## Table S2 Studies and surveys linking play and welfare outcomes in domestic cats and kittens.

| Object play | Experimental Design | Measures | Cat age during study | Sample size | Outcomes |
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| Caro (1980) | 11 kittens assigned object play (OP) group and given opportunities to play with 2 toys: a black table tennis ball and an elliptical black woollen ball filled with sand.<br>8 control kittens not given opportunities or exposure to object play with toys. Kittens in both groups reared normally with mothers and littermates. | At 6 mnths of age, kittens from both OP and Control groups individually tested on ability to catch and kill 4 types of live prey (rat, mouse, canary, and goldfish). Behaviours recorded and analysed for differences in predatory motor patterns, frequencies, and latencies between the groups. | 4 weeks – 6 months | 19 kittens n=11 for OP, n= 8 for C | Small differences in latency with prey between the OP and control group. OP kittens slower in some circumstances to paw at or initiate behaviour pattens with prey. No differences between no of prey killed and eaten between groups. Within this study, object play did not show any quantitative difference in the development of adult predatory skills. |
| Bateson & Young (1981)<br>Bateson et al. (1981)<br>Bateson et al. (1990) | Bateson and Young (1981): Kittens raised with mothers until 31-35 days of age when 2 kittens from each litter gradually separated to create 2 groups: Control: kittens raised with mother<br>Early weaned: kittens raised separated from mother and minimal human handling. | Checklist of 9 play behaviours and 2 non-play behaviours every 2-3 days for 30 mins (presented with a tennis ball, a stuffed toy dog and a stuffed piece of rabbit skin) | Birth – 9 weeks | 28 kittens. for each condition n=14 | Separated, early weaned kittens showed significantly higher play frequencies than control kittens. Similar results through induced onset of early weaning using bromocriptine injection (Bateson et al. 1981), or malnourishment of the mother (Bateson et al. 1990). Play increased in kittens as their mother decreased her care of them (Bateson et al. 1981; Bateson et al. 1990). |
| Hall & Bradshaw (1998) | To study the impact of hunger on play, cats presented with a large or small toy, immediately after, or 16 hrs after their last meal. | 24 behavioural patterns observation through video footage. | 5-6 years | 9 cats | Cats played more with the small toy and generally avoided the large toy. Avoidance of large toy decreased and play intensity and frequency of close-contact behaviours with the small toy (such as a 'kill bite') increased when cats had been fasted for 16 hours. The authors compare these results to a study on predatory behaviour in cats which showed that the probability of a kill was able to be predicted by the hunger level of the cat and the size of the prey (Biben 1979). These findings could suggest that predatory behaviour and object play may have a shared motivational basis. If this is correct, this information may provide cat guardians with an opportunity to satisfy predatory instincts with play. However, these findings may instead indicate that as hunger levels increased, inhibition levels may have decreased as per Pellis et al., 1988. |
| Hall et al. (2002) | Experiment 1: Effects of colour and sensory contact in cats with no hunting history. *Treatments:* white or black ellipsoidal fake-fur covered toy.<br>Experiment 2: Effects of interval length between play sessions on magnitude of disinhibition. *Treatments:* inter-session interval of 5, 15 or 45 minutes.<br>Experiment 3: Replication of part of experiment 2 on a population of cats with hunting experience. *Treatment:* 5 min inter-session interval with toy either changed or kept same for 4th session.<br>Experiments 1 and 2 conducted in a walled cubicle and experiment 3 conducted within the cat's home. | Analysis conducted on play intensity using:<br>Clutch: cat holds the toy close to the body with one or both front paws<br>Kill-bite: cat delivers a forceful bite to the toy | Experiment 1 and 2: 5-8 years<br><br>Experiment 3: 13 months – 7 years | 21 cats, for experiments 1 and 2: n =8 for experiment 3: n=8 | Play intensity declined in both group-housed and pet cats by 3rd play session. When a contrasting new toy was presented in the 4th session, play response intensified and became disinhibited. This intensity in the 4th session associated with inter-session interval duration. When durations between sessions were longer (25-45min) play not observed to recover its initial intensity. Shorter durations between sessions showed a higher intensity of play response, roughly equal to its initial level when duration was 15 mins and even higher than 1st session when inter-session was 5 mins. This finding of heightened intensity vs even the first session is indicative of post-inhibitory rebound, proposed as an indicator of frustration and therefore diminished welfare in farm animals (Freire et al., 2009). Since this study was published many sources have recommended regular rotation and replacement of toys to reduce habituation, including: Alho et al. (2016) and Ellis (2009). |
