Facial Representations: Modeling, Rigging, Retargeting

Iain Matthews

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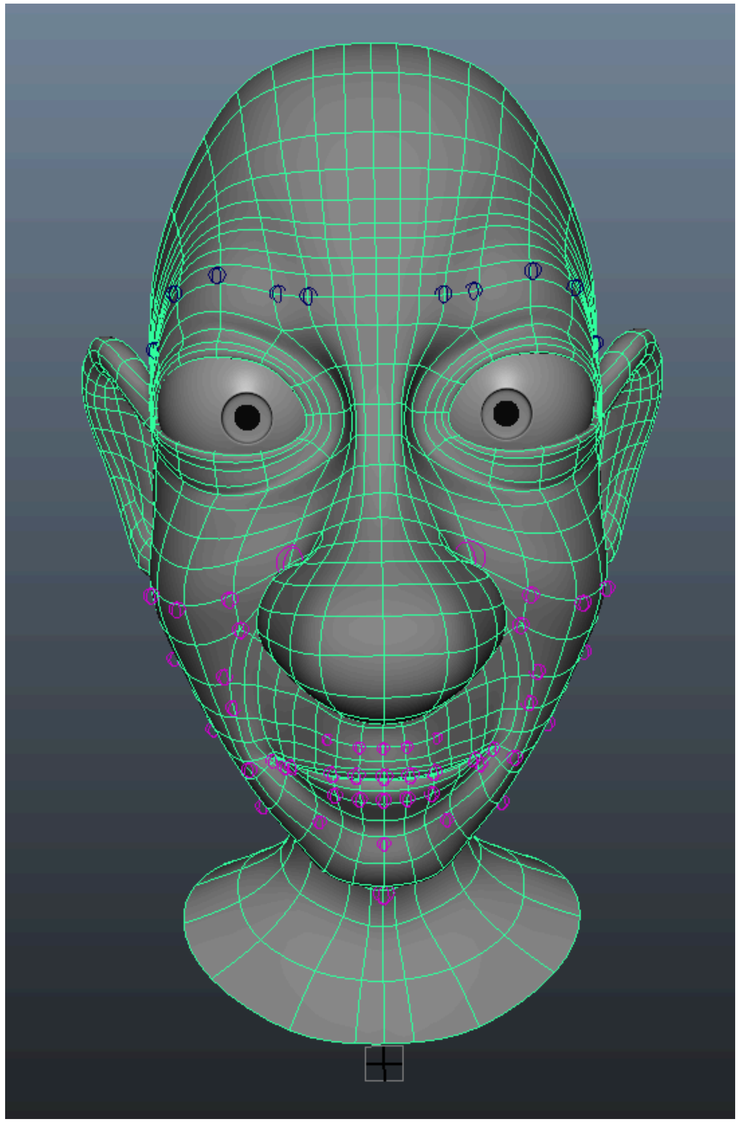
Disney Research, Pittsburgh

Representing Faces

- Modelling
  - Polygon mesh / subdivision surface
  - NURBS
- Parameterisation / Rigging
  - Static vs. Dynamic
  - Learned vs. Divined
  - Blend-shapes and or Deformers
  - None? Data interpolation and retargeting
- Retargeting / Animation
  - Geometric
  - Parametric



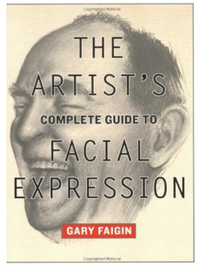
How to Parameterise or Describe a Face?

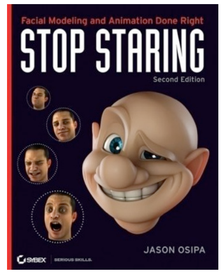
Describing a Face

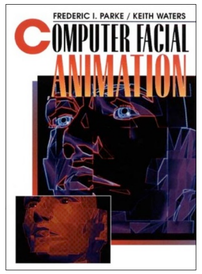
- Identity
- Rigid motion
- Skull
- Expression (Emotion?)
- Speech
- Eyes
- Eye Lids / Blinks
- Jaw Motion
- Neck
- Nasal breathing

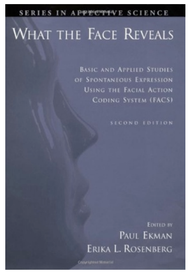
- Dynamics / Ballistics
- Sticky Lips
- Tongue
- Teeth
- Hair / Lashes
- Skin
  - Pore structure
  - Wrinkles
  - Subsurface scattering
  - Hair
  - Blood flow

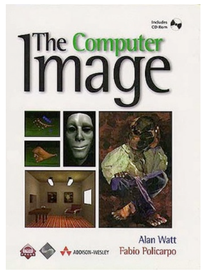
- Sweat and Tears
- Fat and soft tissue
- Hard tissue
- Muscles
  - Attachment points
  - Strength
  - Volume
  - Compression / Tension
  - SMAS (Superficial musculoaponeurotic system) fascia
  - Orbital muscles

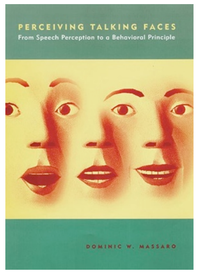






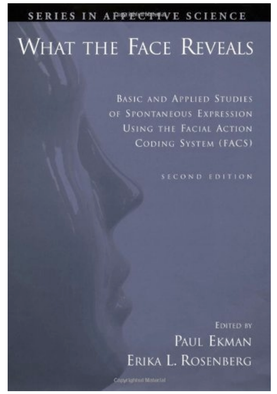


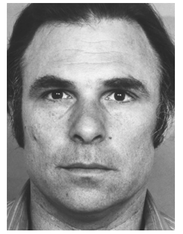


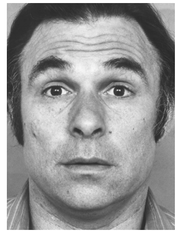


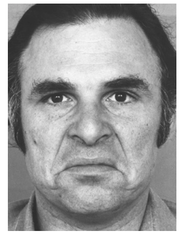
Facial Action Coding System (FACS)

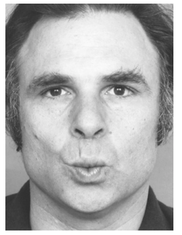
- Facial Action Coding System (FACS)
  Paul Ekman, Wallace Friesen, 1976
- **Description** tool for psychology
- Animation "concept": Pixar, IMD, Weta...

