs. 3 white mice), and 2) with two single prey items of different size (a white mouse vs. a white rat). We tested each cat's choice several times to evaluate if there were repeatable individual differences in the

95 choices they made and in associated behaviours (cf. Mendl and Harcourt 2000; Hudson et al. 2015;

96 Urrutia et al. 2019).

97

General methods

99
100 **Subjects**

101
102   We tested a total of 24 adult mixed breed pet cats after obtaining permission from their owners to

103 allow repeated testing in the cats' everyday home environment. All were at least 6 months old (9 months

104 − 10 years, mean 4.16 ± 2.87 SD), 12 females (11 neutered) and 12 males (11 neutered), and weighed 2.4

105 − 6 kg (mean 4.05 ± 1.23 SD). Thirteen were exclusively indoor and 11 were indoor/outdoor cats. None

106 had participated previously in behavioural experiments or received training on the test procedures before

107 or during the study. The two experiments took place at the cat owners' homes once a week for six weeks.

108 In each session each cat was tested twice. Half the cats started with the three sessions of Experiment 1

109 (number) and the other half with the three sessions of Experiment 2 (size).

110
111 **Stimuli and equipment**

112
113   We used tame, laboratory-strain mice and rats as the live stimuli due to their ecological relevance;

114 small rodents are the most common prey of the domestic cat (Baker et al. 2005; Bonnaud et al. 2007; Kutt

115 2012; Lanszki et al. 2015; Széles et al. 2018), and because of the ease with which they can be maintained

116 and handled. Two Wistar (white) adult female rats were kept in a commercial two-level 80 x 60 x 45

117 (height) cm wire mesh cage for small rodents, and eight BALB/c (white) adult female mice were kept in

118 groups of four in two standard 53 x 43 x 19 (height) cm polycarbonate laboratory rodent cages. The cages

119 were lined with wood shavings and the animals had permanent access to a variety of fresh foods,

120 commercial rodent chow and water, and were provided with nest material and a variety of cardboard

121 refuges. Before starting the study we conducted pilot tests to check the suitability of the test procedure

122 (see below) for the cats and rodents. Consistent with a previous study (Biben 1979) the pilot cats showed

immediate interest in the stimulus animals, and these showed no obvious signs of fear in the presence of the cats; no signs of panic or attempted escape, moved around in apparent calm, groomed themselves, and reared against the front of the tank in apparent curiosity at the presence of the cats. At the end of the study the rodents were adopted by student participants.

Two transparent plastic Imagitarium™ Temporary Holding Habitat fish tanks 17.7 x 29.8 x 20.3 (height) cm were used to present the stimulus animals to the cats during the tests. The tanks were closed with plastic lids with slits through which the cats could presumably smell the stimulus animals but without being able to make physical contact with them. For Experiment 1 (Fig. 1a) the tanks were divided into equal size compartments by transparent acrylic walls. During trials, the stimulus animals were placed individually in one of the compartments inside one of the experimental tanks to ensure they were equally visible and had the same amount of space to move around so that the cats could assess their different numbers or size (Fig. 1). The tanks were thoroughly washed with water and unscented soap after each test session.
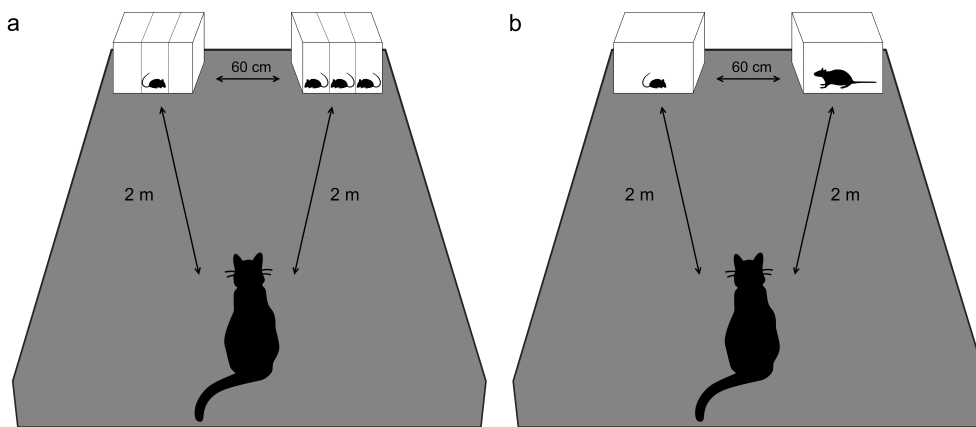
Fig. 1 Schematic overview of the test set-up. The stimuli were presented in similar 17.7 x 29.8 x 20.3 (height) cm transparent plastic fish tanks with plastic lids with slits. Cats were placed by their owners facing the tanks from a distance of 2 m and mid-way between them, and after 5 s were released. a) Experiment 1: numerosity test (1 mouse vs. 3 mice). For this, the tanks were divided into equal-size compartments by transparent acrylic walls. b) Experiment 2: size test (1 mouse vs. 1 rat).

14

Test procedure

To assess cats' quantity discrimination in a quasi-predatory situation we followed the experimental design of Bánszegi et al. (2016). We tested each cat in its own home in a familiar room. The time of day of testing depended on the owners' convenience and was between 12:00 noon and 07:00 pm. The cats were not food deprived.

In the absence of the cat, the experimenter prepared the trials by placing the two experimental tanks containing the stimulus animals against a wall 60 cm apart and mounted a video camera in one of the corners opposite. The experimenter then turned on the camera and asked the owner to come in carrying the cat and to place it at the starting point, a position marked on the floor, midway between and 2 m from the tanks (Fig. 1). The owner positioned the cat facing the stimuli and gently held it there from behind for 5 s to give it the chance to view both tanks. As both the experimenter and the owner were positioned behind the cat and avoided eye contact with it (by looking at the wall in front, at the floor or the ceiling), visual cueing by either of them was unlikely. Moreover, as soon as the cats noticed the stimulus animals they appeared to focus exclusively on them. Each test lasted two minutes. We chose a short trial time to minimize possible stress to the stimulus animals, to minimize possible habituation by the cats to the test set-up, and to allow repeated testing in the same session and so optimize visits to owners' homes.

