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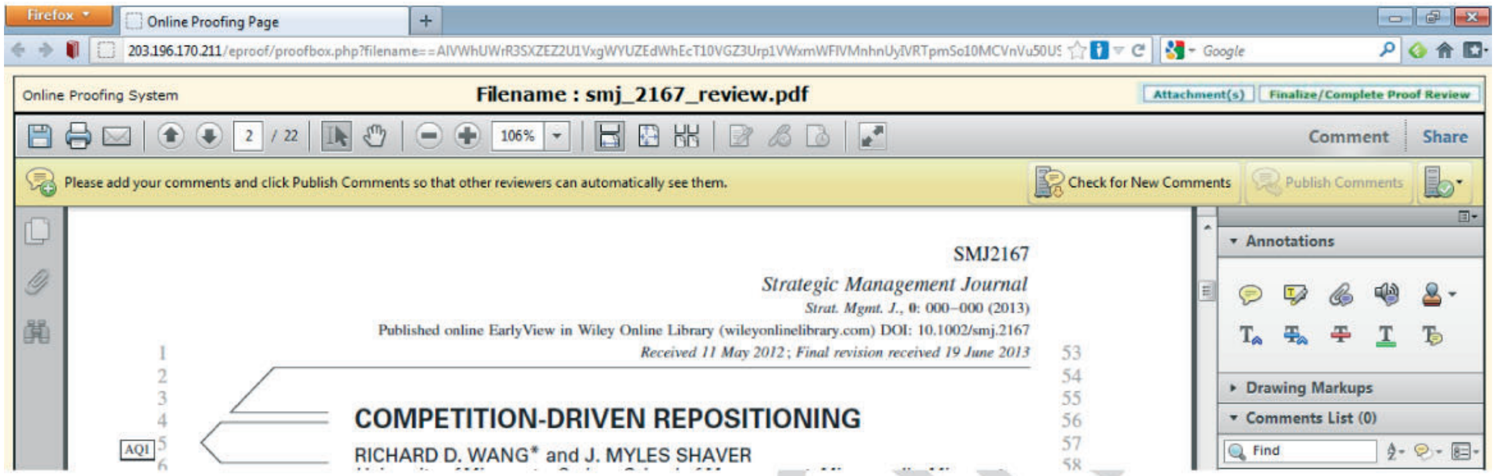

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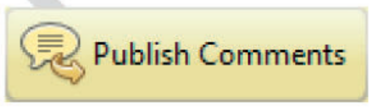

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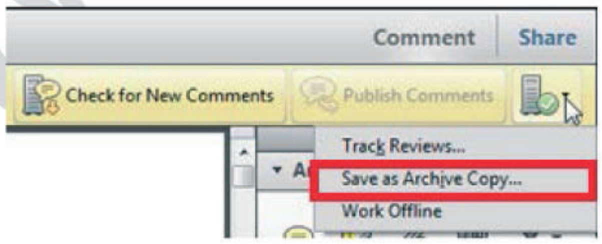

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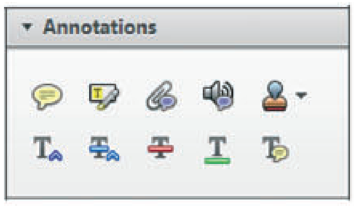

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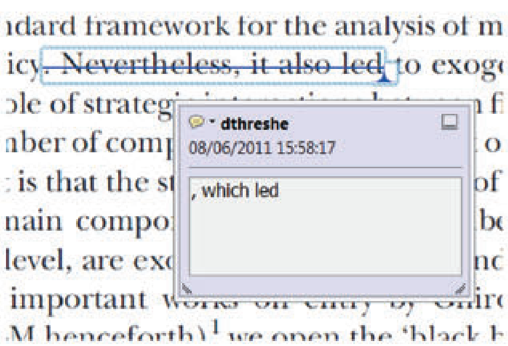