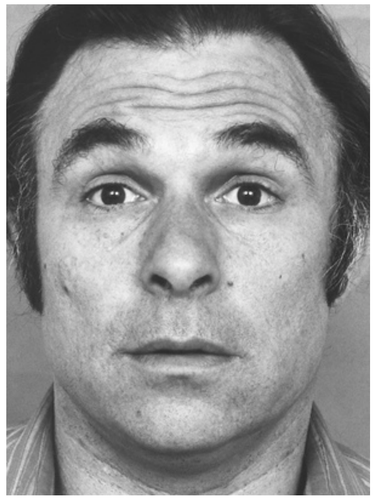






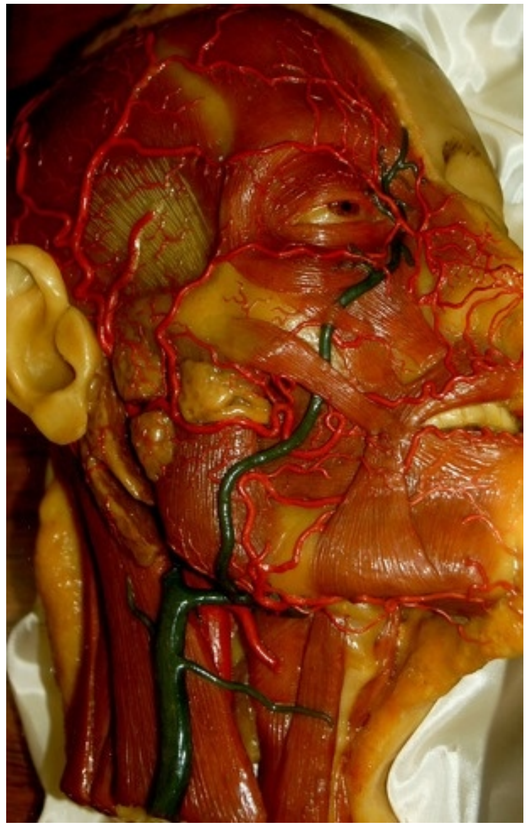


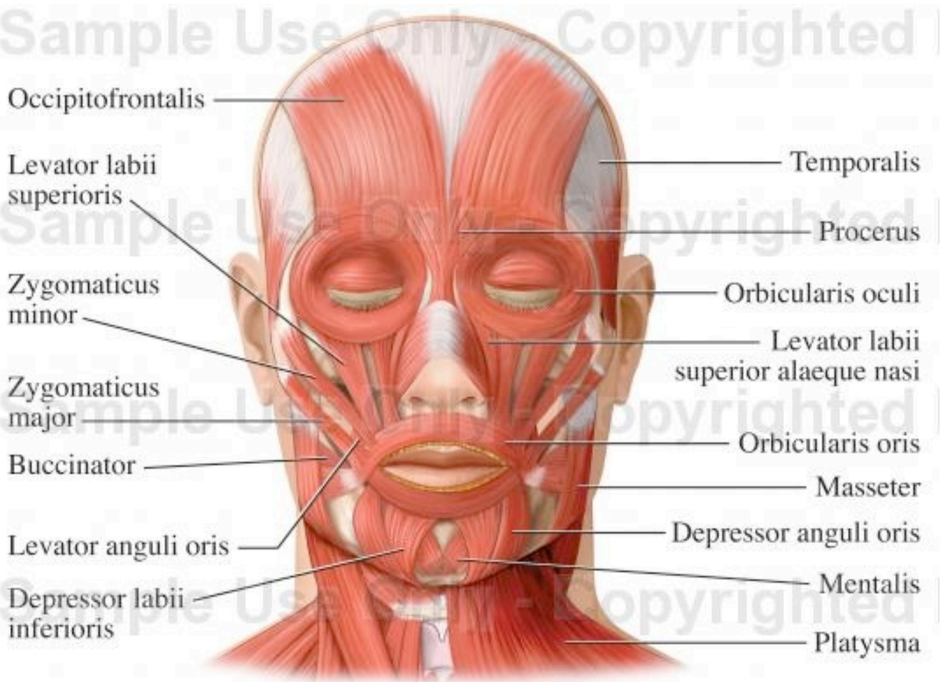


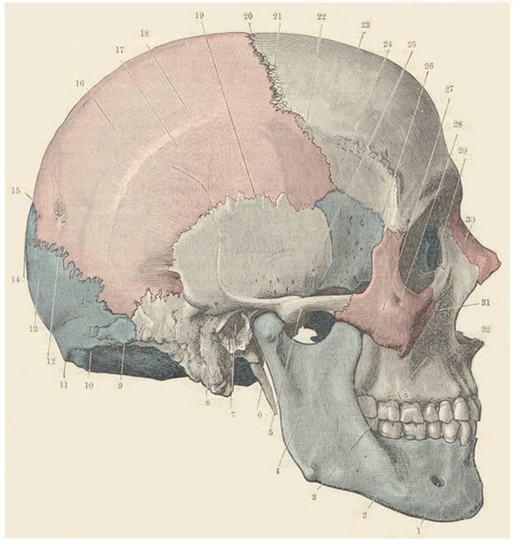


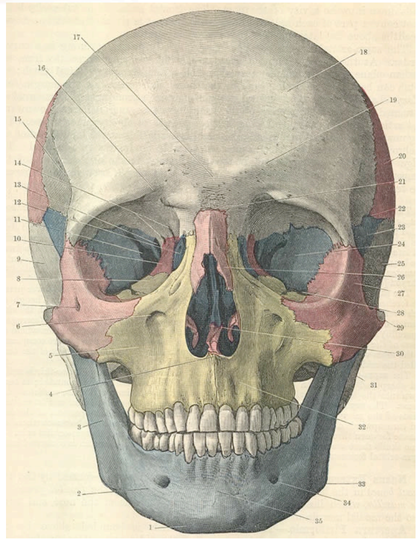
AU 1+2

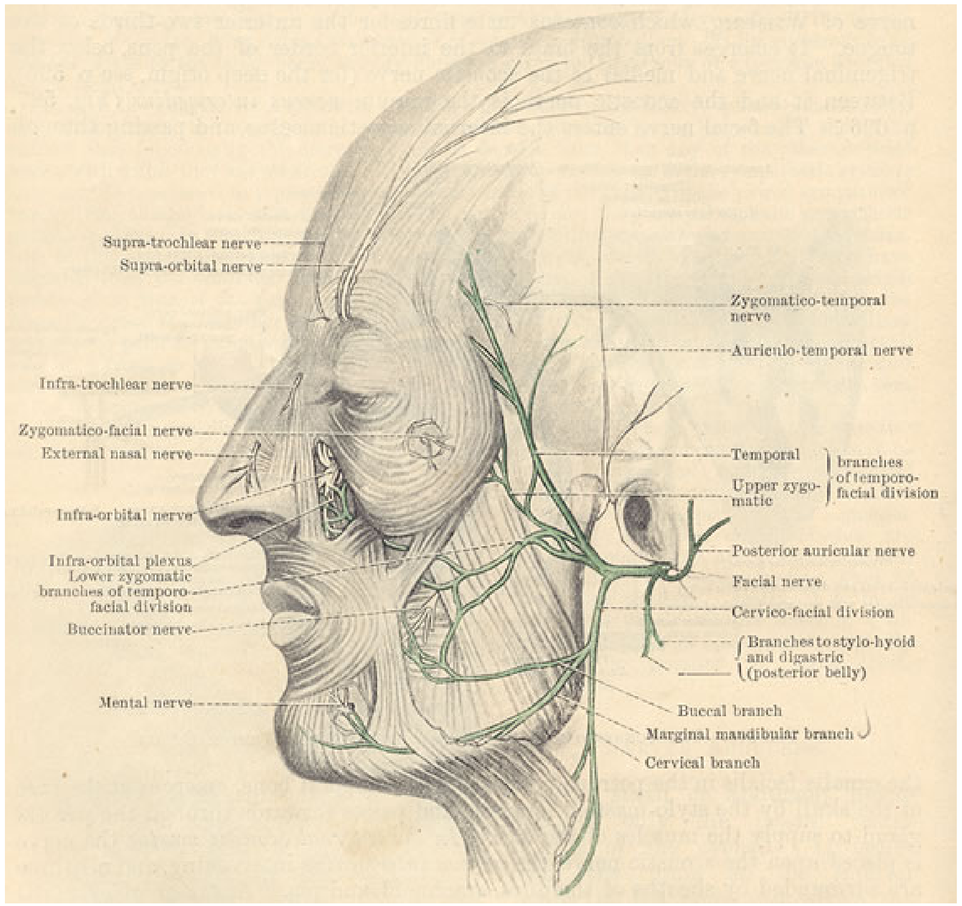
Facial Anatomy











CN VII

http://www.artnatomia.net/uk/artnatomyProgram.html

Facial Anatomy

- "there are no grounds, as far as I can discover, for believing that any muscle has been developed or even modified exclusively for the sake of expression."
  (Darwin, 1872, p355)

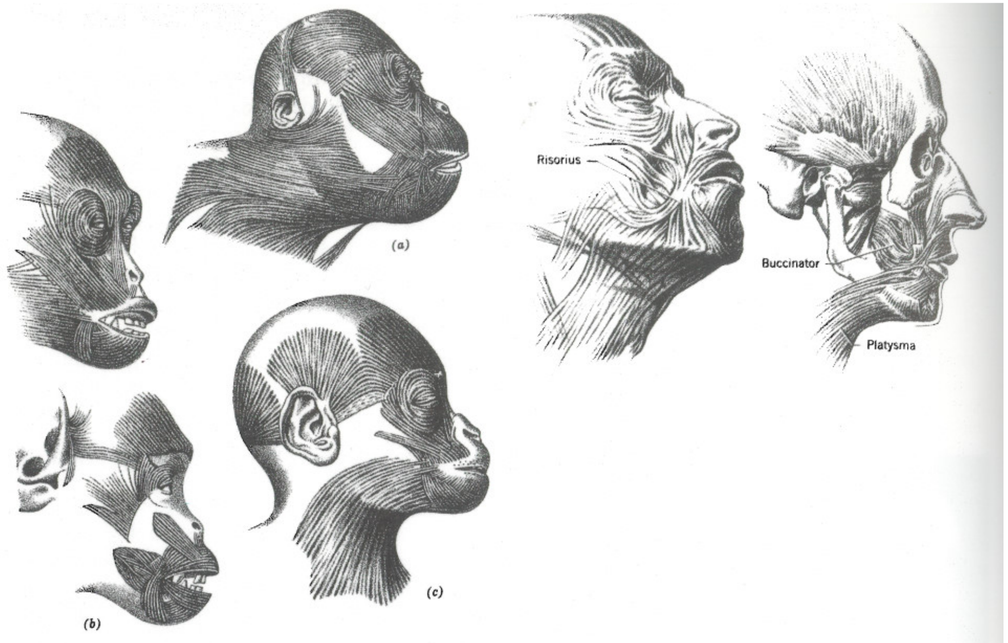
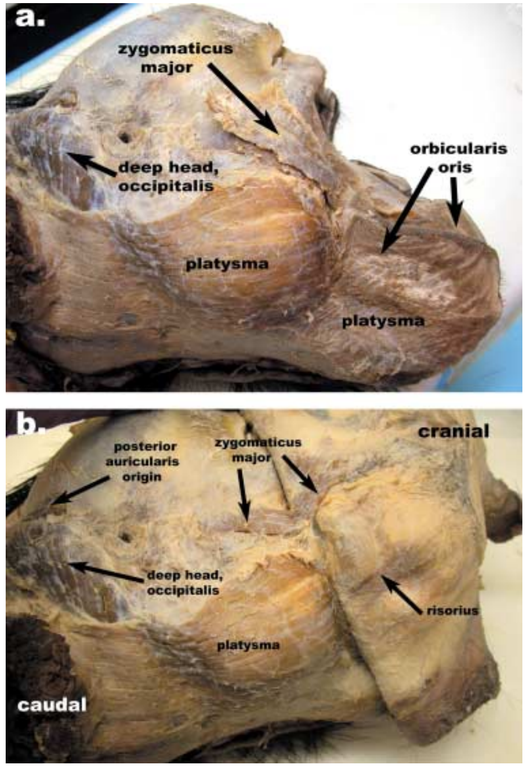
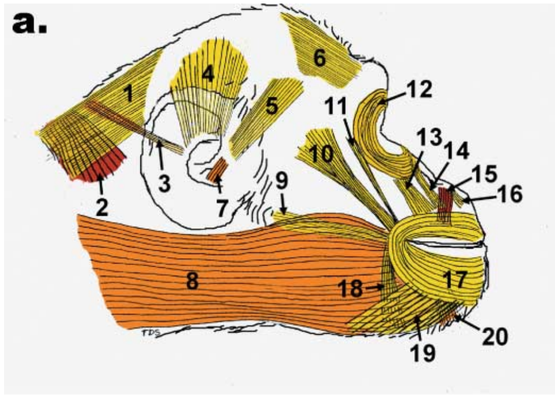


Fig. 1.36 Similarities in the musculature of human and primate faces allow comparisons to be made about the different expressions used by different primate and human species. The left panel shows facial musculature in (a) orang-utan; (b) chimpanzee; and (c) gorilla infant. From Lenneberg (1967).

