CatFACS

The Cat Facial Action Coding System Manual

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1. INTRODUCTION

The **CatFACS Manual** (Cat Facial Action Coding System) is an objective tool to investigate facial movements in cats. It is based on an anatomical, standardized and systematic method developed originally to study human facial behavior (Ekman and Friesen 1978, Ekman et al 2002a, b). This manual aims to train people to code individual facial movements in the cat face, providing a comparative and evolutionary approach to study communication and emotion.

1.1. What is the Facial Action Coding System?

The essential concept of the Facial Action Coding System (FACS) was first described by Hjortsjö (1969) and later extended by Ekman and colleagues (Ekman and Friesen 1978, Ekman et al 2002a, b). These researchers created a standardized coding system that identified and described in detail the human facial movements based on their underlying musculature. In the FACS manual, each individual muscle movement is given a distinct numerical code and a descriptive name, designated by **Action Unit** (AU). For instance, "AU1" corresponds to "Action Unit 1 - Inner Brow Raiser" and is coded when the medial portion of the frontalis muscle on the human forehead raises the inner portion of the eyebrows. These individual muscular movements produce a defined set of appearance changes on the face that, in turn, act as cues to code each AU. In order to code broad movements or non-mimetic muscle actions, FACS uses **Action Descriptors** (ADs), for example, tongue movements.

With FACS, it is possible to systematically and objectively measure the facial movements based exclusively on the appearance changes caused by the action of the underlying musculature, instead of classifying holistic facial expressions (which are typically composed by more than one AU: Calder et al 2000). This system also avoids interpretations of what observers perceive when seeing a face, and thus, any emotional context biases.

FACS is a robust system and accounts for individual differences in facial morphology (for instance, variation in bone structure, fatty deposits or permanent wrinkles) by using common facial landmarks among individuals and by establishing the minimum criteria needed to code an AU. The presence of a neutral expression is also essential for video and still image analyses, in order to identify the features that may vary between individuals (Waller et al 2007).

Following the same approach as the human system, FACS was modified to be used with several other species, namely chimpanzees (ChimpFACS: Vick et al 2007), rhesus macaques (MaqFACS: Parr et al 2010), hylobatids (GibbonFACS: Waller et al 2012), orangutans (OrangFACS: Caeiro et al 2013) and also a domestic species, the dog (DogFACS: Waller et al 2013). The adaptation of FACS for other species was based on the examination of anatomical homologies (Burrows et al 2006, 2009, 2011) while accounting for species differences in facial morphology. Inter-specific FACS adaptations not only allow a new insight into the objective and standardized study of animal communication but also sets the frame for comparative and evolutionary perspectives on cognitive processes.

1.2. Adapting FACS for cats

Despite its relatively recent domestication (Serpell 2000, Driscoll et al 2009), cats have a very widespread presence among humans and recently have surpassed the dog as a preferred companion animal in most of Europe and North America (Serpell 2000). Derived from the nocturnal African wildcat (*Felis silvestris libyca*), the domestic cat has adapted surprisingly well to the human diurnal lifestyle (Fitzgerald and Turner 2000). Having a nocturnal species as direct ancestor, the cat would be expected to make a predominant use of communication channels other than the visual one (such as chemical: Johnston 1983 or auditory: Stein and Meredith 1990). However, facial expressions and other visual signals are frequently described in the literature (a few examples: Darwin 1872, Leyhausen 1979, Dards 1983, Gaynor and Muir 2008) and are usually linked to an emotional context. Even though all the previous reports of cat visual signals are broadly descriptive and freely interpretative, it is possible that even in an early stage of domestication the species has developed some modifications on their visual signalling and made use of a multimodal communication approach to accommodate to their new human environment. Thus, the CatFACS manual here presented is the first FACS adaptation for a predominantly nocturnal feline species in a relatively early stage of domestication. The development of FACS for cats is intended to allow a more scientific approach to the study of feline communication and cognitive abilities.