| Arhant et al (2015) | 30 animal shelters visited twice, 50-76 days apart. | Shelter management questionnaire plus number of toys available, cat physical condition, behaviour and housing environment | Adults (Ages unreported) | 30 animal shelters, mean of 63 cats per shelter (range, 3-583) | Poor physical condition of the cats significantly associated with low provision of toys. The authors suggest providing toys to stimulate object play might be important for shelter cat welfare. However, they caution that because 20-31% of agonistic encounters occur around re- sources such as toys, toys need to be provisioned in adequate numbers for all cats and disinfected to avoid transmission of disease. |
| Kogan & Grigg (2021) | Online survey | Questions on demographics, cat problem behaviours, environmental conditions, daily play times, toy use, use of laser light pointers and a measure for guardian-cat relationship called the Pet Relationship Scale (Kafer et al. 1992). | Adult cats (range 1 year to 10+ years) | 618 cat guardians | Significant associations between higher frequency of laser light play and occurrence of abnormal repetitive behaviours such as spinning on the spot, tail chasing, staring 'obsessively' at lights or reflections or fixating on a specific toy. These findings suggest that laser light play may be associated with abnormal repetitive behaviour development in cats. |
| **Object and Social Play** | **Experimental design** | **Measures** | **Cat age during study** | **Sample size** | **Outcomes** |
| West (1974) | Fourteen kittens were observed within laboratory settings.<br>Fourteen kittens were observed within a rural home with access to the outdoors.<br>All kittens were kept with their mothers. | Observations of development of motor patterns, motor patters during social play, frequency of play and observations of object play were reported daily. | 14 days – 7 months | 28 kittens, for each condition n=14 | Motor patterns associated with social play appeared to provide an opportunity for exercise.<br>Social play may function to develop and maintain friendly social relations as well as allow cats to identify friendly or threatening approaches by other cats. |

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| Guyot (1980) | Kittens experimentally assigned to the following rearing conditions:<br>[1] biological mother and 1 littermate<br>[2] biological mother only<br>[3] brooder device and 1 littermate (brooder provided constant warmth of 32-38°C, a shag carpet for contact and milk through a nipple)<br>[4] brooder device only | Kittens tested weekly in an open field to determine separation distress (not a measure of play so might have to move this to the outcomes section) and then in a playroom from 8 to 20 wks of age for social and individual behaviours against a checklist. | Birth - 20 weeks | 32 kittens, for each condition n=8 | Kittens in brooder only condition developed object play normally, though at a lower frequency than kittens raised with a mother and/or littermates. Socially deprived kittens did not engage normally in social play, appeared to lack social communication skills, and struggled to cope with exposure to novel stimuli or environments well into adulthood (it is not clear when or how this was checked by the researchers). These findings suggest that socialisation, and in particular social play, may be important in developing and maintaining social skills in cats. |
| Carlstead et al. (1993) | Laboratory born and reared cats randomly assigned to:<br>STR: Altered caretaking including irregular cleaning and feeding times, no talking or petting by caretakers and unpredictable daily manipulations.<br>CON: Standard caretaking schedule. | Measures included 24 hr video of behaviour, daily urine samples for cortisol and pre- and post-trial testing of hormone stimulation with adrenocorticotropic hormone (ACTH) and luteinizing hormone-releasing hormone (LHRH). | 9 months-6 years | 16 cats, for each condition n=8 | Cats in STR group showed consistently elevated urinary cortisol concentrations, enhanced adrenal sensitivity to ACTH and reduced pituitary sensitivity to LHRH throughout 3-week trial period. Play and exploratory behaviour was suppressed.<br><br>This study showed that irregular or poor caretaking is a strong psychological stressor in domestic cats. These results connect physiological and behavioural signs of stress in cats and provide evidence for the reduction or absence of play behaviour during times of stress in cats. |