Duchenne and later Ekman draw important distinctions between genuine smiles and false smiles used to hide other feelings, and there is no doubt that smiling can be used in a nervous or threatening way by humans. Interestingly, Darwin devotes some discussion to 'grinning' in dogs, 'A pleasurable and excited state of mind, associated with affection, is exhibited by some dogs in a very peculiar manner; namely, by grinning' (1872, p. 120), and notes that Sir Walter Scott's famous greyhound Maida was much prone to this (see Fig. 1.4). This was not





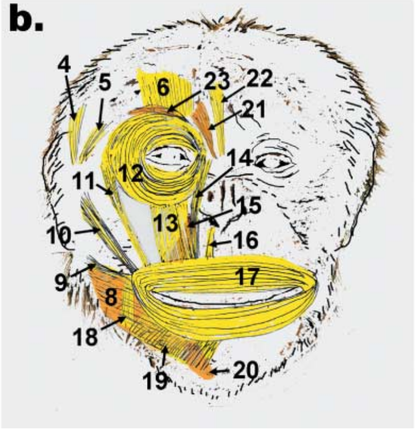


Fig. 1 Abstracts of facial expression musculature in *Pan troglodytes*. (a) Lateral view; (b) frontal view. In both diagrams, yellow represents the most superficially located musculature, red represents the most deeply located musculature and orange represents muscles located intermediate to the others. For both views: 1 – superficial head, occipitalis muscle, 2 – deep head, occipitalis muscle, 3 – posterior auricularis muscle, 4 – superior auricularis muscle, 5 – anterior auricularis muscle, 6 – frontalis muscle, 7 – tragicus muscle, 8 – platysma muscle, 9 – risorius muscle, 10 – superficial head, zygomaticus major muscle, 11 – zygomaticus minor muscle, 12 – orbicularis occuli muscle, 13 – levator labii superioris muscle, 14 – levator labii superioris alaeque nasi muscle, 15 – caninus muscle, 16 – depressor septi muscle, 17 – orbicularis oris muscle, 18 – depressor anguli oris muscle, 19 – depressor labii inferioris muscle, 20 – mentalis muscle, 21 – depressor supercilli muscle, 22 – procerus muscle, and 23 – corrugator supercilli muscle.

[1] Anne M. Burrows, Bridget M. Waller, Lisa A. Parr, and Christopher J. Bonar. Muscles of facial expression in the chimpanzee (pan troglodytes): descriptive, comparative and phylogenetic contexts. Journal of Anatomy, 208:153–167, 2006.

Facial Action Coding System (FACS)

- 43 muscles?
- 33 Single AUs

Ideally, the Facial Action Coding System would differentiate every change in muscular action. Instead, it is limited to what humans can reliably distinguish, since it is used by human operators viewing facial behavior, not a machine-based classification. FACS includes most but not all of the subtle differences in appearance which result from different muscle action. The fineness of the scoring categories in FACS depends upon what can be reliably distinguished when a facial movement is inspected repeatedly, and in stopped and slowed motion.

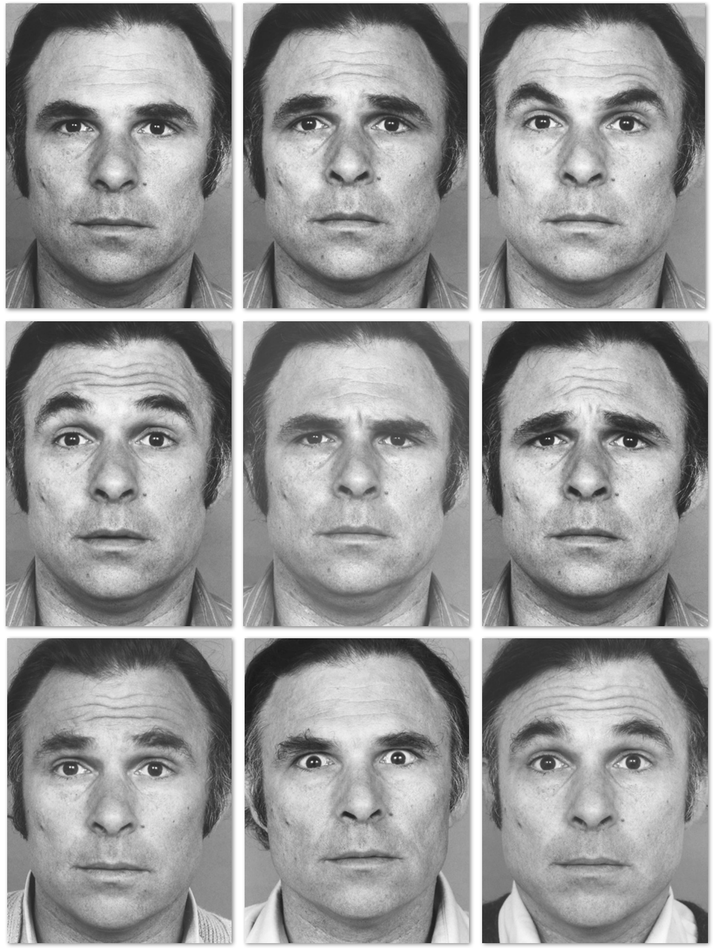
Speech production involves movements of the lips, jaw, tongue, and other structures that produce appearance changes in the lips, mouth, cheeks, chin, and neck. Many of these appearance changes are produced by the same muscles that are the basis for AUs. Users of FACS are most likely to be interested in measuring movements that are different from those of speech, and these are the movements that FACS is designed to represent. The subtle movements of the lips and other movements involved in speech production cannot be measured by FACS. Distinguishing movements that are part of speech production from functionally different movements remains an issue for FACS users. A goal in FACS scoring is to disregard movements that function only to produce speech and score the other movements that co-occur with speech.

Table 1-1: Single Action Units (AU)

AU Number	FACS Name	Muscular Basis
1	Inner Brow Raiser	Frontalis, Pars Medialis
2	Outer Brow Raiser	Frontalis, Pars Lateralis
4	Brow Lowerer	Depressor Glabellae; Depressor Supercilli; Corrugator
5	Upper Lid Raiser	Levator Palpebrae Superioris
6	Cheek Raiser	Orbicularis Oculi, Pars Orbitalis
7	Lid Tightener	Orbicularis Oculi, Pars Palebralis
8	Lips Toward Each Other	Orbicularis Oris
9	Nose Wrinkler	Levator Labii Superioris, Alaeque Nasi
10	Upper Lip Raiser	Levator Labii Superioris, Caput Infraorbitalis
11	Nasolabial Furrow Deepener	Zygomatic Minor
12	Lip Corner Puller	Zygomatic Major
13	Cheek Puffer	Caninus
14	Dimpler	Buccinnator
15	Lip Corner Depressor	Triangularis
16	Lower Lip Depressor	Depressor Labii
17	Chin Raiser	Mentalis
18	Lip Puckerer	Incisivii Labii Superioris; Incisivii Labii Inferioris
20	Lip Stretcher	Risorius
22	Lip Funneler	Orbicularis Oris
23	Lip Tightner	Orbicularis Oris
24	Lip Pressor	Orbicularis Oris
25	Lips Part	Depressor Labii, or Relaxation of Mentalis or Orbicularis Oris
26	Jaw Drop	Masetter; Temporal and Internal Pterygoid Relaxed
27	Mouth Stretch	Pterygoids; Digastric
28	Lip Suck	Orbicularis Oris
38	Nostril Dilator	Nasalis, Pars Alaris
39	Nostril Compressor	Nasalis, Pars Transversa and Depressor Septi Nasi
41	Lid Droop	Relaxation of Levator Palpebrae Superioris
42	Slit	Orbicularis Oculi
43	Eyes Closed	Relaxation of Levator Palpebrae Superioris
44	Squint	Orbicularis Oculi, Pars Palpebralis
45	Blink	Relaxation of Levator Palpebrae and Contraction of Orbicularis Oculi, Pars Palpebralis
46	Wink	Orbicularis Oculi

Facial Action Coding System (FACS)

Muscles ≠ FACS



Combinations...

Subject:_____ Date: 7/__/2009

AU 0
AU 1
AU 2
AU 1+2
AU 4
AU 1+4
AU 1+2+4
AU 5
AU 1+2+5
AU 4+5
AU 1+2+4+5
AU 7
AU 5+7
AU 6+7
AU 43
AU 6+43
AU 7+43
AU 6+7+43
AU 9
AU 10
AU 12
AU 6+12
AU 14
AU 10+14
AU 14 (unilateral)
AU 15
AU 10+15
AU 12+15
AU 16
AU 17
AU 9+17
AU 10+17
AU 9+10+17

AU 12+17
AU 14+17
AU 15+17
AU 10+15+17
AU 12+15+17
AU 18
AU 19
AU 20
AU 23
AU 18+23
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AU 20+25+27
AU 28
AU 29
AU 30
AU 31
AU 32
AU 33
AU 34
AU 35
AU 36
AU 37
AU 38
AU 39
AU 61/62
AU 63/64
Eyes around

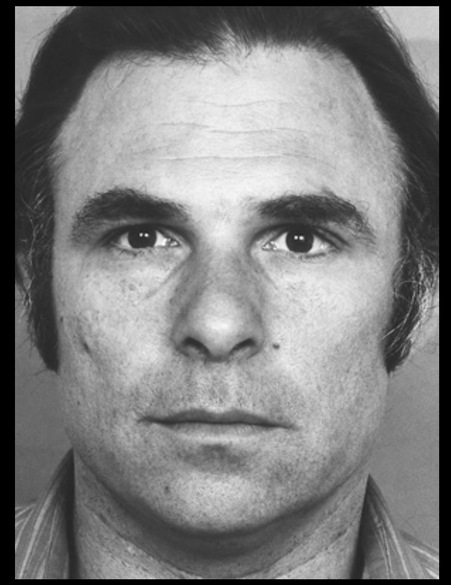
AU 50 = “Speech”

[1] P. Ekman, W. V. Friesen, and J. C. Hager. *Facial Action Coding System: The Manual*. 2002.