Following a similar methodology used in previous FACS adaptations, the first step in adapting this system for cats was a detailed review of the facial muscular plan (Mivart 1881, Reighard and Jennings 1901, Davidson 1923, Crouch 1969, Done et al 1996, Tomo et al 2002; **Fig. 1**) and a subsequent comparison with humans facial musculature in order to identify possible homologies (Diogo et al 2009, 2012; **Annexe I**). When the anatomical information is extensively available like it is for the cat, electrical stimulations to evaluate the functional similarity of the musculature become redundant and unethical, and so were not carried out. The proposed muscle movement function in cats is illustrated on **Fig. 2**, based on the points of origin, insertion and fibre direction.

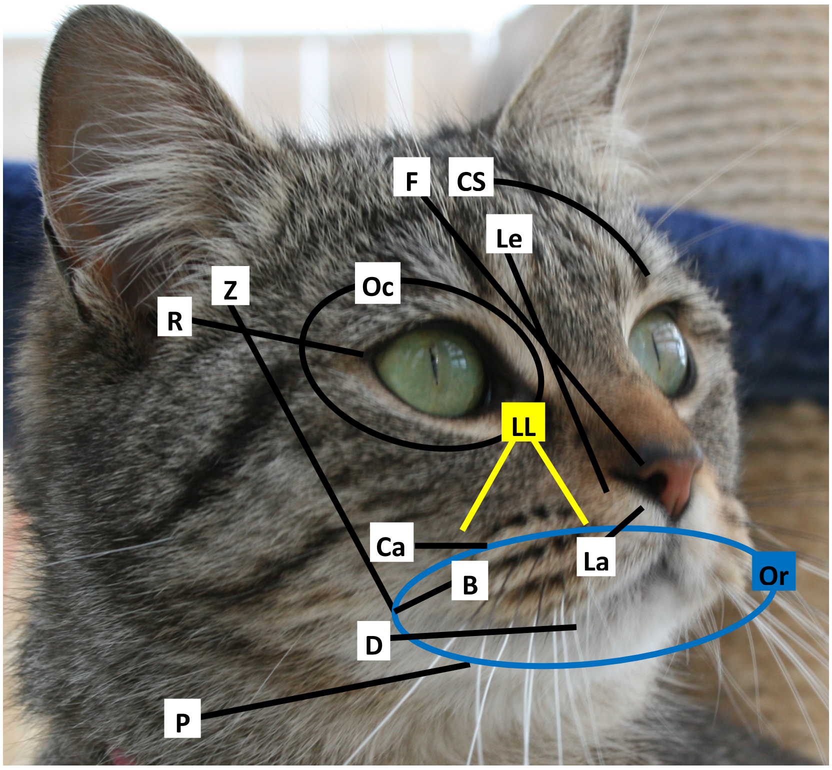

Fig. 2 Direction of muscle contraction with the labels as approximate points of origin (except for the orbital muscle Oc, which has an insertion point at the medial corner of the eye, and the Or muscle, which has no clear insertion). B, buccinator; Ca, caninus; CS, corrugator supercilii medialis; D, depressor labii inferioris; F, frontalis; La, lateralis nasi; Le, levator nasiolabialis; LL, levator labii maxilaris; Oc, orbicularis occuli; Or, orbicularis oris; P, platysma; R, retractor anguli occuli lateralis; Z, zygomaticus major; (coloured muscles to facilitate visualization only).