| Edwards et al. (2007) | Cats underwent an adapted version of the Ainsworth Strange Situation Test (Ainsworth et al. 2015). | Cat behaviour when alone, with their guardian or with a stranger were compared. | 1-7 years | 28 cat and guardian pairings, n=28. | Cats reported to show play behaviour only when with their guardian, not with the stranger or alone. This study showed initial evidence for the presence of attachment or social bonds between guardians and cats. Further, it illustrates that this attachment may impact a cat's behaviour, including play. This study was repeated by Potter and Mills (Potter & Mills 2015) with slightly changed experimental procedures and analysis. Their version of the study indicated that though cats vocalised more when their guardian left compared to when the stranger left, there was no further evidence for a secure attachment bond between cat and guardian. |
| Loberg & Lundmark (2016) | Cats exposed to large group living (15 or 14 cats at a time) in varying floor areas, per cat, of $1m^2$, $2m^2$ and $4m^2$. | Cats tested in a balanced order between the three flooring sizes for 3 days at a time with acclimation periods between treatments for a total of 54 days. Stress measured using the Cat-Stress-Score (Kessler & Turner 1997) and observations of behaviours recorded. | 1-12 years | 89 cats, in groups of 15 or 14 | As space increased, cats showed more solitary play with significant differences in solitary play frequency between the $1m^2$ and $4m^2$ treatments. The study argues these results indicate that increased space was associated with increased welfare in cats. No difference was found in social play, however the definition of social play used relied on social-object play and did not include rough and tumble play or chasing (social-locomotor) play. |
| Shreve et al. (2017) | Free operant preference assessment. Cats from 2 populations (shelter and pet) presented with 3 stimuli within 4 categories: food, human social interaction, scent and toy. | The proportion of time each cat spent interacting with each stimulus recorded and analysed. In a final assessment, the most-preferred stimulus from each of the 4 categories presented to determine the cat's most-preferred stimulus overall on both a population and individual level. | 1-20 years | 38 cats, for each condition n=19 | The largest no of cats (n=25) selected playing as their most preferred social interaction. However statistically, there was no difference in preference between playing and petting so both were used randomly in the final between-category assessment.<br>When presented with their most-preferred selections from all four categories, cats generally preferred social interaction (playing or petting) to food, scent, or a toy. The study also highlights that there is significant individual variability in cat preferences, and these differences should be considered when seeking to improve cat welfare. |
| Cecchetti et al. (2021) | Cats with known hunting history. 6 interventions to decrease predatory behaviour tested. A before-after-control-impact design was utilised with: bell collars, Birdsbesafe collar cover, food in a puzzle feeder, provision of high quality, grain free food or 5-10 minutes of daily social-object play. | Guardians reported the total no of prey animals, as well as a breakdown of the no of mammals or birds, captured and brought home by cats living in the same household. | Juveniles and adults (exact ages unreported) | 355 cats, n per intervention is unclear | When compared to pre-treatment period, total nos of predation per cat were significantly reduced by the play (-25%). However, food puzzles increased predation (+33%).<br>Though food was the most successful intervention overall (-35%), only 33% of participants in the food treatment indicated they would be happy to continue with the intervention, compared to 76% of participants in the play intervention, suggesting that play may be an accessible and easy to implement intervention for the general public. |
| **Social Play** | **Experimental design** | **Measures** | **Cat age during study** | **Sample size** | **Key findings** |