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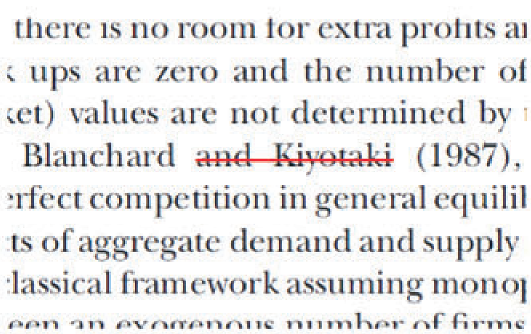

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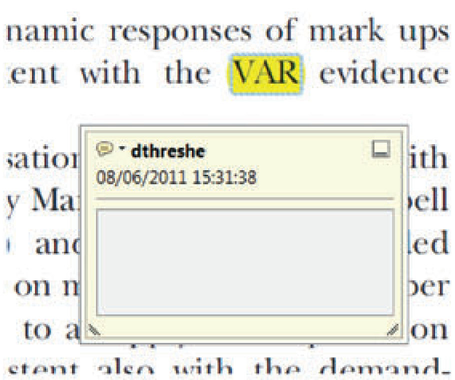

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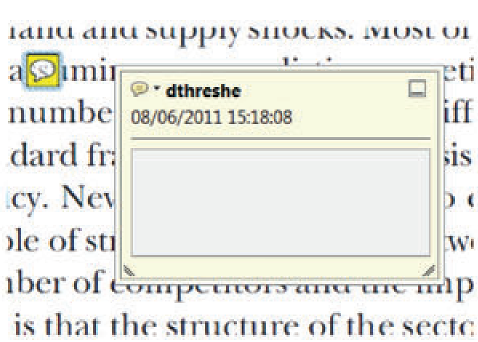

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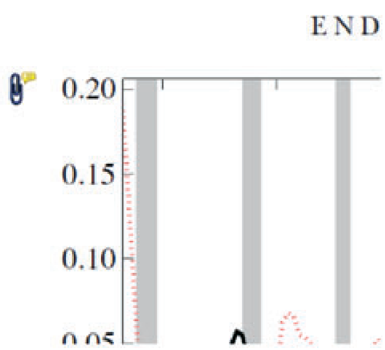

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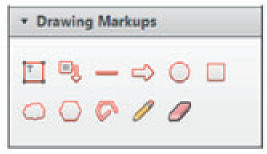

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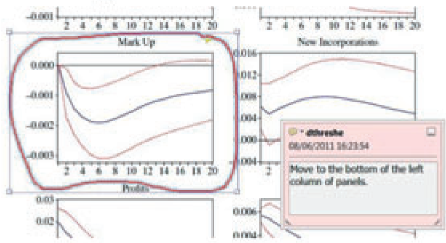

PAPER

Evaluation of facial expression in acute pain in cats

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Objectives: To describe the development of a facial expression tool differentiating pain-free cats from those in acute pain.

Methods: ~~Sixty-eight observers~~ shown facial images from painful and pain-free cats were asked to identify if they were in pain or not. From facial images, anatomical landmarks were identified and distances between these were mapped. Selected distances underwent statistical analysis to identify features discriminating pain-free and painful cats. Additionally, thumbnail photographs were reviewed by two experts to identify discriminating facial features between the groups.

Results: Observers (n=68) had difficulty in identifying pain-free from painful cats, with only 13% of observers being able to discriminate more than 80% of painful cats. Analysis of 78 facial landmarks and 80 distances identified six significant factors differentiating pain-free and painful faces including ear position and areas around the mouth/muzzle. Standardised mouth and ear distances when combined showed excellent discrimination properties, correctly ~~classifying between~~ pain-free and painful cats in 98% of cases. Expert review supported these findings and a cartoon-type picture scale was developed from thumbnail images.

Clinical Significance: Initial investigation into facial features of painful and pain-free cats suggests potentially good discrimination properties of facial images. Further testing is required for development of a clinical tool.