The cats were given two trials per session, both from the same experimental condition. To reduce learning or side preference effects, the right-left position of the tanks was counterbalanced across trials. Sessions were repeated once a week until the subjects had completed three sessions (six trials) for each of the two experiments. In each session, the cat was taken out of the test room between trials for approximately a minute while the position of the tanks was reversed.

Behavioural recording

All tests were recorded on video using a SONY Handicam CX455 camera for later analysis. The

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171   following behaviours were scored from the videos using Solomon Coder software (Péter 2017):

172   Latency to approach each stimulus, defined as the time the cat took to reach each of the tanks to

173   within a radius of 30 cm.

174   Duration near each stimulus, defined as the time the cat spent within 30 cm of each of the

175   tanks. We originally also scored duration of watching, defined as the time the cat spent directing its gaze

176   towards each of the tanks from any point in the room, but later discarded this as too difficult to determine

177   with accuracy from behind the cat.

178   Duration of tail twitching or waving defined as the per cent of time the cat spent repeatedly

179   moving its tail from side to side in an arc of any size while orienting toward each of the tanks and thought

180   to express arousal (Stanton et al. 2015).

181   Stalking towards the tanks, crouching, sniffing at a tank, and touching it with a paw or the nose

182   were also registered but were found too difficult to score accurately or occurred too rarely to be included

183   in the analysis.

184   To assess inter-rater reliability we randomly selected 15 videos from 7 cats (6 % of all videos),

185   and a naïve second observer coded them independently. Inter-rater reliability was assessed by calculating

186   intra-class correlation coefficients using the R package irr (Gamer et al. 2012). Agreement between the

187   two independent observers was high for all variables: latency to approach each stimulus (the less

188   numerous/smaller stimulus RICC = 0.98, $P < 0.001$; the more numerous/larger stimulus RICC = 0.99, $P <$

189   0.001), time spent near each of the stimuli (the less numerous/smaller stimulus RICC = 0.98, $P < 0.001$;

190   the more numerous/larger stimulus RICC = 0.98, $P < 0.001$), and duration of tail waving (the less

191   numerous/smaller stimulus RICC = 0.97, $P < 0.001$; the more numerous/larger stimulus RICC = 0.99, $P <$

192   0.001).

193
194   **Data treatment and analysis**

195
196   Statistical analyses were carried out using the program R, version 3.5.1 (R Core Team 2018). To

16

197 analyse the behaviour of the cats on the latency to approach, remain near the different stimuli and tail

198 waving, we used paired t-tests on the averaged values for each cat. Consistency in the cats' behaviour,

199 that is, the proportion of phenotypic variation that can be attributed to between-subject variation, was

200 estimated using linear mixed-effects model (LMM)-based intra-class correlations (ICC) using the R

201 package rptR (Stoffel et al. 2017). Individual identity was used as a random factor, sex of the individuals

202 was included in all models.

203   To examine the factors that might have affected an individual's behaviour during testing we

204 applied Generalized Estimating Equations (GEE) using the R package geepack (Halekoh et al. 2006).

205 GEE is an alternative to likelihood-based generalized linear mixed models that can be used on repeated

206 measurements or other correlated observations. It is commonly applied to clinical trials and biomedical

207 studies as it is less sensitive to variance structure specifications and as its focus is on estimating the

208 average response over the population rather than the regression parameters.

209   The dependent variables were latency to approach and time spent near each of the tanks, duration

210 of tail waving while orienting to each of the tanks, and the time spent near the more numerous/larger

211 stimulus as a per cent of the total time spent near both tanks. Sex and experience (indoor or

212 indoor/outdoor) were included in the models as factors, weight and age were included as covariates.

213

214 **Experiment 1: choice by number (1 mouse vs. 3 mice)**

215
216   Here our aim was to investigate whether domestic cats would spontaneously distinguish between

217 simultaneously presented stimulus arrays comprising different numbers of prey of the same size, colour

218 and sex (Fig. 1a). In a previous study (Bánszegi et al. 2016) we found that cats chose the larger number of

219 food items more often than the smaller number, raising the question whether they would do the same if

220 faced with live prey, where a greater number might cause confusion and so would be avoided (van Orsdol

221 1984; Jeschke and Tollrian 2007). We were also interested in knowing if there would be stable individual

222 differences among the cats in their behaviours and choices. Of the 24 cats tested, 19 performed in at least

three out of the six trials, that is, they did not try to leave the room, they attended to the stimuli, and did

not show a persistent side bias. Only these animals' data were included in the statistical analysis.

Descriptive data are given as means and SD.

Results and discussion

Most cats directed their attention almost immediately towards the stimuli. They quickly

approached the tanks (18.98 ± 26.5 s) and spent considerable time near one or the other (87.5 ± 35.5 s).

The number of changes they made between the tanks was low (1.42 ± 1.28). They also almost always

exhibited some amount of tail waving, even if only briefly (mean 6.62 ± 7.61 s), while directing their

attention towards the stimuli.

The cats did not approach one stimulus significantly faster than the other (paired t-test: t (18) =

1.01, P = 0.33); 10 of the 19 cats approached the three-mouse tank first more often than they approached

the one-mouse tank, 5 cats approached either tank first equally often, and 4 cats approached the one-

mouse tank first more often than they approached the three-mouse tank (two-sided sign test: approaching

the three-mice first, median = 0.6, CI 95 [0.5, 0.69], P = 0.18). However, they spent significantly more

time near the three-mouse versus the single mouse tank (t (18) = 2.97, P < 0.01); 14 of the 19 cats spent

more time more often near the three-mouse tank than near the one-mouse tanks, 3 cats spent more time

equally often near either of the tanks, and 2 cats spent more time more often near the one-mouse tank