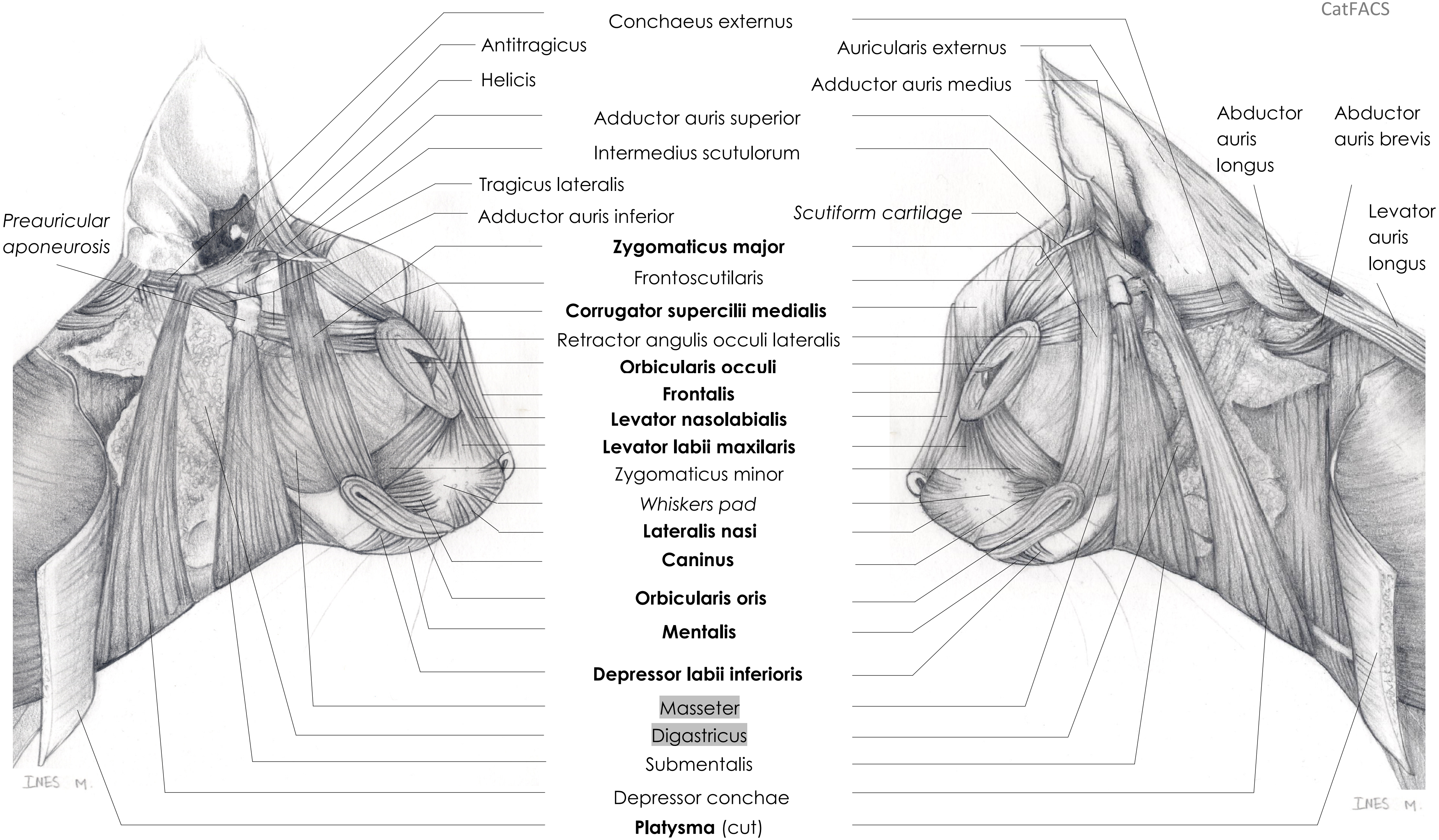

Fig. 1a Representation of facial and ear muscles in the cat in profile view (Images by Inês Martins, Crouch 1969). In bold: facial muscles, highlighted: masticatory muscles, in italics: non-muscular structures.