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INTRODUCTION

The inability of animals to self-report their symptoms provides a major challenge for observers attempting to assess pain. The medical profession faces a similar challenge in the case of non-verbal humans for instance infants and adults with cognitive impairment. Consequently, in both humans and more recently in veterinary medicine, observer-based pain assessment tools have been developed that use a range of cues or behaviours for assessing pain. These may include body movements and posture, physiological variables and in the case of human neonatal and paediatric patients, crying and facial expression (Stevens *et al.* 1996, Bussières *et al.* 2008, Brondani *et al.* 2013). Of these, facial expression is considered a sensitive indicator of noxious procedures, and extensive research has centred on the use of facial expression for measuring acute and postoperative pain intensity in neonates (Grunau *et al.* 1998, Tomlinson *et al.* 2010). Facial expression scales may also be incorporated into multidimensional measure pain instruments that combine behavioural and physiological parameters (Stevens *et al.* 1996, Hand *et al.* 2010).

Darwin (1872) proposed that non-human animals demonstrate facial expression when he stated animals were capable of expressing emotion, including pain, through facial expression. Recently, a growing interest in facial expression has developed as a possible means of assessing pain in non-human animals. The mouse grimace scale (MGS) (Langford *et al.* 2010) is a standardised facial coding system developed by observing changes in facial expression after a noxious stimulus. Similarly, the rat grimace scale (RGS) was developed (Sotocinal *et al.* 2011) and both scales demonstrated high accuracy, reliability and validity. Further studies have involved rabbits (RbGS) (Keating *et al.* 2012) and more recently the development of a pain expression scale for horses has been described (Dalla Costa *et al.* 2014).

The recognition of pain in cats is difficult and has been suggested as one cause of the sub-optimal treatment of pain in this species (Lascelles *et al.* 1999). The purpose of this study was to identify anatomical landmarks and measurable distances on two-dimensional (2D) digital facial images of the feline face, which would discriminate between pain-free and acutely painful cats and to further investigate whether observers could use visual cues based on these findings to distinguish between pain-free and acutely painful cats. The intention was to use the results to construct a caricature faces scale, ultimately to complement the previously described composite measure pain scale for cats (CMPS-feline) for the assessment of acute pain in cats (Calvo *et al.* ~~unpublished~~).

MATERIALS AND METHODS

Study 1: Facial landmark development

Fifty-nine 2D facial images of healthy, pain-free cats were collected from a variety of sources such as veterinary clinics, cat breeders and cat owners recruited from the general public. Each image was a clear, un-obscured, front-on portrait that included the tips of the ears. Photo images were to be of good quality, focused on the face and taken directly in front for a symmetrical view. Firm restraint was avoided. Photos were recommended not be taken in bright light, spotlights or with flash in order to prevent light shadows and squinting due to bright light. All images were formatted using Fiji, an open source computer software package (Schindelin *et al.* 2012). Each image was aligned to avoid rotation, portraying a true portrait format, cropped to include only the face and standardised to a set pixel width size of 1000. After landmarking, each image was saved to file (Fig 1a, b).

Seventy-eight landmarks (points) were chosen on the feline face based on anatomical knowledge and ease of identification on 2D images and between cats with different hair lengths (Appendix 1). Preliminary landmarks were numerically identified on each 2D facial image using the software package Fiji (Schindelin *et al.* 2012).

Following identification of landmarks, 80 distances between pairs of landmarks were developed based on the accuracy of measurement and where changes might be expected between painful and pain-free cats incorporating knowledge of facial changes described during pain in other species. The 80 distances were measured and analysed.

Subsequently, a separate group of cats undergoing postoperative care or hospitalised for traumatic or medical conditions were recruited. Each cat was assessed by an attending veterinarian and allocated a pain score using a numerical rating scale (NRS) (0 for no pain and 10 for worst pain imaginable). For the purposes of this study, those cats awarded scores of 1 or greater were classified as painful. If analgesia was required, a 2D portrait facial image was obtained before analgesia administration. All cats recruited were scored for sedation using a simple descriptive scale (0 to 3) modified from Lascelles *et al.* (1994) (see Appendix 2). Cats with a sedation score of greater than 1 or those with facial disfigurement (e.g. enucleation, pinnal amputation) were excluded. Twenty-eight painful cat portrait images were obtained and each was landmarked with the anatomical points identified from the pain-free cats (controls).