FACS Shoot

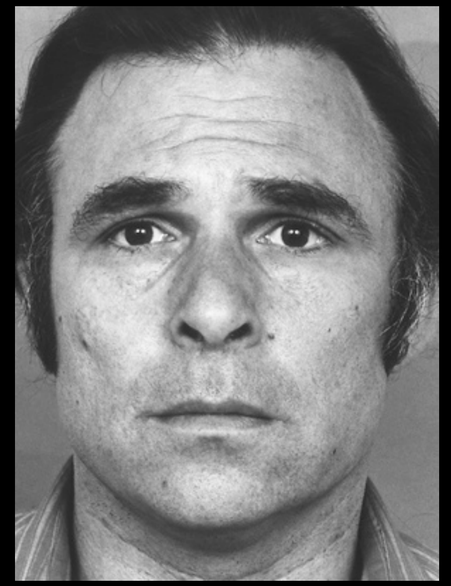
AU 0

The face is not showing any action, often called a neutral face. The face is not actually at rest because the eyes are open, the jaw is closed, but no AU can be scored.



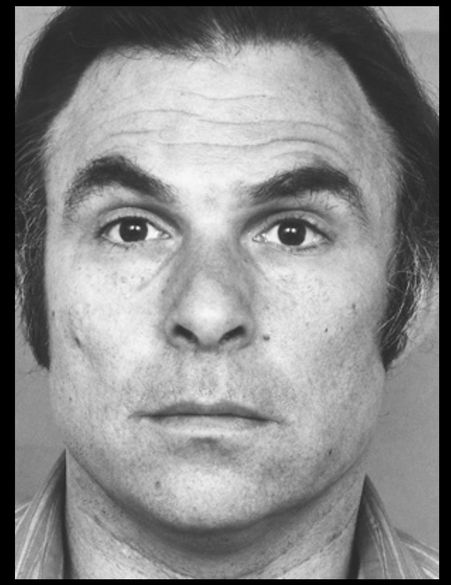
AU 1

The inner corners of the eyebrows are lifted slightly, the skin of the glabella and forehead above it is lifted slightly and wrinkles deepen slightly and a trace of new ones form in the center of the forehead.



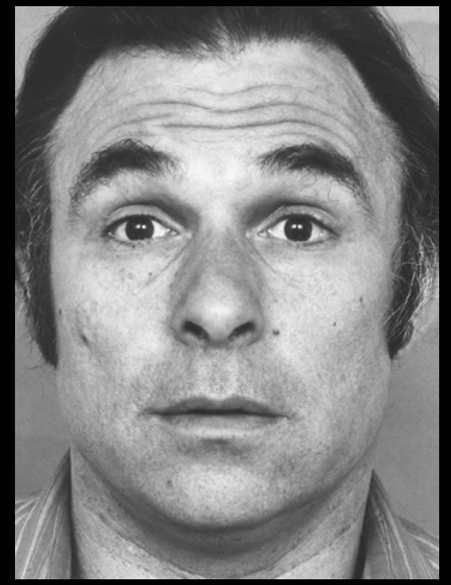
AU 2

The outer part of the eyebrow raise is pronounced. The wrinkling above the right outer eyebrow has increased markedly, and the wrinkling on the left is pronounced. Increased exposure of the eye cover fold and skin is pronounced.



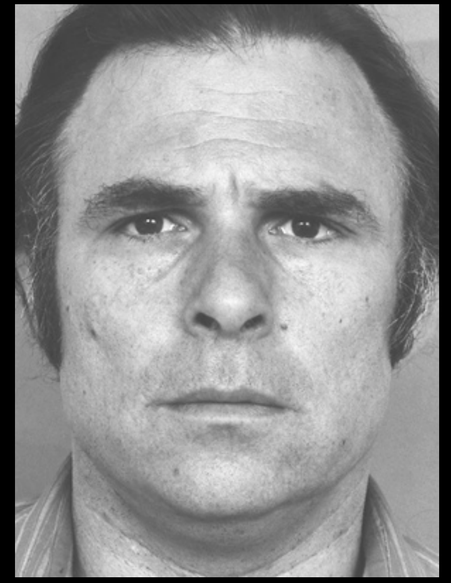
AU 1+2

This action is asymmetrical. The entire eyebrow is raised up extremely. The eye cover fold is exposed extremely.



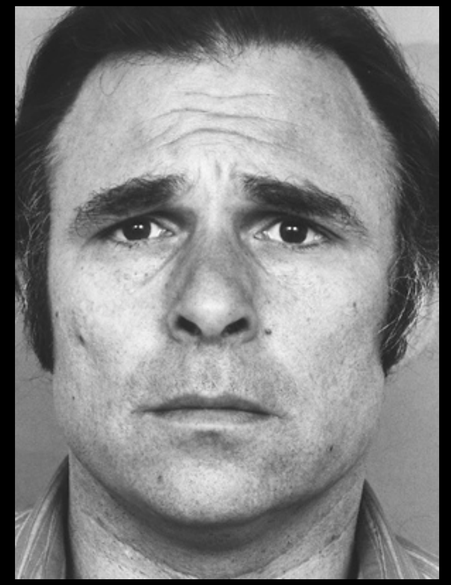
AU 4

Vertical wrinkles appear in the glabella and the eyebrows are pulled together. The inner parts of the eye-brows are pulled down a trace on the right and slightly on the left with traces of wrinkling at the corners.



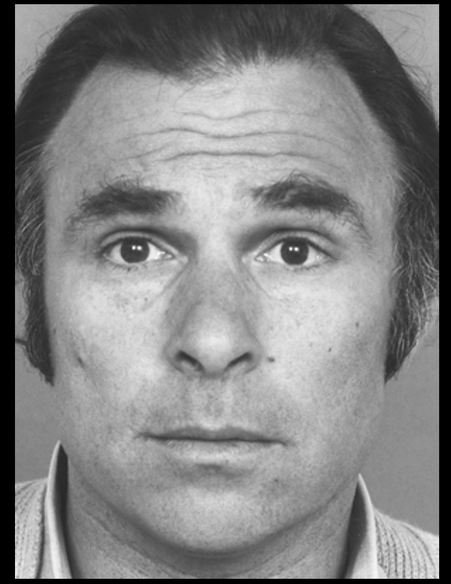
AU 1+4

Raising the inner corners of the eyebrows and pull the eyebrows together.



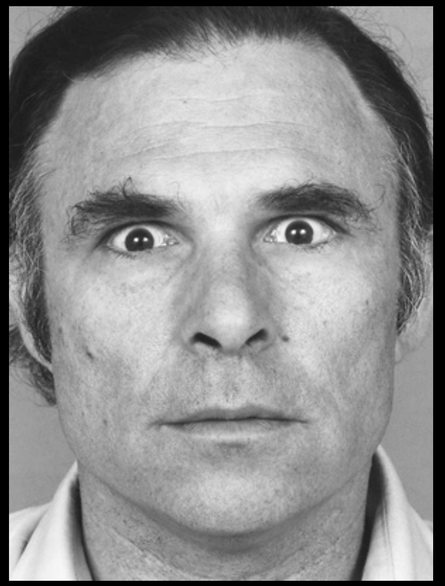
AU 1+2+4

The entire brow is raised markedly. The slight pulling together appears weaker than the raising, with only slight straightening and a trace of bulging between the brows.



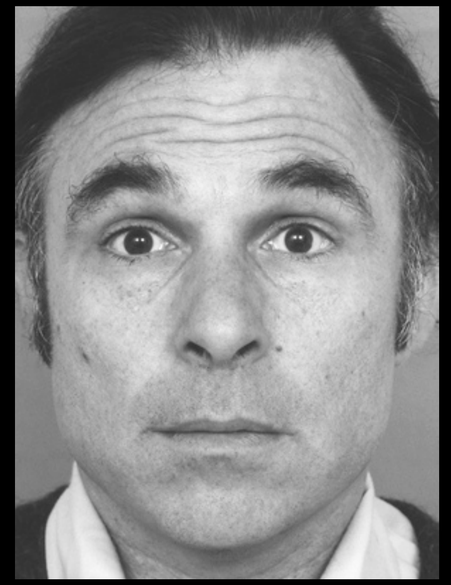
AU 5

The upper eyelid is pulled up, the medial part virtually disappearing into the revulsion margin of the eye cover fold. More sclera around the upper part of the iris is revealed The inner corner of the eye shows more mucosa and sclera.



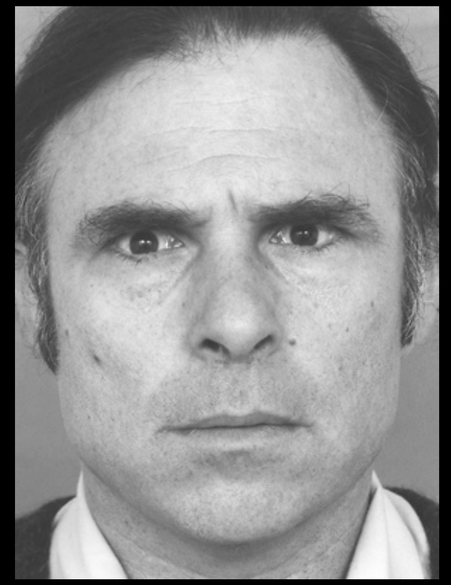
AU 1+2+5

Eye brows raised to expose the eye cover fold. The upper eyelid is raised to expose virtually the
entire iris.