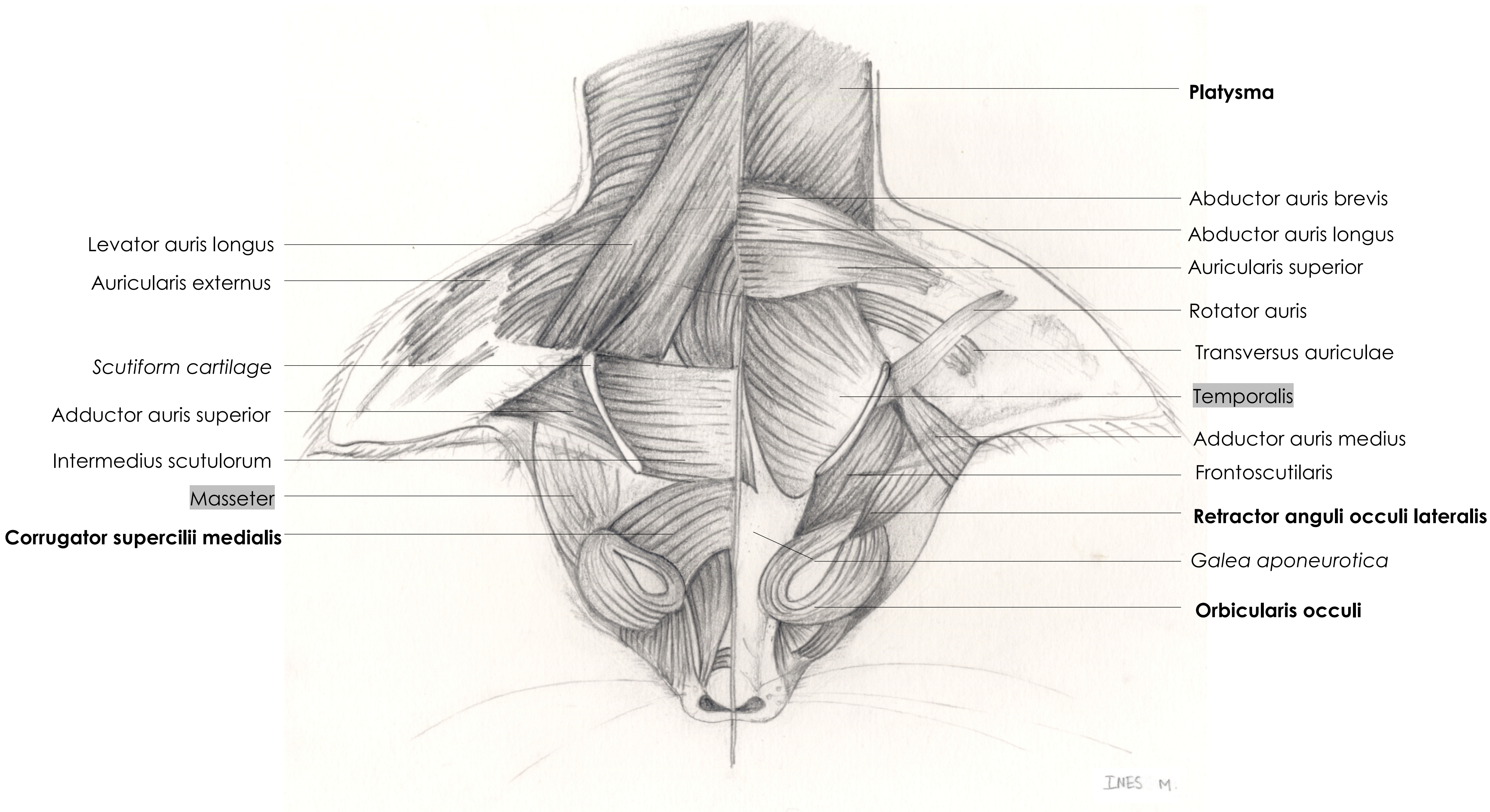

Fig. 1b Representation of facial and ear muscles in the cat in top view (Image by Inês Martins, Crouch 1969). In bold: facial muscles, highlighted: masticatory muscles, in italics: non-muscular structures.

The second step of this process consisted of analyses of spontaneous facial behaviour recorded on video and still images in comparison to the neutral face for each individual. A frame-by-frame analysis was employed in 213 short clips (total of 7 hours) that targeted the head and more specifically the neck, face and ears. Our sample was collected in 13 countries and included 126 individuals of varied breeds, ranging from 2 months to 19 years old. The videos were collected in a wide-range of contexts, including resting, feeding, playing, grooming, conspecific interactions (agonistic and affiliative) and interspecific interactions (insects, birds, humans).

Finally, the facial movements observed in the videos were described, using specific directional and anatomical terms (**Fig. 3** and **Fig. 4**, see also section **1.3.**), and classified according to codes illustrated in previous FACS (including AUs, ADs and EADs - Ear Action Descriptors). Muscular functional homologies were followed whenever possible or new codes were created when the homologies were not identified (for instance, adding "1" before the code used for the original FACS). All the independent facial movements found in cats are summarized in **Table 1**, with the corresponding proposed muscles.