Study 2: Observer discrimination of pain exercise

Sixteen feline facial images were presented in a PowerPoint presentation in no particular order to a group ~~of~~ veterinary surgeons, veterinary nurses, students and support staff (n=68). The photographs presented were from the two groups of images collected as outlined in study 1. Seven images were from the pain-free (control) group (NRS=0) and nine images were cats from the subsequent group of cats rated to be in pain (NRS=1 or greater) by the attending veterinarian using an NRS. Images were displayed for 10 seconds and each respondent marked on a score sheet whether they thought the cat was painful, yes or no, based

(a) (b)

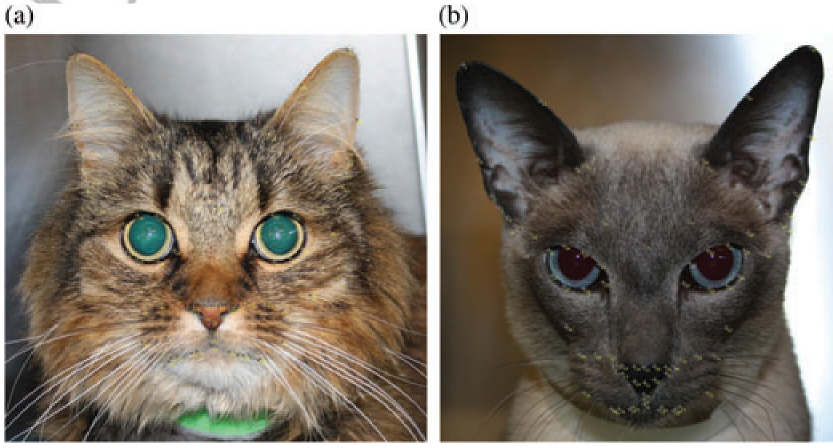

FIG 1. 2D facial images of cats used to develop faces descriptors. Thirty-six paired (right and left face) and six single anatomical landmarks were identified to allow for measurement between points. (a) ~~DSH~~ with landmarks. (b) Pedigree with landmarks

on facial expression. Analysis included tabulation of percent correctly identified and a Pearson correlation analysis of the percent correct and NRS scores.

Study 3: Facial discrimination and development of facial pain assessment tool

Using the database of 87 landmarked facial images (59 pain-free and 28 painful faces) 80 distances identified underwent analysis to reduce the number of distances and assess whether particular distances could discriminate between painful and pain-free cats. To control for size variability between photographs, standardisation of the measured distances was performed against the distance between the outer bases of the ears for the final analyses. The choice of distance with which to standardise against was made on the basis of the consistency of measurement. The total number of distances was then reduced by principal components analysis and factor analysis. Linear discriminant analysis was then used to find the best linear combination of the factors to distinguish between painful and pain-free cats.

A second study was carried out to provide independent and confirmatory identification of painful and pain-free features. This exercise was conducted by displaying two groups of thumbnail images created from the database of facial images and presenting them to two of the authors (JR and AN) with specialist expertise in pain assessment. One image group contained the 28 painful cat facial images and the other contained 51 pain-free images. The experts were asked to look at the images and identify features of the feline face they believed discriminated between these two groups.

The distances identified by the discriminant analysis in conjunction with the two experts' identified features were used to form the basis of a feline "faces" categorical scale depicting an increasing level of pain.

RESULTS

Study 1: Facial landmark development

Cats from which the 59 pain-free images were obtained included 35 domestic shorthair, 10 domestic longhair and 14 purebred cats (six Siamese and eight Persians). Thirty-six paired (right and left faces) and six single anatomical landmarks were chosen as being easily identifiable to allow for consistent measurement between points. Of the paired landmarks, 10 were associated with the ear, 5 with the nose, 11 with the eyes, 4 with the lips, 5 with the muzzle and 1 with the forehead. The six single landmarks were associated with the forehead, nose and mouth (Fig 1a, b).