| Collard (1967) | Kittens divided into groups of 10 and randomly assigned to:<br>[1] 5-person group - kittens handled and played with by a different person each day for 5 consecutive days per wk.<br>[2] 1-person group - kittens were handled and played with the same as group 1 but by one experimenter.<br>[3] No-person group - kittens received no handling or play from any experimenters. | Observations were recorded ad hoc of through tabulation of behaviour occurrences. | 5 weeks – 9 weeks | 30 kittens, for each condition n=10 | Kittens in 5-person group showed less fear of strangers than kittens in other groups.<br><br>Kittens in 5-person group approached a novel string toy more often than kittens in other groups however kittens in the 1-person group showed greater success and motivation in string catching than the other groups. Kittens in no-person treatment showed decreased play behaviour compared to the other groups.<br><br>Kittens in 1-person group showed twice as many playful or affectionate contacts (climbing on, rubbing against, playful mouthing of fingers) with their experimenter vs kittens in other groups. When called, one-person kittens were more likely to approach the tester than kittens in the other groups.<br><br>The experimenters noted individual differences in kittens regardless of their assigned experimental condition. |
| Caro (1981) | Kittens assigned to: | During exposures observations of cat | Birth – 12 weeks | 7 litters of 3 | Prey presence had an inhibiting effect on social play with kittens playing less while prey was alive and in the room. |

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| | Mice group: exposure to live white laboratory mice<br>Canary group: exposure to live canaries. All kittens exposed to prey 34 times for 30 or 40 mins, 17 exposures with their mother present. | behaviour scored and recorded continuously while observations of mother cat or kitten behaviour towards prey or other cats recorded on a focal-animal basis for 30 seconds at a time per individual. | | kittens each, 21 kittens total. Mice group n = 9, canary group n=12 | Play behaviours increased significantly following the prey being killed and consumed. This finding is in line with current concepts that play is most commonly present in situations where all other needs have been met and no intense competing systems are present (Burghardt, 2005). |
| Mendl (1988) | 14 laboratory reared litters of kittens from 10 different mothers culled within 2-3 days of birth to litters of 1 or 2. Only male kittens were used. | Each litter observed for 40 minutes three times a day within home pen from 22 to 83 days of age. Data recorded continuously using the Madingley Interactive Computer for Recording Observations ('MICRO', Styles 1980). | Birth -12 weeks | 21 kittens, 7 litters of n=2 and 7 litters of n=1 | Single kittens played more with their mother than kittens reared with a litter mate. Mother cats of single kittens played more with their kitten than mothers of 2 kittens. However total play was higher for kittens reared with a litter mate and mother due to the kitten also playing with the litter mate. Mothers of single kittens were observed to show more aggressive behaviours towards their kitten that kittens reared with a litter mate. The study's author suggests that kittens may prefer playing with a littermate over a mother cat and that differences in size, skill, and willingness to play between a mother cat and a litter mate may lead to quantitative differences between single reared and litter reared kittens in early and later life. |
| Heidenberger (1997) | Online survey | Demographics, questions about the animal's history, problem behaviours, food, housing conditions, veterinary care and quality of the human-animal relationship. | 2 weeks-27 years | 550 guardians, 1177 cats | 86% of guardians reported play to be their favourite way of handling their cat. On average 3 periods of play were spread over the entire day, with each play session lasting 20-40 minutes. Most guardians reported their cat preferred to play with other cats within the household over play with their guardian. Greater time available to interact with the cat was associated with less problem behaviour. |
| Strickler & Shull (2014) | Online survey | Frequency and duration of guardian daily interactions with their indoor cat and no of toys and activities provided for cat.These factors were assessed alongside measures for the prevalence of : aggression to guardian, aggression to visitors, inappropriate urination, inappropriate defecation, inter-household cat aggression, and inter-cat aggression to outdoor cats. | 6 weeks - 18 years with a mean age of 5 years | 277 cat guardians | Guardians who reported play bout times of 5 mins or more also reported fewer behavioural problems than guardians with play bout times of 1 min. |