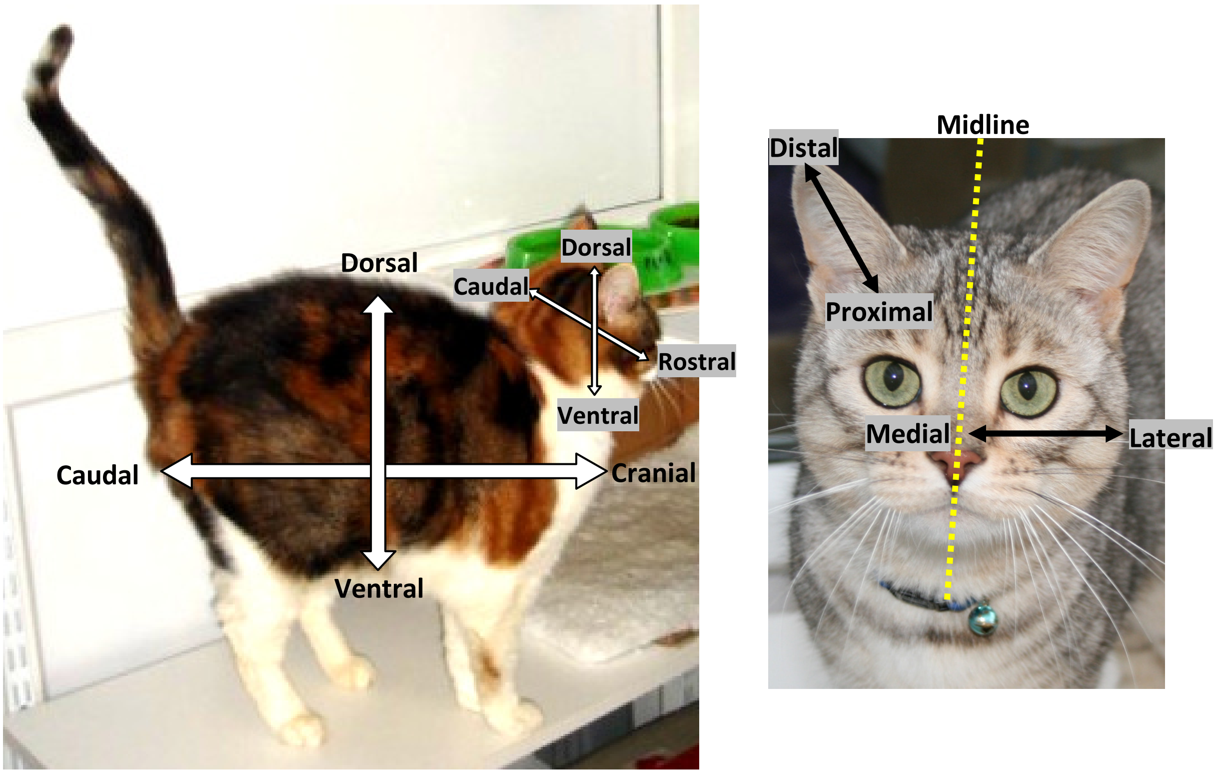

Fig. 3 Spatial representation of directional terminology for a four-footed animal. **Cranial**: towards the cranium, along the long axis of the trunk (craniocaudal axis). **Rostral**: towards the apex of the nose, along the long axis of the head (rostrocaudal axis). **Caudal**: towards the tail or back of the head, along the long axis of the trunk or head, respectively. **Dorsal**: towards the spinal column or the top of the head, along the short axis of the trunk or the short axis of the head, respectively (dorsoventral axis). **Ventral**: towards the abdomen or the underside of the head, along the short axis of the trunk or the short axis of the head, respectively. **Distal**: towards the free end of a projecting structure (e.g.: ears, whiskers, tail). **Proximal**: towards the attachment point of a projecting structure. **Medial**: towards the medial plane (represented by the midline) of the body. **Lateral**: from the medial plane, towards the left or right side of the body. These terms can be combined to describe a movement of a limb or body part in other directions, as for example: dorsocaudal, ventrocaudal, dorsocranial, ventrocranial.