(median = 62.6, CI 95 [52.9, 75.5], P < 0.001). There was no difference in the per cent of time the cats

waved their tail while watching each of the stimuli (t (18) = 1.92, P = 0.07). Five of the 19 cats show a

higher per cent of tail waiving more often while orienting to the three-mouse tank, 5 cats showed a higher

per cent of tail waiving equally often while orienting to each of the tanks, and 9 cats showed a higher per

cent of tail waiving more often while orienting to the one-mouse tank (Fig. 2).
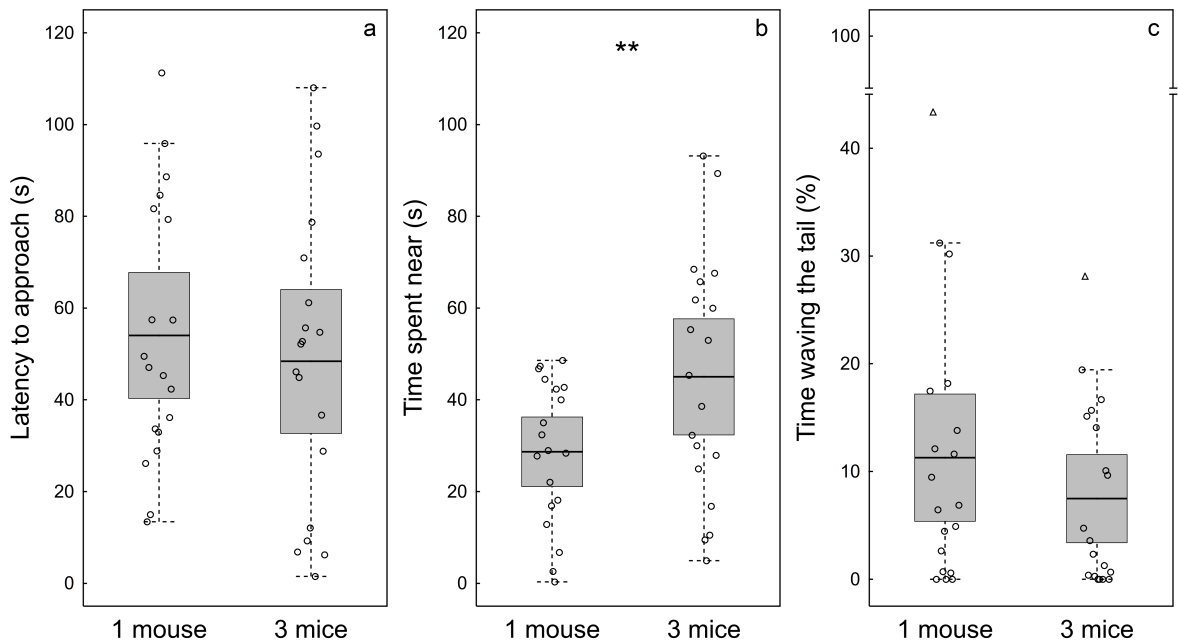
Fig. 2 (a) Latency to approach each of the stimulus tanks, (b) time spent near each tank, and (c) per cent time tail waving while orienting to each of the tanks by the 19 cats in Experiment 1. Data are presented as means (bold horizontal lines), 95% confidence intervals (boxes), and non-outlier ranges (vertical lines). Circles give the average for each individual, and asterisks indicate a significant difference (** $P < 0.01$). See text for statistics.

When we examined which characteristics (age, sex, weight, indoor or indoor/outdoor) might have affected the cats' choice of stimulus, none of the characteristics was related to how fast cats approached or the total time they spent near either stimulus, or the duration of tail waving. We also calculated the time spent near the tank with the larger number of mice as a per cent of the total time spent near either tank, but again found no relation to any of the characteristics considered. For details of the analyses see Supplementary Material 1.

We found stable inter-individual differences for all three behavioural measures across the six trials; in the latency to approach either of the tanks ($R = 0.63$, CI 95 [0.38, 0.78], $P < 0.001$), in the time spent near either of the tanks ($R = 0.53$, CI 95 [0.26, 0.71], $P < 0.001$), and in the frequency of tail waving while orienting to either of the tanks ($R = 0.46$, CI 95 [0.12, 0.68], $P < 0.01$). However, we did not find stable inter-individual differences in the time spent near the three-mouse tank as a per cent of the total

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266   time spent near either tank (R = 0.05, CI 95 [0, 0.69], P = 0.25).

267   Without training and without being food deprived all of the 19 cats qualifying for testing quickly

268   directed their attention to the tanks, quickly approached them, and spent considerable trial time near one

269   or other of them. Thus, the live rodent stimuli appeared highly motivating, and even for the exclusively

270   indoor pets presumably with no experience of encountering or hunting such prey (see General

271   Discussion). The time the cats spent near either of the tanks appeared the most reliable measure of them

272   discriminating and choosing between the two numerical options in our test set-up. That the cats on

273   average spent more time near the tank containing the larger number of mice, that a majority of cats did so,

274   and that the cats did not often change their position between the tanks, suggests that they quickly

275   perceived the difference between the stimuli and made their choice from a certain distance. This, in turn,

276   suggests that cats are able to rapidly and spontaneously assess numerosity in a quasi-naturalistic situation,

277   and is consistent with previous reports of cats distinguishing between different numbers of inanimate food

278   items and generally choosing the larger number (Bánszegi et al. 2016).

279   However, the perceptual cues (for example, visual and/or olfactory) and the cognitive mechanisms

280   underlying such choice are not clear. Most immediately, the cats may simply have been attracted by the

281   greater combined activity of the three-mouse array, without implying any form of "counting".

282   Nevertheless, their choice also implies that they did not perceive this greater activity to represent a threat

283   or confusion, and thus that they may have detected that the activity was generated by several small, non-

284   threatening entities. More speculatively still, this might have led to them choosing the greater number of

285   mice, thereby increasing the possibility of obtaining at least one (cf. van Orsdol 1984). Whatever the

286   underlying explanation for most cats appearing to choose the tank containing the larger number of mice,

287   the results are consistent with previous reports of cats' ability to detect and discriminate numerosity (Pisa

288   and Agrillo 2009; Bánszegi et al. 2016), and extends these by showing that cats are also able to quickly

289   and spontaneously assess numerosity of ecologically relevant, live stimuli, and to make a choice that

290   might be interpreted to be of adaptive significance (see General Discussion).

291

Experiment 2: choice by size (1 mouse vs. 1 rat)

For a solitary hunter and obligate carnivore such as the cat, being able to assess the size of a prey item and weigh up the potential risk and reward of attacking it is presumably of considerable adaptive significance. Thus, our aim in this experiment was to investigate whether domestic cats spontaneously distinguish between two single potential prey items of different size (Fig. 1b). As in Experiment 1, we were also interested to know if there were stable individual differences among the cats in their behaviour and choice, this time based on the size of the stimuli rather than number. Of the 24 cats tested, 22 performed adequately in at least three of the six trials, and only these animals' data were included in the statistical analysis. Again, descriptive statistics are given as means and SD.