For painful cat faces, 28 cats (19 domestic shorthair, 2 domestic longhair and 7 purebred) were recruited from a number of clinical locations including two small animal general practices and three veterinary university teaching hospitals. All painful cats were recruited as part of a study to validate a CMPS-feline. The mean NRS score was 3 (range 1 to 9). Six of the 28 scores were postoperative pain scores for surgical conditions such as fracture repair, neutering and skin biopsy. Five of these cats had a sedation score of 0 and one had a sedation score of 1 at the time of scoring and facial imaging. The remaining 22 cats had sedation scores of 0 and were hospitalised for non-surgical conditions such as abdominal pain, pelvic fracture and acute renal failure. At recruitment, 11 cats had received analgesia (eight had received opioids and three had received meloxicam) and 14 cats had received no analgesia. In three cats it was unidentified whether they had received analgesia or not. Each of the paired and single anatomical landmarks identified in the pain-free cat images were plotted on each painful cat facial images.

Study 2: Observer discrimination of pain exercise

Observers comprised five veterinary nurses, one animal care assistant, five veterinary students, nine interns, 12 residents of varying disciplines, 10 senior university clinicians and 26 general practice veterinarians.

Of the 16 cat facial images shown to observers, 9 had been assessed as being in pain and seven were control cats. The percentage correctly identified ranged from 18 to 94%. (Table 1). In six cases (four control and two painful), less than 50% observers scored correctly.

Two individuals scored 15 of 16 cats correctly while six individuals scored eight or less cats correctly. Forty-six observers, of various experience levels, identified 10, 11 or 12 cats correctly. The percentage correctly identified showed only a weak correlation (Pearson correlation=0·214) with the NRS scores.

Study 3: Facial discrimination

Eighty distances (between pairs of landmarks) were initially identified. Principal component analysis identified six factors that explained more than 85% of the variation in the facial distances; thereafter a varimax factor analysis was carried out to identify these factors. The distance variables were first sorted and any variable with a loading less than 0·5 was set to 0. The six factors were then used as the explanatory variables in a linear discriminant analysis with cross-validation. Using all factors, the percent discrimination was 86%. Subsequently, each factor individually was used in the same procedure, with percent discrimination varying between 52 and 74%. The key descriptions of the factors related to eye and ear, mouth and nose.

Table 1. Percentage of correct classification of 16 facial images shown to 68 veterinary surgeons and veterinary nurses

Cat number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Control/painful	C	P	C	P	P	C	P	P	C	P	C	C	C	P	P	P
NRS	0	8	0	7	7	0	7	2	0	6	0	0	0	2	4	1
Scored correctly (%)	39·7	75	94	92	23	26	53	67	59	35	88	25	18	63	82	71

C Control cat, P Cat scored as in pain using a numerical rating scale where 0=no pain and 10=worst pain imaginable

Individual mouth distances on average were statistically significantly different ($P<0{\cdot}05$) between pain-free and painful cats. The standardised mouth distances showed good discrimination, the percentage correctly classified between pain-free and painful cats was 81%. There were five ear distances identified, three showed statistically significant differences between control and painful cats and when standardised, the four standardised ear distances were all statistically significant (note that four standardised distances since the fifth was used as the standardisation). The standardised ear distances showed good discrimination between the pain-free and painful cats, the percentage correctly classified between pain-free and painful cats was 95%. The standardised mouth and ear distances when combined showed excellent discrimination properties, the percentage correctly classified between pain-free and painful cats was 98%. Identified distances are shown in the portrait image of Fig 2. The distances associated with the eyes were removed owing to concerns regarding changes in eye shape and the potential effects of opioids and sedatives/tranquillisers.

Additionally, the two experts who looked at the thumbnail images identified important distinguishing features to include the landmarks on the ear as well as their position with respect to the eyes as well as the landmarks around the mouth.

There was also concern expressed regarding eye position and changes in eye shape due to effects of drugs such as opioids.

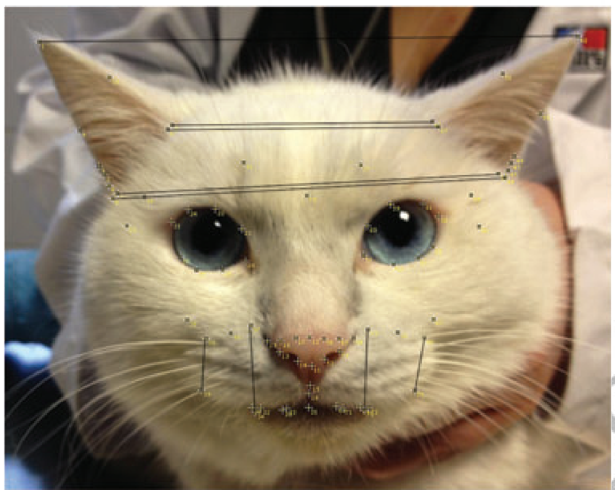

FIG 2. Portrait depicting identified distances significantly different between painful and pain-free cats