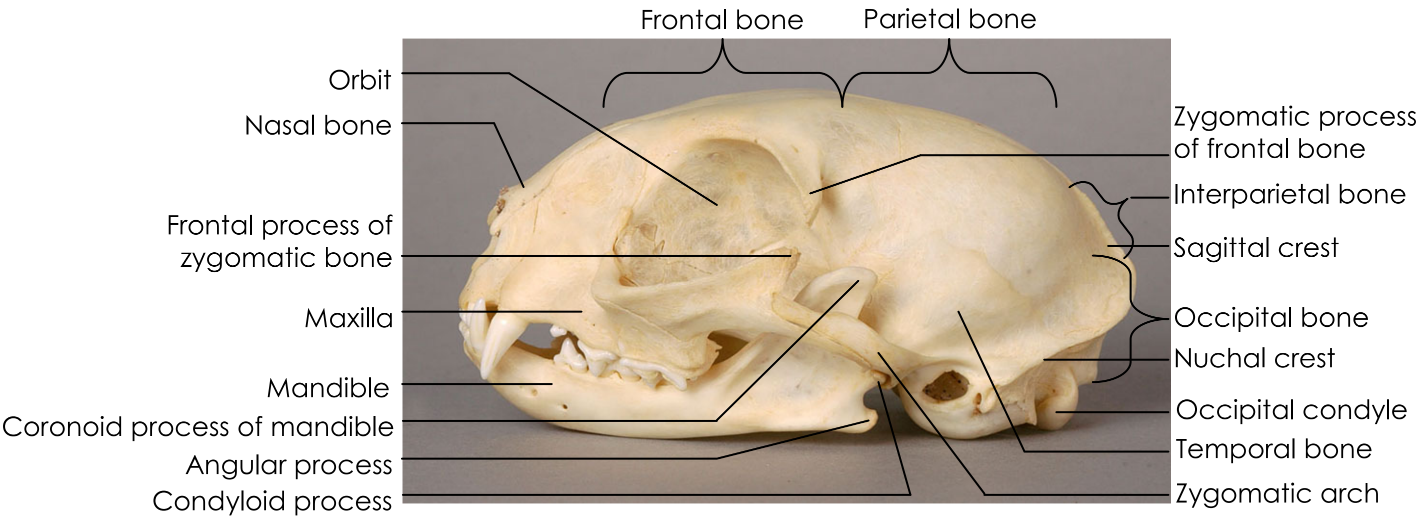

Fig. 4 Lateral view of a cat skull with relevant anatomical terms for facial movements descriptions.

Table 1a Summary of the observed facial actions and its underlying muscles in cats (CatFACS), with comments on the adaptation from the human FACS.

Upper Face

Action Units	Muscles	In human FACS
143 Eye closure	Orbicularis occuli, retractor anguli occuli lateralis, levator palpebrae	Coded as 43 and 45 since only the levator palpebrae superioris acts to move the upper eyelid, producing different visual cues
145 Blink		
47 Half-blink		Not described in FACS
5 Upper lid raiser	Levator palpebrae, corrugator supercilii medialis	The same muscle (levator palpebrae) produces similar visual cues

Lower Face

Action Units	Muscles	In human FACS
109+110 Nose wrinkler and upper lip raiser	Levator nasolabialis, levator labii maxillaris, caninus, lateralis nasi	Coded as 9 and 10. Well defined distinct actions produced by levator superioris labii alaeque nasi and levator labii superioris respectively
12 Lip corner puller	Zygomaticus major	Same code and muscle
16 Lower lip depressor	Depressor labii inferioris	Same code and muscle
17 Lower lip raiser	Mentalis	Designated as Chin raiser, but code is the same due to the same muscle acting
118 Lip Pucker	Orbicularis oris, buccinator	Coded as 18, action of incisivii labii muscles
25 Lips part	Orbicularis oris, caninus, levator labii maxillaris, levator nasolabialis, platysma	Same code and homologous muscles
26 Jaw drop	Non-mimetic muscles: masseter, temporalis, pterygoid, digastricus	Same codes and muscles
27 Mouth stretch		
200 Whiskers retractor	Lateralis nasi, orbicularis oris	Not described in FACS
201 Whiskers protractor	Caninus , orbicularis oris	
202 Whiskers raiser	Lateralis nasi, caninus, orbicularis oris	

Table 1b Summary of the observed facial actions and its underlying muscles in cats, with comments regarding the adaptation from the human FACS.