Results and discussion

As in Experiment 1, the cats quickly approached the tanks (12.8 ± 22.7 s) and spent considerable time near them (83.0 ± 39.1 s). Again, the number of changes they made between the tanks was low (1.43 ± 1.42). Most cats also displayed tail waving, although only briefly, while orienting toward each of the tanks (2.52 ± 3.28 s).

Also as in Experiment 1, there was not a significant difference in the latency of the cats to approach either tank (paired t-test: $t (21) = 0.94$, $P = 0.36$); 9 of the 22 cats approached the rat first more often than they approached the mouse, 5 cats approached the rat or the mouse first equally often, and 8 cats approached the mouse first more often than they approached the rat first (two-sided sign test: approaching the rat first, median $= 0.5$, CI 95 [0.33, 0.66], $P = 1$). However, they spent significantly more time near the mouse than near the rat ($t (21) = 2.54$, $P = 0.02$); 12 of the 22 cats spent more time near the mouse more often than near the rat, 3 cats spent more time near the rat or mouse equally often, and 7 cats spent more time more often near the rat (more time spent near the rat, median $=39.5$, CI 95 [26.4, 50.5], $P < 0.001$). There was no difference in the per cent of time the cats waved their tail while orienting toward each of the stimuli ($t (21) = 0.34$, $P = 0.74$); 6 of the 22 cats showed a higher per cent of tail waiving more

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319 often while orienting to the rat tank, 9 cats showed a higher per cent of tail waiving equally often while

320 orienting to each of the tanks, and 7 cats showed a higher per cent of tail waiving more often while

321 orienting to the mouse tank (Fig. 3).

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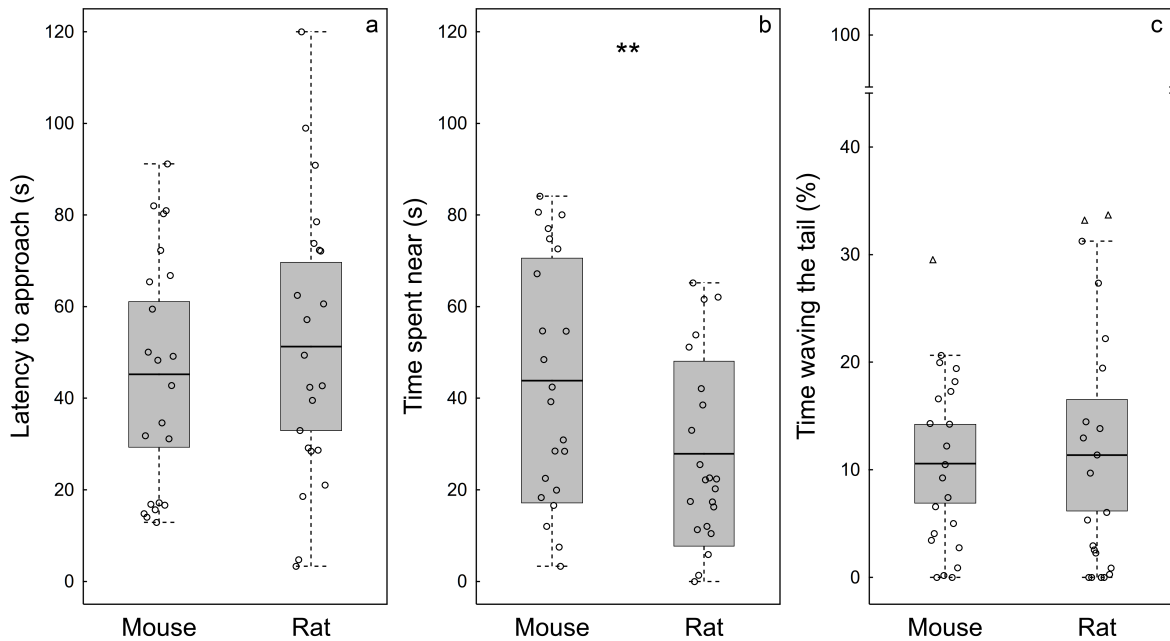
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325 **Fig. 3** (a) Latency to approach each stimulus tank, (b) time spent near each tank, and (c) time spent tail waving while orienting

326 toward each of the tanks by the 22 cats in Experiment 2. Data are presented as means (bold horizontal lines), 95% confidence

327 intervals (boxes), and non-outlier ranges (vertical lines). Circles give the average for each individual, and asterisks indicate a

328 significant difference (** $P < 0.01$). See the text for statistics.

329
330 When we examined which characteristics (age, sex, weight, experience, i.e. indoor or

331 indoor/outdoor) might have affected the cats' choice of stimulus, none of the characteristics considered

332 affected how fast they approached or the total time they spent near either tank, or tail waving while

333 orienting to either tank. However, experience and age were significantly associated with the per cent of

334 time cats spent near the rat (GEE: experience $\chi^2 = 6.65$, P = 0.01, age: $\chi^2 = 4.26$, P = 0.04). Outdoor and

335 older cats spent less time near the rat than the mouse, possibly due to their experience hunting these, both

336 of which, as in most urban environments, are plentiful in Mexico City (own experience). For details of the

337 analyses see Supplementary Material 1.

338   Again, there were stable inter-individual differences in the cats' behaviour when facing live

339   potential prey; significant repeatability in latency to approach either of the stimuli (R = 0.20, CI = [0.01,

340   0.37], P < 0.01), how long individuals remained near either of the stimuli (R = 0.60, CI = [0.37, 0.75], P <

341   0.001), and the duration of tail waving while orienting to either of the stimuli (R = 0.45, CI = [0.16, 0.66],

342   P < 0.001). We also found stable individual differences in the time spent near the rat as a per cent of the

343   total time spent near either stimulus (R = 0.23, CI = [0.03, 0.44]. P < 0.01).

344   As in Experiment 1, all the 22 cats qualifying for testing directed their attention almost

345   immediately to the tanks, quickly approached them and spent considerable time near one or other of them.