| Gajdoš Kmecová et al. (2021b). | Online survey | Demographic information, items about cat behaviour, including 85 from the Fe-BARQ questionnaire (Duffy et al., 2017) and a further 15 miscellaneous items. | 6 months – 11+ years | 1,805 cats | Social play with other household cats was negatively correlated with aggression in cats.<br><br>Playfulness scores reduced with an increase in age of the cat and an increase in the age the cat was obtained. Play also decreased as fearfulness scores increased. Finally, playfulness increased with increased reports of social play with other household cats.<br><br>These findings suggest that social play with other household cats may reduce issues with aggression that may be an indicator of, or in turn impact, a cat's welfare or the welfare of humans and other animals within the home. Findings on fearfulness and age may further support the concept that play reduces or disappears in time when welfare is compromised either due to the ill effects of age or issues coping in their environment as indicated by fearfulness. |

| **Object, Social and Locomotor Play** | **Experimental design** | **Measures** | **Cat age during study** | **Sample size** | **Key findings** |
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| Duffy et al. (2017) | Online survey | The Fe-BARQ, a questionnaire instrument for quantitative guardian-reported assessment of pet cat behaviour was developed and validated. | 7 months -20 years with a mean age of 6 years | 2788 cat guardians | Responses showed associations between play and potential welfare factors. Declawed cats reported to show less playfulness than cats with intact claws while reports of playfulness declined with age. |

| **Social-object Play** | **Experimental design** | **Measures** | **Cat age during study** | **Sample size** | **Key findings** |
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| Pyari et al. (2021) | Cats underwent 3 tests within their own homes. Test 1 'play with ball' tested whether the cats chose to interact with varying sizes of balls rolled towards them. Test 2 'play with chaser wand' tested the cat's interactions with a bird shaped soft toy attached to a stick via a string. Test 3 'sound playback' tested the cats' reaction to pre-recorded sounds of a bird chirping, a mouse squeaking, a sheet of paper being crumpled or a rustling bag, respectively. | Tests were recorded for subsequent analysis. | Adults (exact ages unreported) | 31 cats, Outdoor n=13, Indoor only n=18 | Indoor only cats showed greater interest in toys and sounds that showed closer resemblance to prey, and more interest in most stimuli overall, than outdoor cats. The results of this study may indicate that indoor cats, who do not have access to real prey show more intense reactions towards 'replacement stimuli'. This may indicate that play could fulfill a role in enabling a cat's natural behaviours within a setting where predation is not possible such as indoor-only housing. |

| Unspecified play type | Experimental design | Measures | Cat age during study | Sample size | Key findings |
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| Seitz (1959) | Pregnant mother cats brought into the lab 2 weeks before birth. After birth, litters culled to 3 kittens per litter and randomly assigned to.<br>[1] separated from mother at 2 wks of age<br>[2] separated at the age the kittens spontaneously began to wean themselves by lapping from a saucer<br>[3] kept with mother until 12 weeks of age. | Behavioural testing at 9 months of age, an age that the study considered to constitute adulthood. | Birth – 9 months | 18 kittens, for each condition n=6 | Kittens experimentally separated from mothers at 2 wks showed a "greater proneness to anxiety" (Seitz 1959, p.356) when exposed to novel or stressful situations.<br><br>Kittens allowed to stay with their mother until 12 wks exhibited more play behaviour and general playfulness vs kittens separated early from their mother. |
| Martin (1984) | Kittens were born and observed in laboratory settings with their mothers present. | Instantaneous observations were collected every 10 minutes for 14 hours. Mean metabolic rates during play were calculated from measures of oxygen consumption rate, running velocity during play and food intake. | 10-12 weeks of age | Unclear. Minimum 16 kittens. | Kittens spent less than 10% of their day engaging in play behaviours.<br>Additional energy expenditure associated with play accounted for less than 10% of total expenditure.<br>The authors conclude that play is not a 'costly' activity. |