Action Descriptors	In human FACS
19 Tongue show	Same code
190 Tongue downwards	Not described in FACS
119 Lick	Not described in FACS
37 Lip wipe	Same code
137 Nose lick	Not described in FACS
40 Sniff	Same code
48 Third eyelid show	Not described in FACS
50 Vocalisations	Same code
68 Pupil dilator and 69 Pupil constrictor	Not described in FACS
126 Panting	Not described in FACS
160 Body shake	Not described in FACS
161 Head shake	Not described in FACS

1.3. Facial features and individual variability in cats

In order to describe the facial movements, multiple appearance changes are listed for each AU, accounting for the cat specific facial anatomy and morphology. Facial landmarks, which are specific areas and features of the face, are used as references to explain the movements. Due to the differences in facial landmarks between humans and cats, these were considered and compared during the FACS modification (**Fig. 5**).

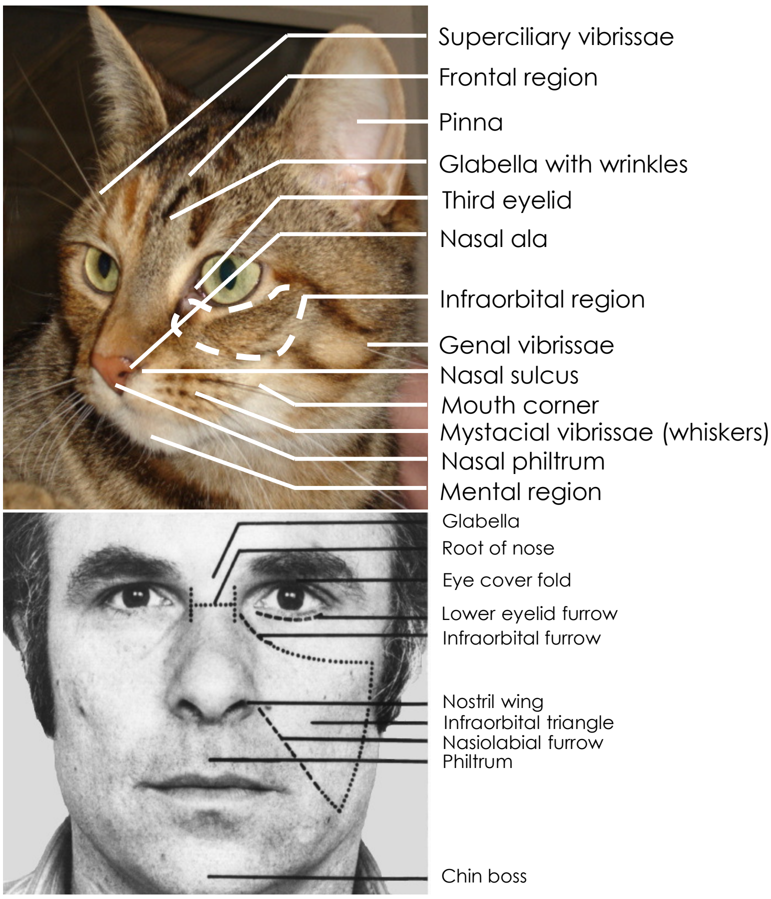

Fig. 5 Facial landmarks in cats and humans.

Depending on the breed (TICA, 2013), the skull of the cat can vary in terms of the cephalic ratio, being classified as brachicephalic (e.g.: Exotic shorthair), mesaticephalic (e.g.: European shorthair) or dolicocephalic (e.g.: Siamese) (Osborne 1902, Künzel et al 2003; **Fig. 6**). These different skull shapes modify the appearance of the head and face, even though cats have relatively shortened faces when comparing with other carnivores.

Fig. 6 Variation in skull shape. Images from left to right: Brachicephalic, frontal and lateral view (persian), mesaticephalic (mixed-breed) and dolicocephalic (sphinx).