346   Again, the time the cats spent near either of the tanks appeared the most reliable measure of them

347   discriminating and choosing, in this case between the two size options. However, in contrast to their

348   behaviour in Experiment 1, where they tended to choose the numerically larger stimulus array, overall the

349   cats spent more time near the volumetrically smaller stimulus (the mouse) than the larger one (the rat),

350   and a majority of individuals did so. This contrast suggests that despite the relatively small number of cats

351   tested, their behaviour represented real discriminative ability and choice and not simply a random

352   response to generally attractive stimuli. Although it is again not clear what perceptual or cognitive

353   mechanisms underlay such choice, this may again be interpreted as of adaptive significance. An adult rat

354   is a considerable adversary for a cat (Biben 1979; Childs 1986; own observations), which as a lone hunter

355   dependent solely on its own abilities, should minimize the risk of injury that could jeopardize its future

356   hunting success. This is consistent with the findings of Bánszegi et al. (2016) who reported cats to prefer

357   a larger to a smaller food item but only until the larger portion exceeded a certain size. Although the

358   number of cats tested in the present experiment was modest, it is potentially interesting to note that

359   outdoor and older cats showed a stronger preference for the mouse than for the rat, perhaps reflecting

360   their experience with the two types of prey, both of which are numerous in the Mexico City environment.

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Consistency in individual cat's behaviour between Experiments 1 and 2

When comparing the behaviour of the cats (n = 17) in the two experiments (number and size) we found correlations in their latency to approach the stimuli (Spearman: rs = 0.55, P < 0.05), in the total time they spent near the stimuli (rs = 0.54, P < 0.05), and in the time they waved their tail while orienting to either stimulus (rs = 0.81, P < 0.0001). However, we found no association with regard to the per cent time they spent near the (larger) three-mouse stimulus in Experiment 1 and the (larger) rat stimulus in Experiment 2 (rs = 0.35, P = 0.15; Fig. 4). This might be explained by the finding that the choice between the two stimuli in Experiment 2 was significantly affected by two variables not influencing the cats' choice in Experiment 1, age and whether they were exclusively indoor or indoor/outdoor cats.
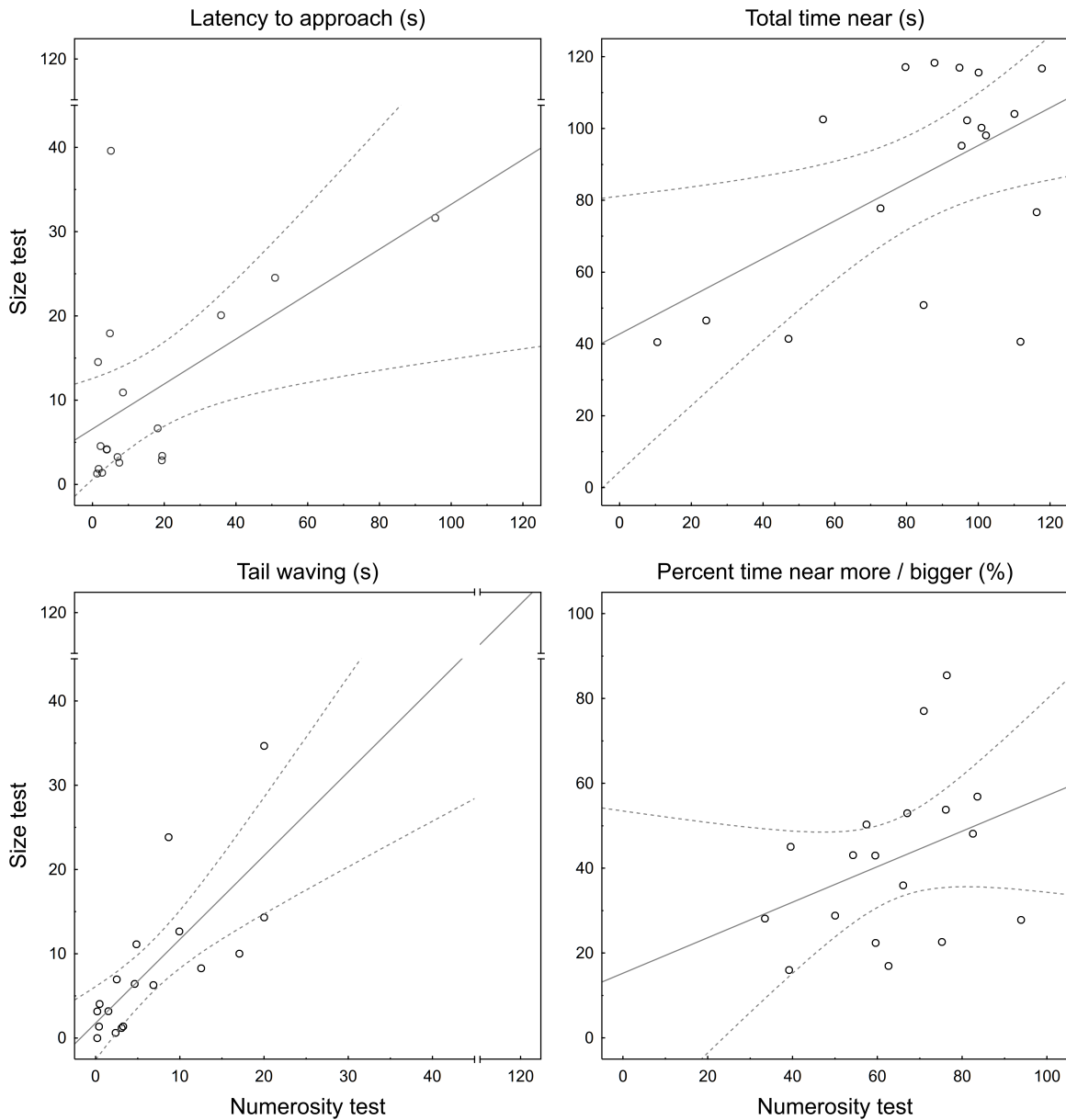
Fig. 4 Correlations between the behavioural measures of each of the 17 cats successfully participating in both Experiment 1 (numerosity) and Experiment 2 (size). Data for individuals are averages for each experiment. Slopes of correlations (solid lines) and 95% confidence intervals of their estimates (dotted lines) are given. See text for statistics.