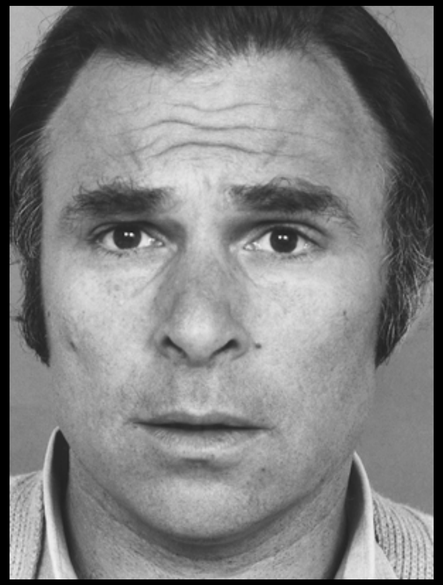


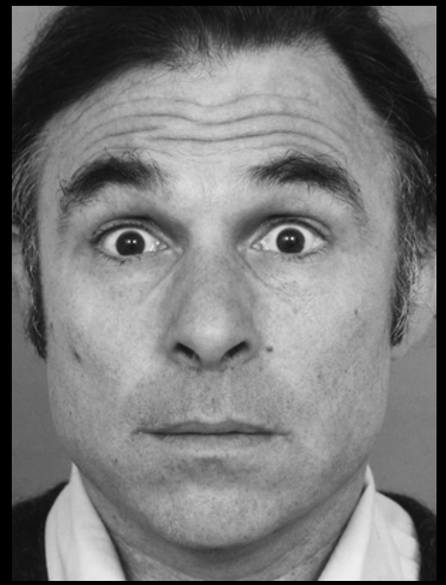
AU 4+5

Pull the inner parts of the eyebrows are pulled together and raise the upper eyelid.



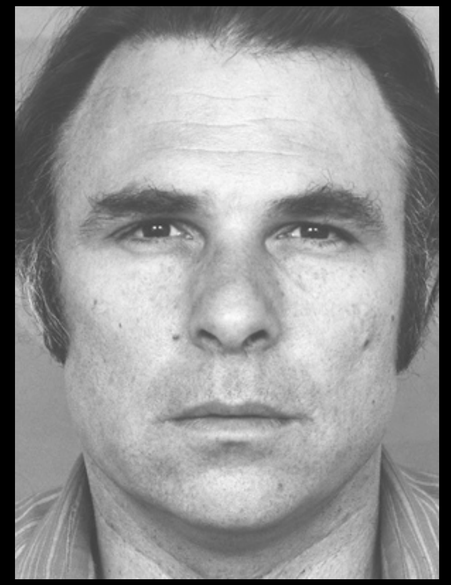
AU 1+2+4+5





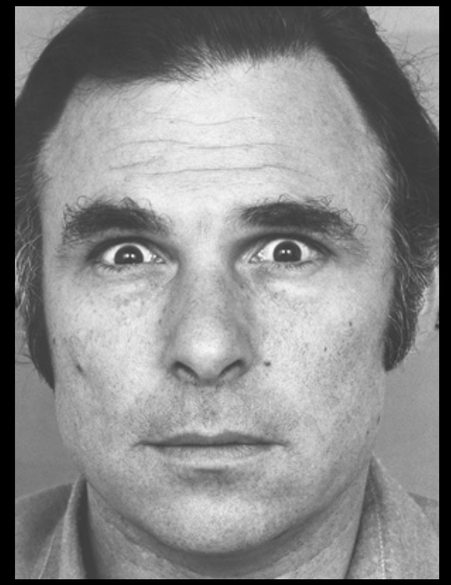
AU 7

The lower eyelid is raised markedly and straightened slightly, causing slight bulging, and the narrowing of the eye aperture is marked to pronounced.

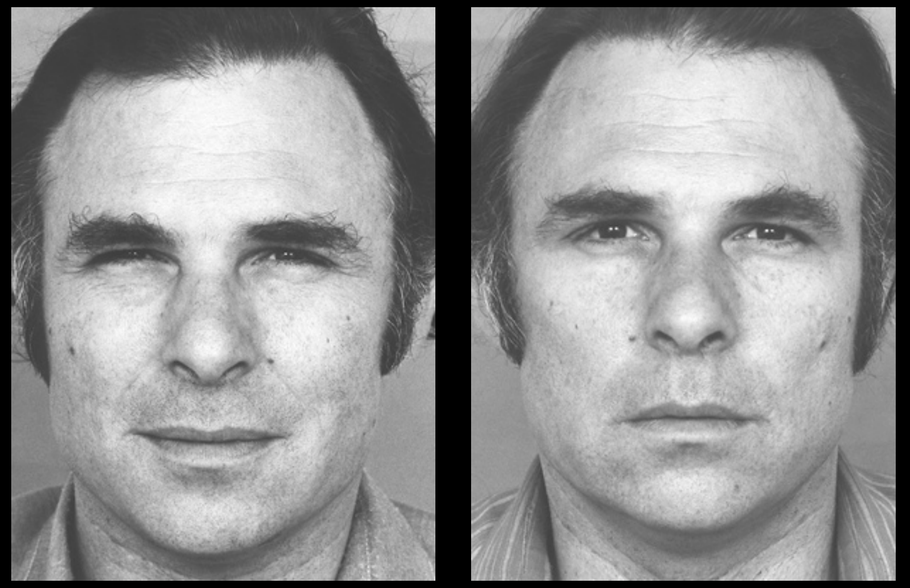


AU 5+7

The upper eyelid is raised to reveal much more than a hairline of sclera around the top of the iris. The lower eyelid is raised and straightened markedly on the eyeball forming a marked bulge.

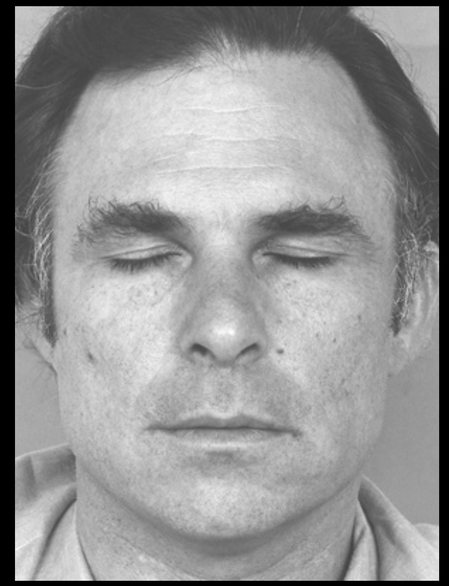


AU 6+7



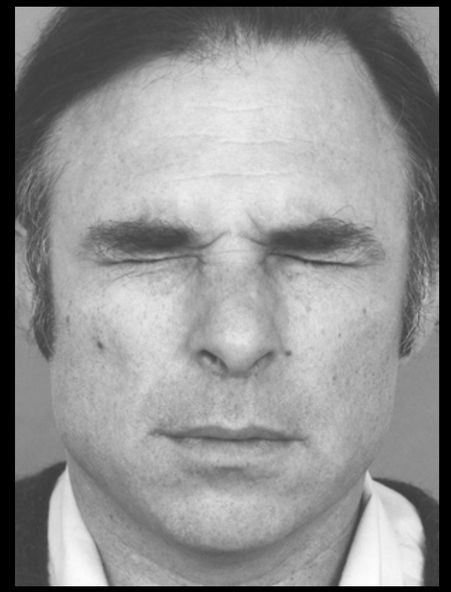
AU 43

Eyes closed.



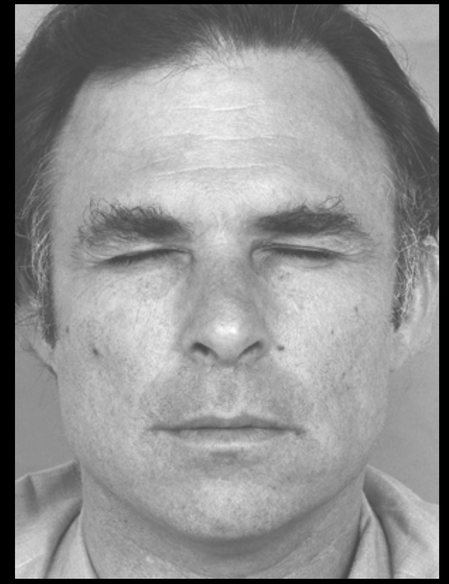
AU 6+43

Squeeze the eyes closed as much as possible.

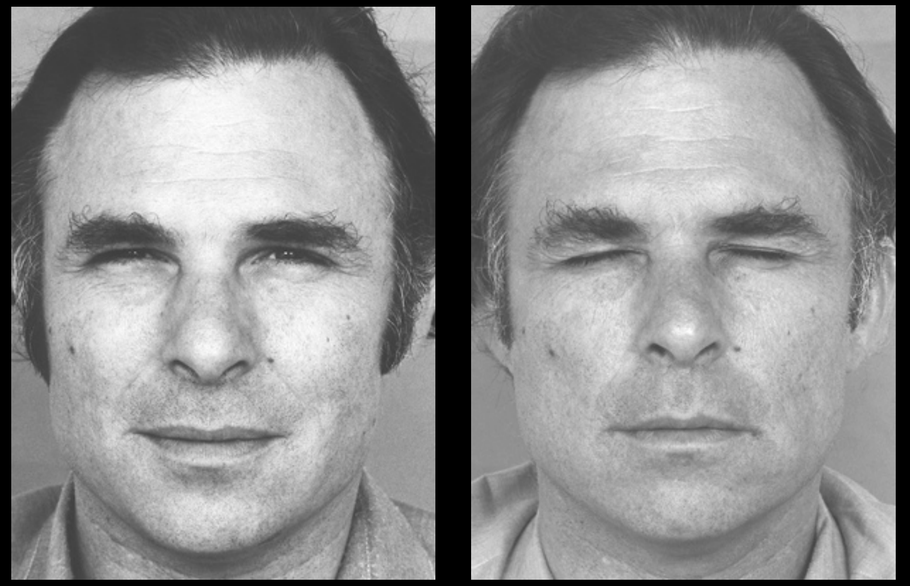


AU 7+43

The eyes are closed. The lids are tensed with the lower lid raised and straightened. The eyelashes appear held between the tensed lids.