Facial pain assessment tool development

As a result of the discriminatory properties of the distances and the pain experts' discussions, an artist was consulted for the development of the pictorial "faces" tool. As a result, a faces scale was designed using the ear position (the slope of the line joining the base of the ear and tip of the ear) and the nose/muzzle shape. Caricatures were developed and sequenced as a facial scoring scale (Fig 3). Two caricature panels were created, one depicting the ear position, the other depicting the nose/muzzle shape. Each panel contained three faces depicting increasing pain; score ranged from 0 to 2.

DISCUSSION

Facial expression is an important feature of pain in human paediatric and neonatal medicine (Grunau & Craig 1987, Tomlinson *et al.* 2010). In veterinary medicine, interest in facial expression as a means of assessing pain is increasing.

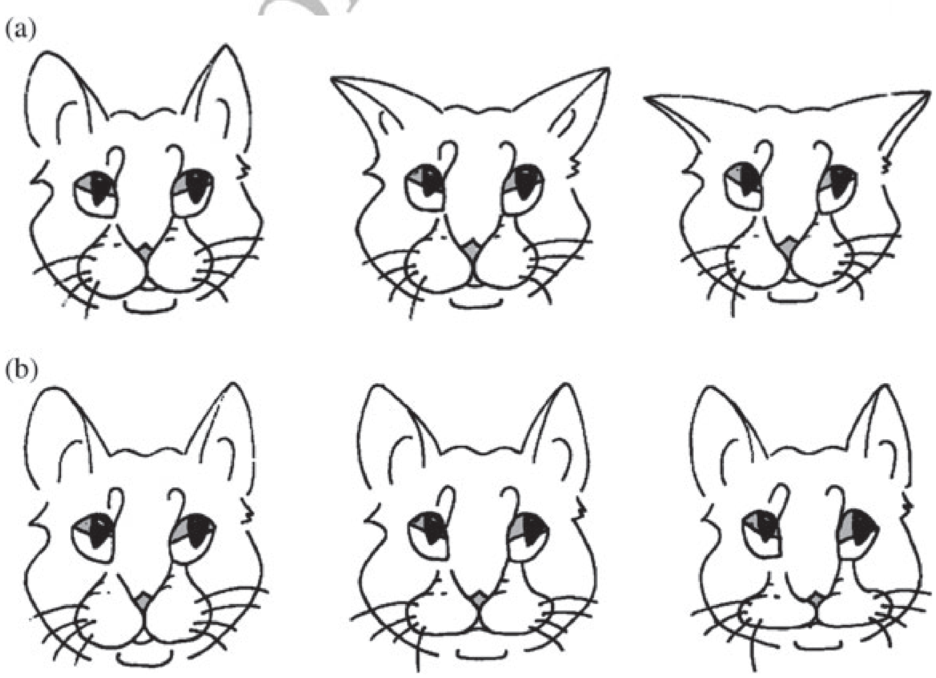

FIG 3. Cartoon images of faces highlighting changes that occur in two features (a) ears and (b) muzzle/cheek that occur in cats in acute pain compared with controls

The approach described here characterising facial features that discriminate cats in pain from pain-free cats differs from previously developed animal facial grimace scales such as those for the mouse, rat and rabbit (Langford *et al.* 2010, Sotocinal *et al.* 2011, Keating *et al.* 2012). These scales characterised facial features or action units that were observed for change using video footage after a pain stimulus. The approach adopted for this study was based on a mathematical basis for comparing movement of facial features between painful and pain-free cats. The method, similar to that used by Schiavenato *et al.* (2008), used distances between anatomical points to compare areas of possible facial expression in painful and pain-free cats. Given that facial expressions in cats have not been investigated previously, this method allowed analysis of a number of features in addition to those that might have been similar to other species.