General discussion

Our main interest in conducting this study was to assess discrimination of number and size in domestic cats by using naturalistic stimuli of relevance to the cats' evolved behavioural biology, in this case live potential prey. Indeed, we found evidence for both forms of discriminative ability, of both number and size. In the trials of number discrimination, the cats signalled what might be interpreted as

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384   prey choice by spending significantly longer near a larger number of small prey (three mice) than near the

385   simultaneously presented smaller number (a single mouse). In contrast, in the trials of size discrimination

386   they spent significantly more time near the smaller stimulus (a single mouse) than near the larger stimulus

387   (a single adult rat). This disjunction between the results of the two experiments, that is, an apparent

388   preference by the cats for the greater number when presented with small prey, but for the smaller size

389   when presented with two potential prey of different size, suggests that the animals were making real

390   judgments of quantity and, as suggested in the discussion following each of the experiments above, taking

391   what in each might be interpreted as adaptive decisions based on this. The results are also consistent with

392   previous reports; first, that the decision by cats to attack live prey is influenced by prey size and cats'

393   reluctance to attack larger individuals whether of the same or different species (Biben 1979; Childs 1986),

394   and second, that in tests of cats' choice of inanimate food items, those above a certain size were rejected,

395   possibly because perceived as threatening or uneconomical to handle (Bánszegi et al. 2016).

396   It was notable how quickly the cats showed interest in and approached the stimuli, and

397   even the exclusively indoor cats presumably with no previous experience of rodents (see also Panteleeva

398   et al. 2013 for a similar phenomenon in naïve hunting mice). Also notable was the consistency in the cats'

399   pattern of responding despite being tested in diverse environments of private homes. However, these two

400   aspects of the methodology might, in fact, have contributed to us obtaining seemingly coherent and

401   consistent results; the combination of using ethologically relevant stimuli (cf. González et al. 2018) with

402   testing untrained animals in a familiar environment minimizing stress and anxiety. Although we evaluated

403   several behavioural variables, the most consistent and useful for determining the cats' discrimination

404   between and "choice" of stimuli, was the time they spent near either of them. This might also reflect the

405   behavioural biology of the cat, which is considered an ambush hunter, which lies in wait for its prey

406   rather than chasing it down (Turner and Meister 1988).

407   Nevertheless, the results obtained in the present study are not absolute, and the apparent

408   choices made by the cats here might not apply to cats tested under conditions different to the present

409   study. Our animals were not food-deprived and thus animals experiencing short-term or life-long food

410 limitation such as stray or feral cats, might be expected to make different, riskier decisions than the

411 animals tested here (Adamec 1976; Biben 1979). Although it is difficult to see how truly feral cats could

412 be tested under controlled, and even semi-laboratory conditions, the more manageable members of shelter

413 cat populations with a background of abandonment and uncertain life on the streets could be suitable (cf.

414 Urrutia et al. 2019).

415   A further question raised by the present study is the extent to which the rapid approach and

416 apparent strong interest of the cats in the rodent stimuli (in our experience in contrast to cats' behaviour in

417 other, often seemingly arbitrary "novel object" tests) was innate? The immediate attraction to and

418 sustained interest of most of the cats in the stimuli, and then a significant number discriminating and

419 choosing between them in tests of just two minutes, and even by individuals raised from birth exclusively

420 in doors, suggests that cats might have inborn mechanisms supporting the rapid visual recognition of

421 potential prey (Spotte 2014; Wang et al. 2019). The nature of these mechanisms is unknown and could be

422 something as general as their propensity to respond to erratically moving small objects, but then also to be

423 cautious if these exceed a certain size. Such general tendencies might be then fine-tuned by experience,

424 enabling animals to make more precise and adaptive choices. A possible indication of this in the present

425 study was the tendency in Experiment 2 of indoor/outdoor cats to choose the smaller, presumably in

426 several respects safer prey option significantly more often than did the exclusively indoor cats. However,

427 as our sample size was rather small, this needs to be investigated more extensively using a larger sample

428 and better defined in terms of past hunting experience.

429   Our second interest in conducting this study was to see if possible individual differences in

430 behavioural style and decision-making, including risk-taking in a quasi-hunting context, would be present

431 among our test subjects. Within the limits of our sample and test set-up, this seems to have been the case.

432 In both Experiments we found consistent repeatability in the scores of individual cats on the three main

433 behavioural measures; latency to approach the stimuli, time spent near them, and duration of tail waving

434 while orienting toward them. In addition, individual cats' scores on each of the three measures were

435 positively correlated across the two Experiments. Individual differences in the per cent of the total trial

time spent near either stimulus that was spent near a particular option ("choice") was also stable in both Experiments. This provides support for the reliability and validity of the present paradigm as a test of cats' cognitive ability. It also suggests that the general variance in cats' responding to the various stimuli may not simply have been random noise but rather, at least in part, also to have reflected consistent differences in individuals' behavioural style or "personality", for example, in adopting a more timid, cautious strategy in a novel and potentially dangerous context, or rather taking a bolder, more risky approach (Carere and Locurto 2011).

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval All applicable international, and/or institutional guidelines for the care and use of animals were followed. Throughout the study, animals were kept and treated according to the Guide for the Production, Care and Use of Laboratory Animals, Mexico (Norma Oficial Mexicana NO-062-200-

462   1999), and with approval by the Institutional Committee for the Care and Use of Laboratory Animals

463   (CICUAL, permission ID 6325) of the Institute of Biomedical Research, UNAM. This article does not

464   contain any studies with human participants performed by any of the authors.