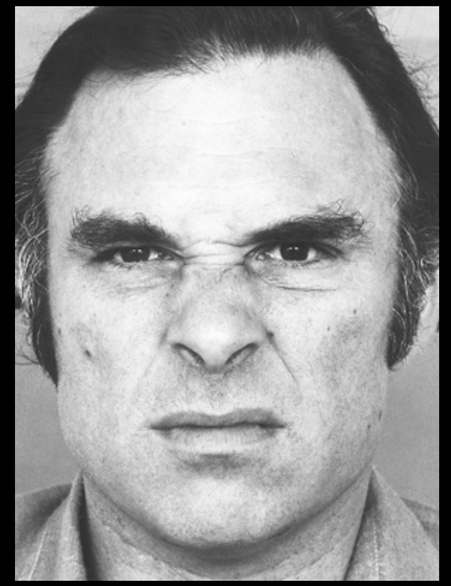


AU 6+7+43



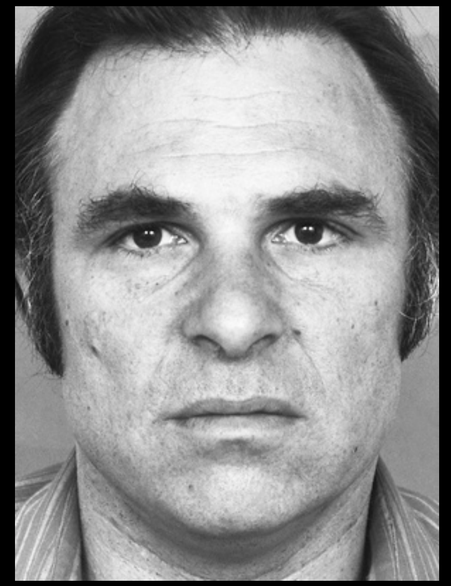
AU 9

Wrinkle the nose, draw skin on bridge of the nose upwards, lift the nasal wings up, raising the infraorbital triangle severely, and deepening the upper part of the nasolabial fold extremely as the upper lip is drawn up slightly.



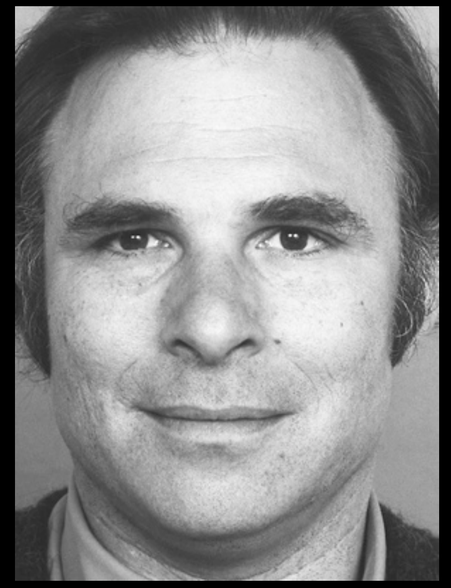
AU 10

Raised upper lip slightly and deepen the nasolabial furrow.

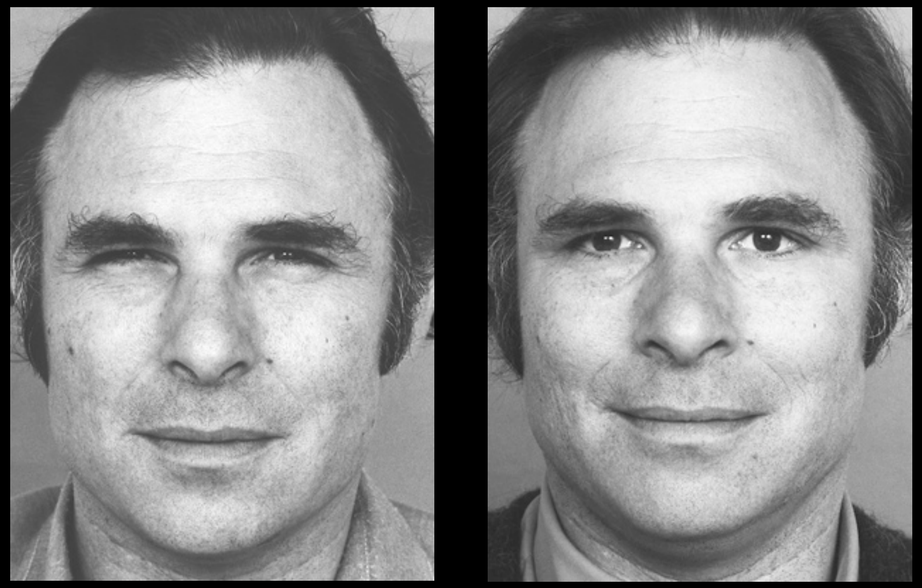


AU 12

The corners of the lips are markedly raised and angled up obliquely. The nasolabial furrow has deepened slightly and is raised obliquely slightly. The infraorbital triangle is raised slightly.

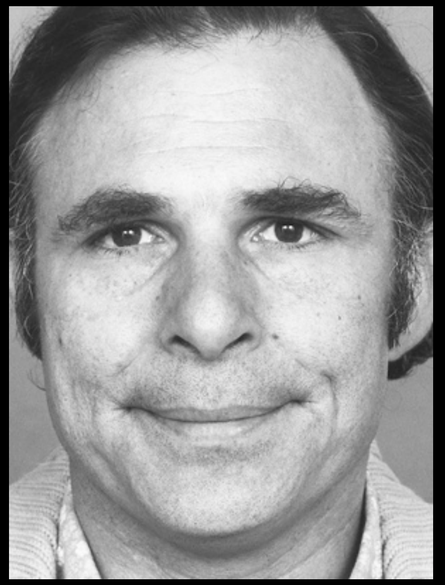


AU 6+12



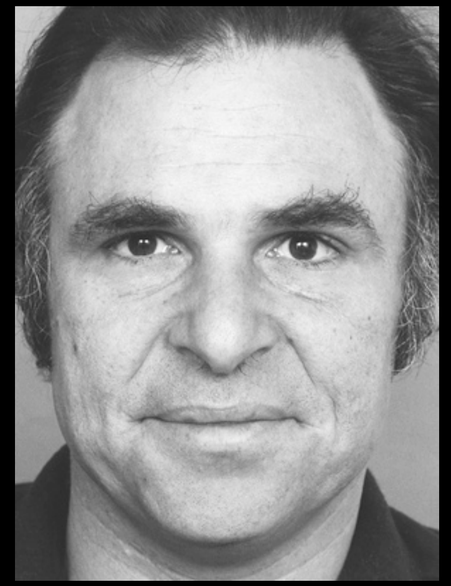
AU 14

The lip corners are extremely tightened, and the wrinkling as skin is pulled inwards around the lip corners is severe. The skin on the chin and lower lip is stretched towards the lip corners, and the lips are stretched and flattened against the teeth.



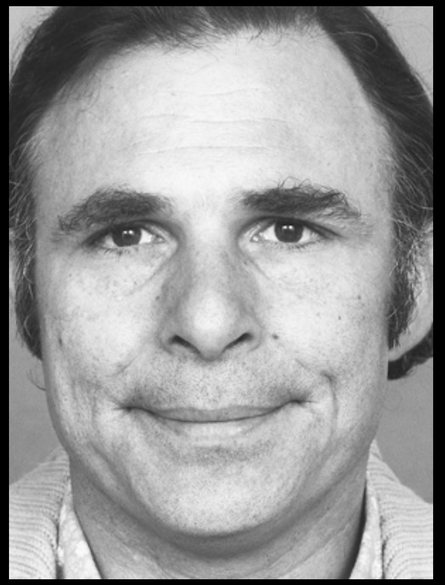
AU 10+14

Lift your upper lip but do not part your lips. Then tighten the corners of your lips. Do not wrinkle your nose in lifting your upper lip.



AU 14 (Unilateral)

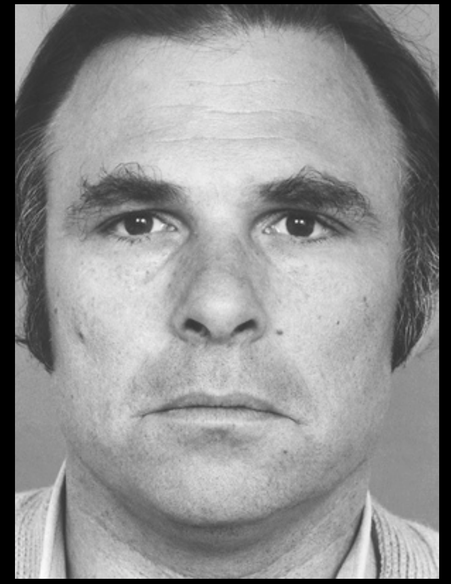
The lip corners are extremely tightened, and the wrinkling as skin is pulled inwards around the lip corners is severe. The skin on the chin and lower lip is stretched towards the lip corners, and the lips are stretched and flattened against the teeth.



ONE SIDE ONLY

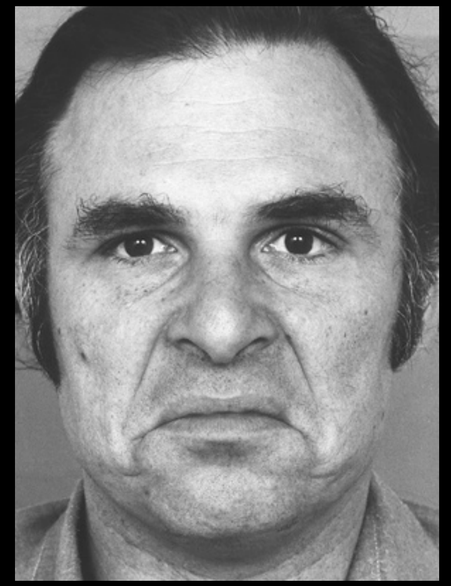
AU 15

The lip corners are pulled down slightly, with some lateral pulling and angling down of the corners, and slight bulges and wrinkles appear beyond the lip corners.