The medial area of the lower jaw lacks a bony chin boss (unique to humans), but for ease of comparison this region is referred to as the mental region. The mouth is able to open in a wide gape due to the caudal situation of the mouth corners and the short cheeks (Dyce et al 2010), exposing the teeth, including long canines (Done et al 1996). The external nose presents a moist bare skin around the nostrils and the nasal plate is divided by a median philtrum that continues ventrally to groove the upper lip (Dyce et al 2010). The vomeronasal organ found in the nasal cavity is related to olfaction, particularly to the perception of other cats' odors. This organ is responsible for the flehmen reaction (Hart and Leedy 1987, Dyce et al 2010, Case 2012), where the lower jaw is lowered, the head is held in a neutral position (or moved dorsally) and the upper lip may be raised, holding this posture for a few seconds. This behaviour has been also described as including an upper lip curl (e.g.: Dyce et al 2010), but from the observations made during the development of the CatFACS (see also **Fig. 48** in section **2.2.**), only the jaw drop was clearly present in cats during flehmen (as described by Hart and Leedy 1987). Both eyelids lack lashes and the protruding orbits are relatively large and face forward, providing a wide field of binocular vision. Unlike some of the wild felines, pupils in domestic cats range from round to vertical slits when constricted (Dyce et al 2010). The eyelids sweep over the eye frequently in a blinking/closing movement varying between an opened or a closed position, in order to ensure diverse functions: corneal wetting, hygiene and protection; visual information processing support and behavioural states expression (Darwin 1872, Gruart et al 1995). However, unlike humans, cats seem to present a range of eyelids positions, exposing different degrees of the eyeball in non-transitory movements, i.e. cats have a precise graded motor control of the eyelids responses (Gruart et al 1995). Since the eyes are such a conspicuous and central feature in the cats face, any appearance changes to this area should be carefully examined. The area above the eyes and cranial to the ears is the frontal region, which in humans corresponds to the forehead (limited inferiorly by the supraorbital ridge and superiorly by the hairline). In cats, it can vary its shape to some extent, but it appears to always present permanent vertical wrinkles (sometimes accentuated by the hair striped pattern) in the glabella, giving the false impression of a permanent corrugation movement. These wrinkles are smoothed when cats lower their eyelids. The external ear consists of the external auditory canal and its cartilaginous extensions, the pinna (auricular cartilage) and the scutiform cartilage. The scutiform cartilage lays craniomedially to the pinna and serves as origin/insertion point for facial and ear muscles (Reighard and Jennings 1901, Paterson and Tobias 2013). Most cats have straight triangular ears with a wide base and an apex pointing upwards. Variations to this ear shape are rare, like in the Scottish Folds where the tip of the ear bends ventrocranially. Cats can move each ear independently of the other and independently of the position of the head, allowing for a directional hearing. The cat's ears are highly mobile, creating conspicuous movements and modifying the global appearance of the face. Another prominent feature in the face of cats are the tactile hairs or vibrissae, which are hairy outgrowths of the skin, distinct from pelage hair because they are longer, mostly localized in the face, with large, highly innervated and blood-filled follicles and are represented in the sensory cortex in a specific way. Unlike pelage hairs, vibrissae are attached to striated muscles under voluntary control. Different functions have been suggested ranging from aid in feeding, aggression, communication or environmental monitoring. They can be classified according to their localization in mystacial (upper lip), superciliary (above the eyes in a small protuberance), genal (on the cheeks and of variable presence) and submental (on the lower lip and chin). The mystacial vibrissae (whiskers) show a special importance, since they are the only tactile hairs presenting independent movement (Sherrington 1917, Ahl 1986). The whiskers are attached to a fibrous pad where some facial muscles originate or insert (Reighard and Jennings 1901). However, some individuals lack some or all of these tactile hairs (e.g.: the Sphinx breed lacks any kind of hair).

1.4. How to use the CatFACS manual

The AUs, ADs and EADs have a list of appearance changes describing in detail the visual results of each muscular movement on the face of the cat. Each movement is illustrated by several still images and short embedded video-clips (some accompanied of a slow-motion version), that can be repeatedly watched. In order to watch the clips in a larger format, either zoom in on the PDF file or right-click on the clip and view it in fullscreen. For a correct clip visualization, the latest version of Adobe Reader or Adobe Acrobat software must be installed in the computer. Adobe Reader can be freely downloaded from www.Adobe.com.

As with all FACS systems, to become a CatFACS coder, training and certification is required through a test to ensure system reliability. The CatFACS Manual and the certification test are freely available through the website www.CatFACS.com.