465

Supplementary Material 1. Results of the General Estimating Equations

	Experiment 1 (numerosity)				Experiment 2 (size)			
	Estimate	SD	$\chi2$	*P*	Estimate	SD	$\chi2$	*P*
Minimum latency to approach								
Intercept	28.9	13.7			2.17	8.81		
sex (m)	8.56	16.0	0.07	0.79	2.79	6.57	0.93	0.34
age	-0.27	1.56	0.00	0.96	-0.05	0.91	0.03	0.87
weight	-4.28	3.30	1.62	0.20	2.26	2.40	0.86	0.35
experience (od)	1.03	14.5	0.01	0.94	0.05	6.42	0.00	0.99
Total time near stimuli								
Intercept	80.9	15.8			79.9	20.9		
sex (male)	-19.8	16.6	1.71	0.19	-18.2	16.0	1.51	0.22
age	-1.21	1.93	0.89	0.35	1.60	2.24	0.79	0.37
weight	5.14	3.72	1.88	0.17	1.22	4.97	0.05	0.82
experience (od)	-0.58	12.7	0.00	0.96	3.99	14.1	0.08	0.78
% time near the more numerous/larger stimulus								
Intercept	77.8	10.2			63.4	9.78		
sex (male)	16.6	6.78	2.44	0.12	14.0	8.54	2.39	0.12
age	-0.15	1.42	0.04	0.85	**-1.30**	**1.20**	**4.26**	**0.04**
weight	-5.38	4.54	1.32	0.25	-4.47	2.03	3.05	0.08
experience (od)	-3.57	8.81	0.16	0.69	**-18.2**	**7.06**	**6.65**	**0.01**
Time tail waving								
Intercept	8.99	4.82			6.00	3.97		
sex (male)	-4.99	3.67	3.21	0.07	-2.99	3.11	1.37	0.24
age	-0.39	0.65	0.36	0.56	0.24	0.64	1.17	0.28
weight	0.26	0.61	0.13	0.72	-0.07	0.62	0.06	0.81
experience (od)	1.93	4.69	0.17	0.68	4.98	4.14	1.45	0.23

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2. DISCUSIÓN GENERAL

En el Experimento 1, 19 de 24 gatos fueron incluidos en el análisis. Sin haber sido entrenados ni haber sido privados de alimento previo a las pruebas, dirigieron de inmediato su atención a los estímulos y se acercaron rápidamente a alguno de ellos, también pasaron una cantidad considerable del tiempo total de las pruebas cerca de alguno de los mismos. Esto nos sugiere que los estímulos (roedores vivos) son altamente motivantes para los gatos, incluso para aquellos que habitan exclusivamente en interiores y no cuentan con experiencias de encuentros con estas presas. El tiempo que los gatos pasaron cerca de alguno de los tanques parece ser la medida más confiable para evaluar su discriminación y elección entre las dos opciones numéricas que les presentamos en el experimento. El hecho de que en promedio los gatos hayan pasado más tiempo cerca del tanque que contenía el mayor número de ratones, que la mayoría de los gatos lo haya hecho así, y que los gatos no hayan cambiado con frecuencia su posición entre los tanques, sugiere que rápidamente percibieron la diferencia entre los estímulos y que hicieron su elección a cierta distancia. Esto a su vez, sugiere que los gatos son capaces de evaluar números de manera rápida y espontánea en una situación casi-natural, lo que es consistente con reportes previos en los que se encontró que los gatos pueden distinguir entre diferentes números de porciones de alimento (inanimadas) y que generalmente eligen el mayor número (Bánszegi et al. 2016).

Sin embargo, los detonantes perceptivos (por ejemplo, visuales u olfativos) y los mecanismos cognitivos detrás de esta elección no son claros. Los gatos pudieron haber sido atraídos simplemente por la mayor actividad que presenta el arreglo de tres ratones, sin implicar ninguna forma de que ¨cuentan¨. No obstante, su elección también implica que esta mayor actividad no les representaba una amenaza, y que lo que detectaron fue que la actividad era emitida por varias entidades pequeñas e inofensivas. Especulando un poco más, esto pudo haberlos llevado a elegir el mayor número de ratones

para incrementar la posibilidad de obtener por lo menos uno (van Orsdol 1984). Cualquiera que sea la causa que explique porqué la mayoría de los gatos eligió el tanque que contenía el mayor número de ratones, los resultados coinciden con resultados previos que reportan la habilidad de los gatos para detectar y discriminar diferentes números (Pisa & Agrillo 2009; Bánszegi et al. 2016), además de ampliarlos al demostrar que los gatos también son capaces de evaluar de manera rápida y espontánea la numerosidad de estímulos vivos ecológicamente relevantes, y elegir de tal manera que se puede interpretar como de significancia adaptativa.

En el Experimento 2, 22 de 24 gatos fueron incluidos en el análisis. Como en el Experimento 1, dirigieron casi inmediatamente su atención hacia los tanques, se acercaron a ellos rápidamente y pasaron un tiempo considerable cerca de uno u otro. De nuevo, el tiempo que los gatos pasaron cerca de alguno de los tanques resultó la medida más confiable de su discriminación y elección, en este caso entre dos opciones de presas de diferente tamaño. Sin embargo, en contraste con su comportamiento en el Experimento 1, en el que su tendencia fue elegir el estímulo de mayor número, aquí los gatos en su mayoría pasaron mayor cantidad de tiempo cerca del estímulo de menor volumen (el ratón) que con el de mayor volumen (la rata). Este contraste sugiere que a pesar del número relativamente pequeño de la muestra de gatos que realizaron los experimentos, su conducta representa una habilidad real de discriminación y elección y no simplemente una respuesta aleatoria a estímulos generalmente atractivos. Aunque, de nuevo, no es claro qué mecanismos perceptuales o cognitivos subyacen a esta elección, eso se puede volver a interpretar como de valor adaptativo. Una rata adulta es un adversario considerable para un gato (Biben 1979; Childs 1986) que debe minimizar el riesgo de heridas que pudieran poner en juego su éxito futuro al cazar, ya que al ser un cazador solitario depende exclusivamente de sus propias habilidades. Esto es consistente con los hallazgos de Bánszegi et al. (2016) quienes reportaron que los gatos prefieren una mayor porción de alimento a una pequeña, hasta que la mayor poción excedía un cierto tamaño. Aunque el número de gatos puestos a prueba fue modesto, es interesante notar que los gatos de mayor edad con acceso a exteriores mostraron una

mayor preferencia por el ratón que por la rata, lo que quizá refleja su experiencia con los dos tipos de presa, ambas muy numerosas en la Ciudad de México.