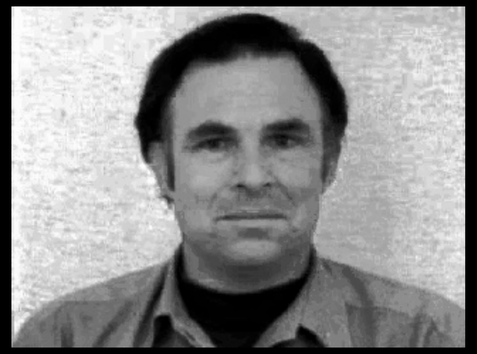
AU 10+15

Lip corners are maximally pulled down and angled into an inverted-U.



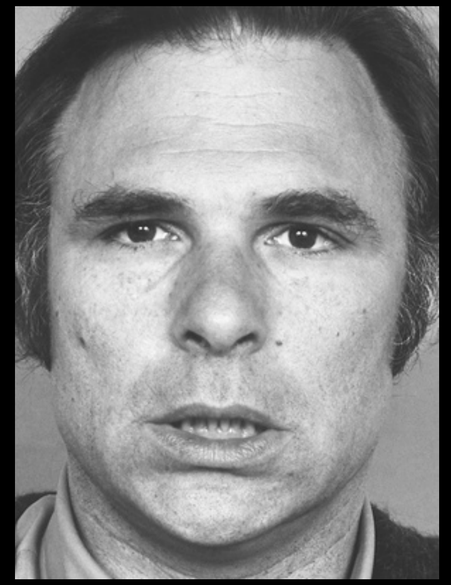
AU 12+15

Smile and pull your lip corners downwards.



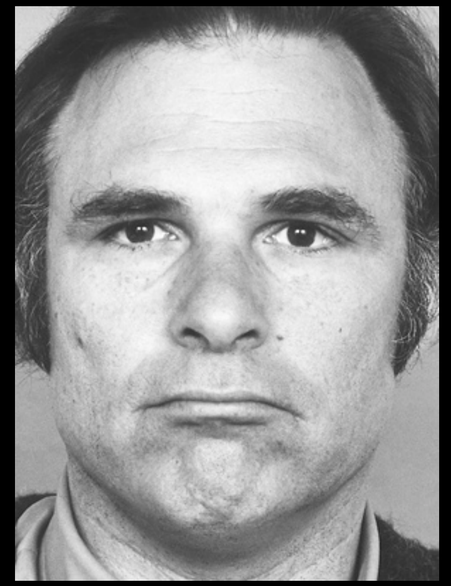
AU 16

With your mouth closed, and your teeth together but not clenched, pull your lower lip straight down so that the center of your lip is lowered to show the lower front teeth, as though baring your teeth to check how clean and bright they are.

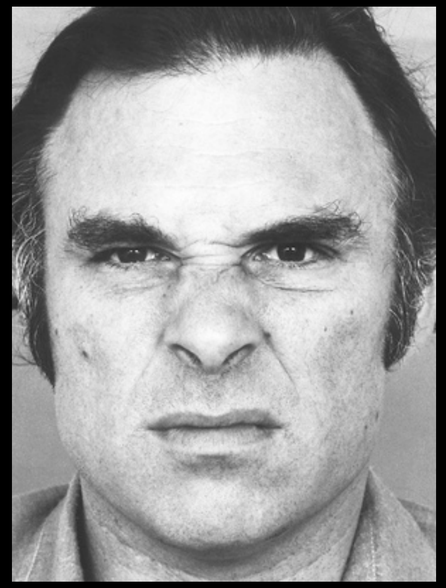


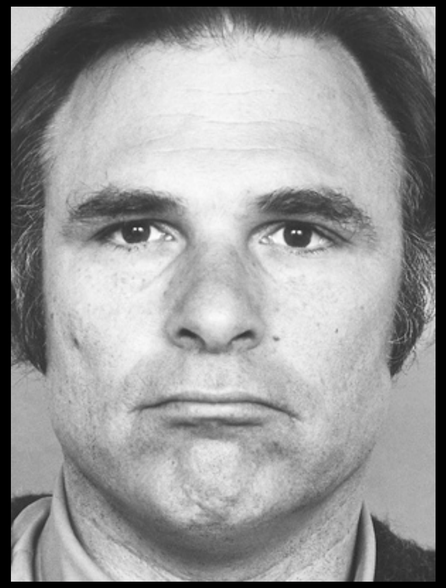
AU 17

The chin boss shows severe to extreme wrinkling as it is pushed up severely, and the lower lip is pushed up and out markedly.

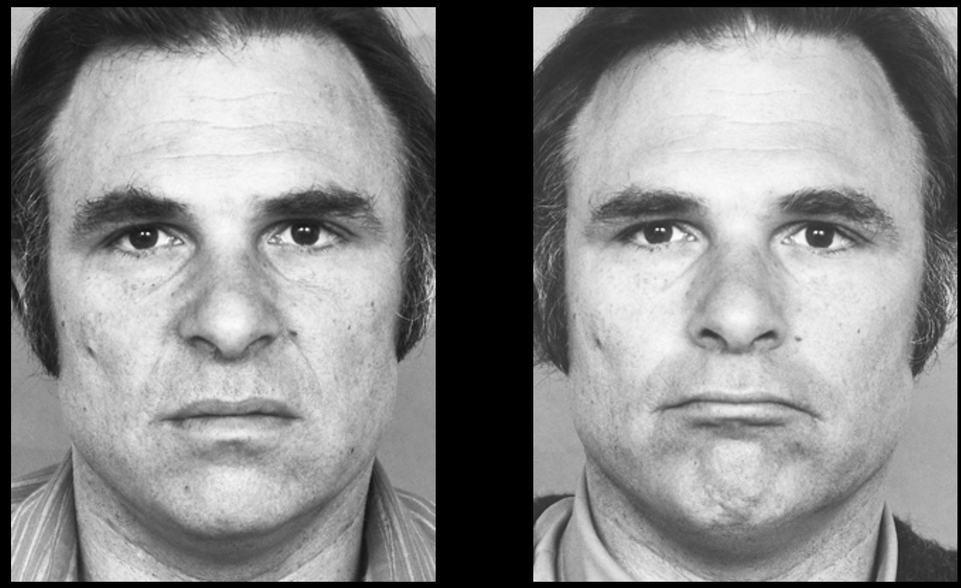


AU 9+17

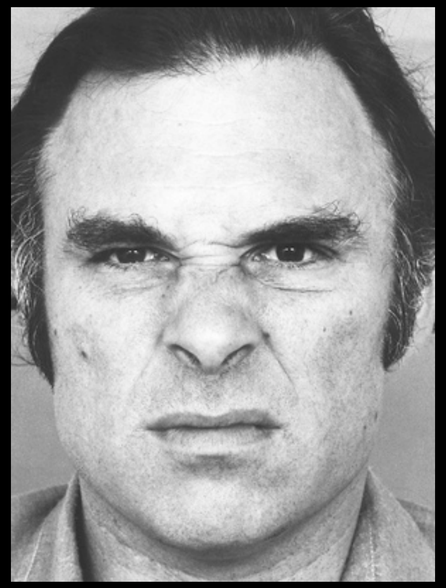
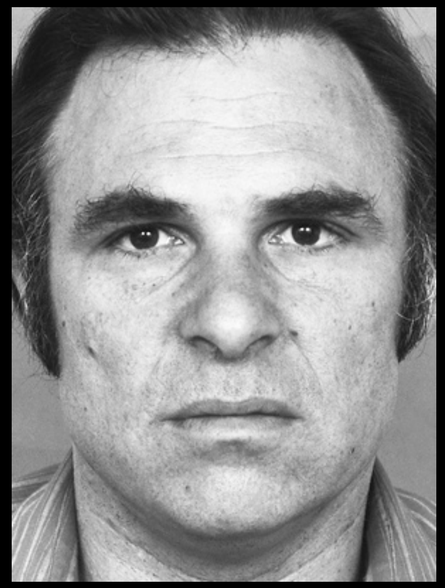
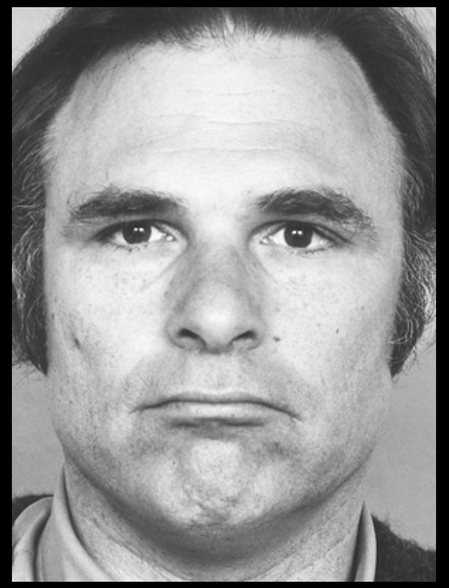




AU 10+17

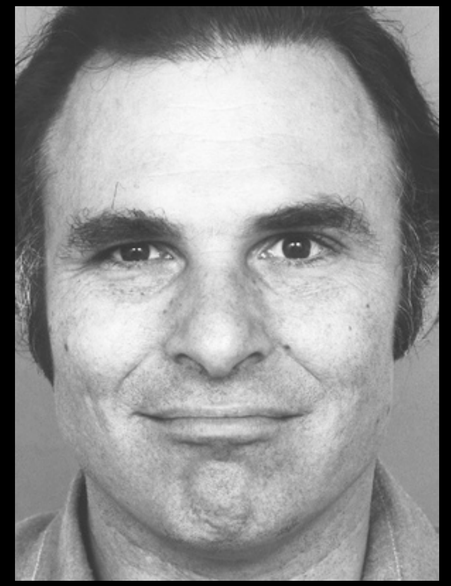


AU 9+10+17

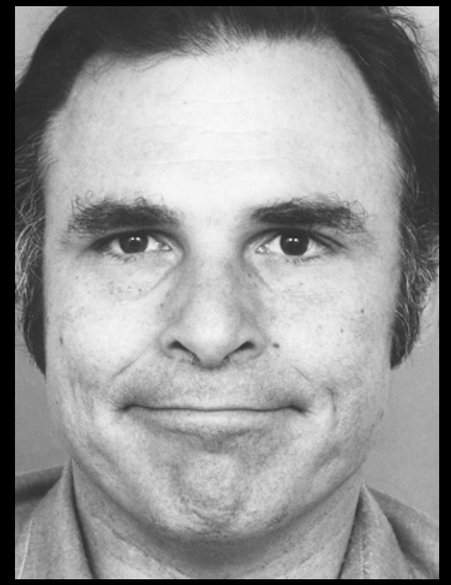
AU 12+17

Smile and pull your lip corners downwards.
Push your lower lip upwards.