Features that showed statistical difference between painful and pain-free cats included areas of the orbit (eyes), ears and mouth. These distinguishing features are similar to features reported to be significant in other facial scales such as the mouse and RGS (Langford *et al.* 2010, Sotocinal *et al.* 2011), which included orbital tightening, nose/cheek flattening, ear changes and whisker changes. Similar to other reports, the eyes were included as a distinguishing feature between painful and pain-free cats. However, the concern over the possible effects of analgesic drugs made interpretation of this finding difficult and this feature was ultimately omitted when the facial scale was developed. Further investigation into the effects of drugs such as analgesics and sedative drugs on facial changes is warranted.

Grimace scales for the mouse (Langford *et al.* 2010) and rat (Sotocinal *et al.* 2011) have been developed and coded in response to evoked non-clinical pain stimuli. Similarly a number of neonatal facial scales have been developed using evoked acute pain stimuli such as heel sticks and venepuncture (Grunau *et al.* 1990, Schiavenato & von Baeyer 2012). However postoperative and disease-associated pain that is longer lasting and arguably less acute in nature may result in less obvious pain expression over time. Accordingly, the validity of such scales for assessing postoperative pain in a clinical setting is unknown. In contrast, pain aetiologies in this study were variable in type and intensity due to the clinical nature of the population of cats recruited for the study. A painful face can be demonstrated across varying types of stimuli as shown in the MGS study (Langford *et al.* 2010). Despite the controlled nature of the noxious stimulus, Langford *et al.* (2010) demonstrated facial changes in response to a range of somatic and visceral assays varying in duration and intensities. Additionally, the Neonatal Facial Coding System (Grunau & Craig 1987) has also been shown to be useful for both acute procedures in infants and in the postoperative period after abdominal and thoracic surgeries (Peters *et al.* 2003). Therefore, given the aim of developing a tool for clinical use, facial changes demonstrated have been characterised in response to clinical pain (postoperative and disease-associated), which will make it useful in a clinical setting.

The MGS, RGS and RbtGS (Langford *et al.* 2010, Sotocinal *et al.* 2011, Keating *et al.* 2012) used the same individual for the painful and pain-free images by observing images before and after a painful stimulus, providing a baseline for the comparison of the painful face. However in the clinical study reported here, it proved impossible to obtain a pain-free image of individual cats in the pain group ~~since~~ cats recruited to the study presented for a painful condition. An alternative approach in a clinical situation would be to obtain facial images for comparison before and after analgesia administration on the assumption that analgesic administration would reduce pain intensity.

The recognition of pain using the facial images exercise demonstrated that some veterinary professionals could identify cats in pain from non-painful cats from the 2D images alone, but the majority had difficulty in doing so. Five of the 16 facial images where the majority of observers wrongly classified the pain status included two cats with high pain scores (NRS=7). This may be a reflection that cats generally display more subtle pain behaviours that extend to subtle changes in facial cues or it may be that those who deal with pain on a more regular basis may become desensitised to it (Balda *et al.* 2000). Given the possible subtlety of changes in the feline face due to pain, training may be required to direct the observer's attention to specific features as in the MGS study, where observers were provided with a short training session before use of the scale (Langford *et al.* 2010).

It is possible that body language and posture play an equally important role in providing information to the observer about pain status. The Colorado State University Feline Acute Pain Scale (Hellyer *et al.* 2006), though not a validated pain scale, includes illustrations of different body postures in cats experiencing different levels of pain. This provides a useful and visual example of cues to evaluate pain.

Limitations regarding the collection of facial images include lack of image control. Multiple people collected facial images and despite guidelines there was variation in the standard of the image. To account for this difficulty, photographs were standardised for comparison. The assessments of facial expression in other animal grimace scales (Langford *et al.* 2010, Sotocinal *et al.* 2011, Keating *et al.* 2012) have been based on still images grabbed from video footage. This avoids the need for a subjective judgement as to when is the optimum time to take a still photograph and allows the investigator to obtain a clear facial image at a point when facial expression in response to pain is at its most obvious. An added advantage of video is the ability to continuously record a patient from a distance, whereas the presence of a camera in close proximity to the face may influence the cat's behaviour and facial expression. However, this technique is more time consuming and equipment-reliant, something which would have been difficult in the multi-centre set-up in which the study was conducted.