Nuestro mayor interés al realizar este estudio era evaluar la discriminación de número y tamaño en el gato doméstico utilizando estímulos de relevancia natural para la biología conductual de la especie, en este caso potenciales presas vivas. Efectivamente, encontramos evidencia para ambas formas de habilidad discriminativa, de número y de tamaño. En las pruebas de discriminación de números, los gatos señalaron lo que se podría interpretar como elección de presa permaneciendo significativamente más tiempo cerca del mayor número de presas pequeñas (tres ratones) que cerca del menor número de presas pequeñas (un ratón) que se les presentaron simultáneamente. En contraste, en las pruebas de discriminación de tamaño pasaron significativamente más tiempo con el estímulo de menor tamaño (un ratón) que cerca del estímulo de mayor tamaño (una rata adulta). Esta disyunción entre los resultados de los dos experimentos, esto es, una preferencia aparente de los gatos por el mayor número si se les presenta presas pequeñas, pero por el tamaño pequeño cuando se les presenta dos potenciales presas de diferente tamaño, sugiere que los animales estaban haciendo juicios reales y, como sugiere previamente la discusión de cada uno de los experimentos, en cada caso se puede interpretar que están tomando decisiones adaptativas basadas en estos juicios. Los resultados también son consistentes con reportes previos en dos puntos. Primero, que la decisión de los gatos de atacar presas vivas es influenciada por el tamaño de la presa y la aversión de los gatos a atacar individuos de mayor tamaño (Biben 1979; Childs 1986). Y segundo, que en las pruebas de elección de porciones de alimento, los gatos rechazaban las porciones mayores a cierto tamaño, posiblemente porque las percibían como amenazadoras o de un manejo poco económico (Bánszegi et al. 2016).

Fue notable la rapidez con la que los gatos respondieron a los estímulos, inclusive los gatos que habitan exclusivamente en interiores y que presumiblemente no tenían experiencia previa con roedores (ver también Panteleeva et al. 2013 donde se muestra un fenómeno similar en ratones sin experiencia previa. También fue notable la consistencia en los patrones de respuesta a pesar de haber realizado las pruebas en el ambiente particular de cada una de las casas. Sin embargo, estos dos aspectos de la metodología pueden haber contribuido a que los resultados obtenidos sean coherentes y consistentes; la combinación de usar estímulos etológicamente relevantes (cf.González et al. 2018) y haber puesto a prueba animales no entrenados y en un ambiente familiar que minimizaba el estrés y la ansiedad. Aunque evaluamos numerosas variables conductuales, la más consistente y útil para determinar la discriminación de los gatos y su elección del estímulo, fue el tiempo que pasaron cerca de alguno de los dos. Esto también puede ser un reflejo de la biología conductual del gato doméstico, al cual se le considera un depredador que acecha, que espera a su presa en lugar de perseguirla (Turner & Meister 1988).

Hay que tener en cuenta, que los resultados obtenidos en el presente estudio no son absolutos, y que las aparentes elecciones aquí hechas por los gatos pueden no aplicarse a gatos que sean puestos a prueba en condiciones diferentes a las de este estudio. Nuestros animales no estaban privados de alimento, podría predecirse que los animales que han experimentado privación de alimento durante corto tiempo o a lo largo de su historia de vida como los gatos ferales, tomarán decisiones diferentes, más arriesgadas a las de los animales que pusimos a prueba aquí (Adamec 1976; Biben 1979). Aunque sería difícil ver realmente la respuesta de gatos ferales bajo condiciones controladas e incluso de laboratorio, los miembros más manejables de gatos en condiciones de albergue con historial de abandono y de vida callejera podrían ser considerados para este tipo de pruebas (cf.Urrutia et al. 2019).

Otra de las preguntas que surgieron en este estudio es ¿hasta qué punto el acercamiento rápido y el aparente gran interés de los gatos en los roedores (en nuestra experiencia en contraste con la

conducta de los gatos hacia otros objetos frecuentemente arbitrarios en pruebas de objeto nuevo) es innato? La atracción inmediata y el interés sostenido hacia los estímulos por parte de la mayoría de los gatos, así como un número significativo de ellos discriminando y eligiendo entre ellos en pruebas de solamente dos minutos, incluso en animales que nacieron y se desarrollaron exclusivamente en interiores, sugiere que los gatos pueden tener mecanismos innatos que propician un rápido reconocimiento visual de presas potenciales (Spotte 2014; Wang et al. 2019). La naturaleza de estos mecanismos es desconocida y podría ser algo tan general como su propensión a responder a objetos pequeños en movimiento errático, pero también a ser cautelosos si estos exceden cierto tamaño. Tendencias tan generales pueden ser afinadas por la experiencia, permitiendo a los animales tomar decisiones más precisas y adaptativas. Una posible indicación de esto en este estudio fue la tendencia de los gatos de exteriores en el Experimento 2 a elegir la presa más pequeña y presumiblemente en varios aspectos, la más segura significativamente con mayor frecuencia que los gatos que habitan exclusivamente en interiores. Sin embargo, al ser el tamaño de nuestra muestra bastante pequeño, esto necesita ser investigado usando un tamaño de muestra mayor y acotando de manera mejor definida los términos de la experiencia previa de depredación de cada individuo.

Nuestro segundo interés al conducir este estudio era ver si en los sujetos de estudio estarían presentes diferencias individuales en el estilo conductual y en la toma de decisiones, incluyendo la toma de riesgos en un contexto de potencial depredación. Dentro de los límites de nuestra muestra y las condiciones de nuestras pruebas, parece que este fue el caso. En ambos Experimentos encontramos repetibilidad consistente en los registros individuales de los gatos de las tres principales medidas conductuales; latencia para acercarse al estímulo, tiempo pasado cerca de un estímulo y duración de tiempo moviendo la cola mientras estaban orientados hacia algún estímulo. Es más, los registros individuales de los gatos para las tres medidas se relacionan positivamente a través de los dos Experimentos. Diferencias individuales en el porcentaje de tiempo que pasaron cerca de alguno de los

estímulos y específicamente cerca de una opción en particular (elección) fue estable en ambos Experimentos. Esto le da soporte a la confiabilidad y validez del presente paradigma que pone a prueba la habilidad cognitiva de los gatos. También sugiere que la varianza general en la respuesta de los gatos a los diferentes estímulos no fue azarosa, si no, que por lo menos en parte, también refleja diferencias individuales consistentes de estilos conductuales o ¨personalidad¨, por ejemplo, al adoptar una estrategia más tímida y cautelosa en un contexto nuevo y potencialmente peligroso, o adoptando un acercamiento más intrépido y arriesgado (Carere & Locurto 2011).

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