In the clinical setting, a pain assessment tool that discriminates only between pain and no pain is of limited value compared with an evaluative instrument that provides information as to the level of intensity of the pain. Like the MGS (Langford *et al.* 2010) and RGS (Sotocinal *et al.* 2011), the feline facial scale described here is based on a 3-point intensity scale with three illustrations portraying increasing pain. Three facial expressions might be considered to be too few for a useful clinical evaluative tool t in paediatric medicine, clinically useful tools include CRIES (Krechel & Bildner 1995) and premature infant pain profile (PIPP) (Stevens *et al.* 1995) where the facial expressions comprise a 3-point and 4-point intensity scale~~s~~ respectively. Notably, the facial component of both these scales does not stand alone, but is embedded within a multidimensional pain assessment instrument. This is consistent with the intention to combine the facial scale described here with the Glasgow CMPS-feline (Calvo *et al.* ~~unpublished~~) to create a single acute pain assessment tool. Further investigation with the cartoons include their usefulness for training the observer to recognise pain-face features in addition to testing the combined tool (CMPS-feline and faces).

This study is the first to demonstrate that facial features can be used to discriminate between painful and pain-free cats and subsequent development of the facial scale represents a potentially ~~very~~ significant advance in the measurement of acute pain in cats. Further studies will investigate its validity, reliability and responsiveness.

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Conflict of interest

None of the authors of this article has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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APPENDIX 1: CAT FACIAL LANDMARKS AND CORRESPONDING NUMBER – LEFT- AND RIGHT SIDE OF FACE

Anatomical landmark name	Landmark number – right-hand side	Landmark number – left side
Pinna/Auricular cartilage		
Auricular apex – cranial edge	1	42
Marginal cutaneous pouch (MCP)	2	43
Dorsal origination of MCP	3	44
Ventral termination of MCP	4	45
Caudal insertion of tragus (medial side)	5	46
Caudal insertion of tragus (lateral side)	6	47
Caudal Antitragus (medial side)	7	48
Caudal Antitragus (lateral side)	8	49
Anti-tragic border (lateral border)	9	50
Tragic border (medial border)	10	51
Nose		
Nasal Philtrum (on the planum nasale)	11*	
Cranial edge of the planum nasale, above the philtrum	12*	
Lateral edge of external nares	13	52
Medial edge of external nares	14	53
Labial philtrum	15	
Philtrum at the lip edge	16	
Dorsolateral nasal cartilage (comma) – lateral edge	17	54
Cranial edge of planum nasale above medial edge of nares	18	55
Cranial edge of planum nasale above lateral edge of nares	19	56
Eyes		
Medial palpebral commissure	20	57
Lateral palpebral commissure	21	58
Dorsal eyelid	22	59
Medial dorsal eyelid	23	60
Lateral dorsal eyelid	24	61
Ventral eyelid	25	62
Medial ventral eyelid	26	63
Lateral ventral eyelid	27	64
Zygomatic process of frontal bone	28	65
Frontal process of zygomatic bone	29	66
Cranial ventral point of zygomatic bone	30	67
Lips		
Ventral labia at philtrum	31*	
External edge of dorsal labia	32	68
Median dorsal labial edge	33	69
External edge of ventral labia	34	70
Median ventral labia	35	71
Snout/Muzzle		
Labial edge of "whisker pad"	36	72
Nasal edge of "whisker pad"	37	73
Zygomatic edge of "whisker pad"	38	74
Point between labial and zygomatic points	39	75
Point between zygomatic and nasal edge	40	76
Forehead		
Whiskers/fibrissa above eye	41	77
Forehead		78*

APPENDIX 2: SEDATION SCALE, MODIFIED FROM LASCELLES *ET AL.* (1994)

0: fully alert and able to stand and walk
1: alert, able to maintain sternal recumbency and walk but may be ataxic
2: drowsy, able to maintain sternal recumbency but unable to stand
3: fast asleep, unable to raise head
Sedation Score ....

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