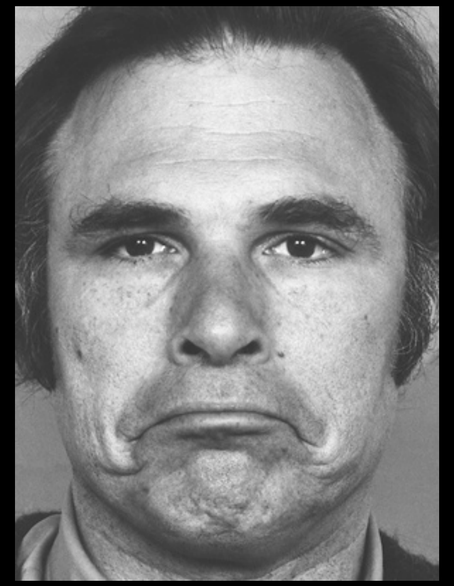
AU 14+17

Make a dimple in your cheek appear and squeeze very hard, pressing your cheeks against your teeth. Push your lower lip upwards.



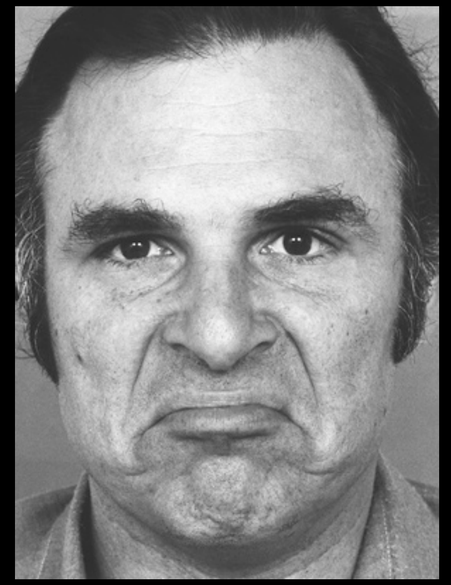
AU 15+17

Lip corners are maximally pulled down forming a curved inverted-U-shape. Lower lip pushes up.



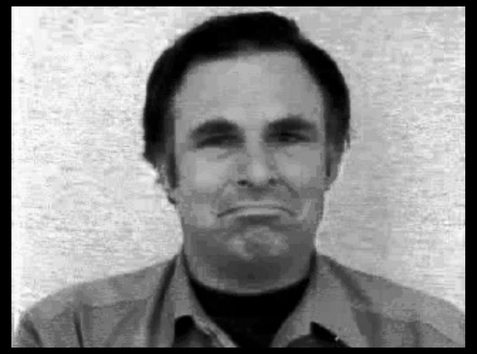
AU 10+15+17

Pull down the lip corners to form an angled down inverted-U shape. Push up the lower lip. Raise the upper lip as much as possible.



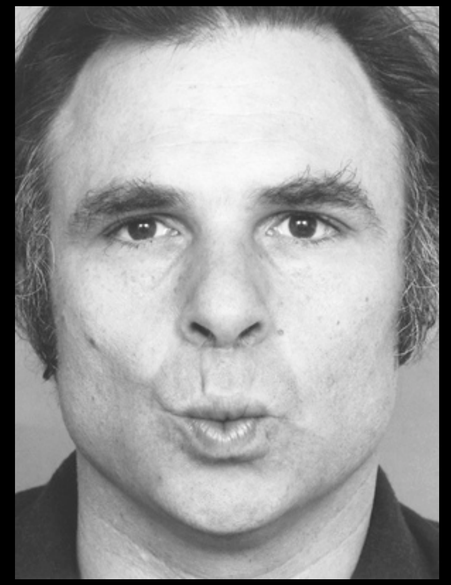
AU 12+15+17

Smile and pull your lip corners downwards and push lower lip upwards.



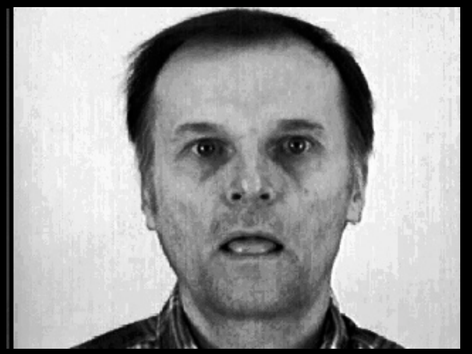
AU 18

The corners of the mouth are pulled towards the philtrum extremely, puckering the mouth, de-elongating the lips and mouth extremely, forming severe wrinkles in the skin and red parts of the lips, and protruding the lips extremely.



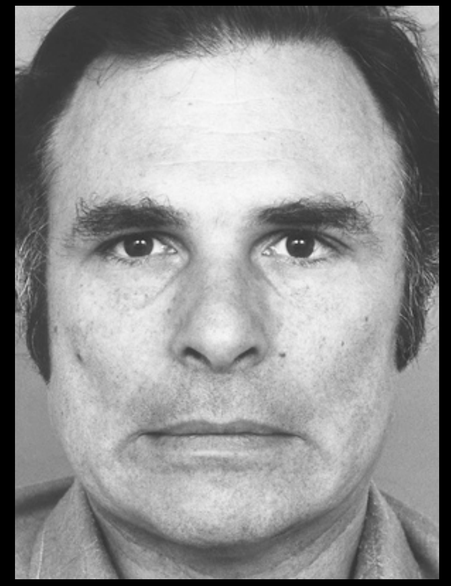
AU 19

Show the tongue.



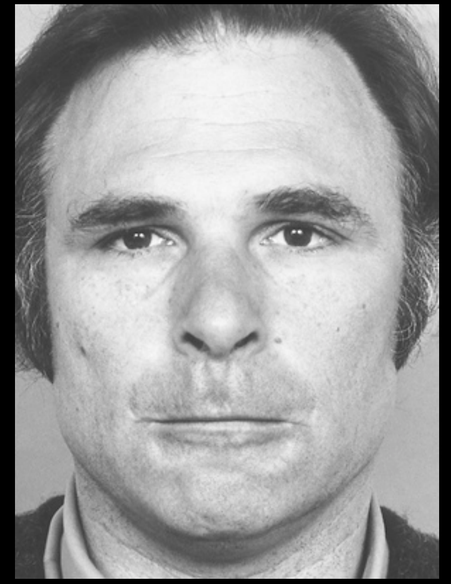
AU 20

Marked lip stretching to the side, marked mouth elongation, and marked wrinkling and bulging at the lip corners.



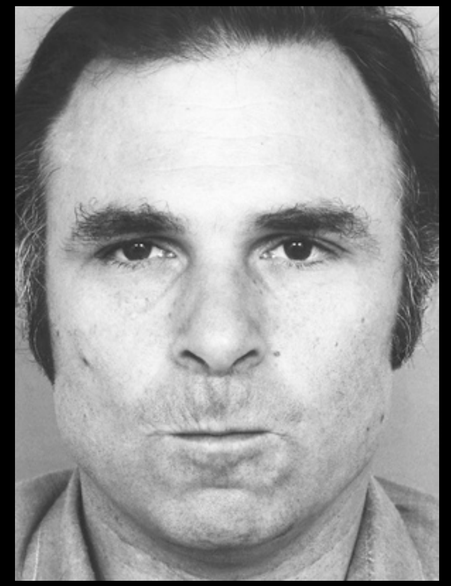
AU 23

The lips are tightened maximally and the red parts are narrowed maximally, creating extreme wrinkling and bulging around the margins of the red parts of both lips.



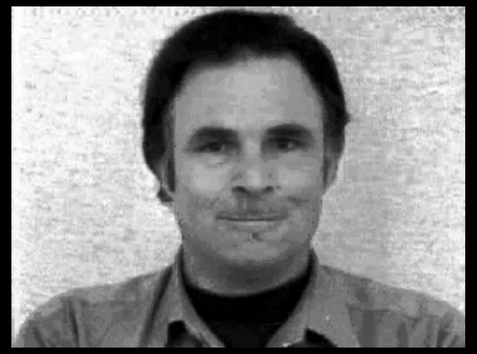
AU 18+23

Purse your lips and pucker-up as if for a kiss. Speak the word “fool” holding your lips in the vowel position. Tighten your lips. Make them thin and tense. Be careful not to press them together.



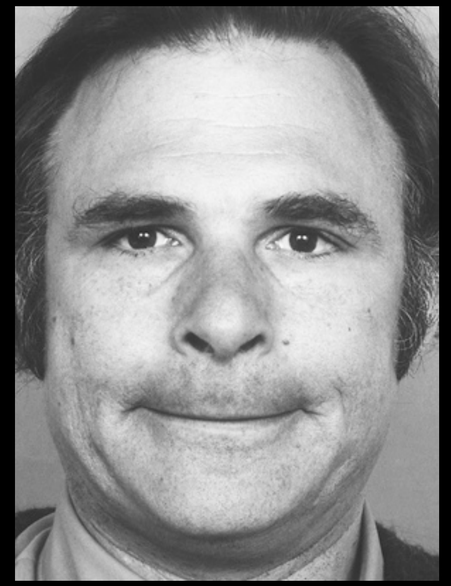
AU 12+23

Smile and tighten your lips. Make them thin and tense. Be careful not to press them together.



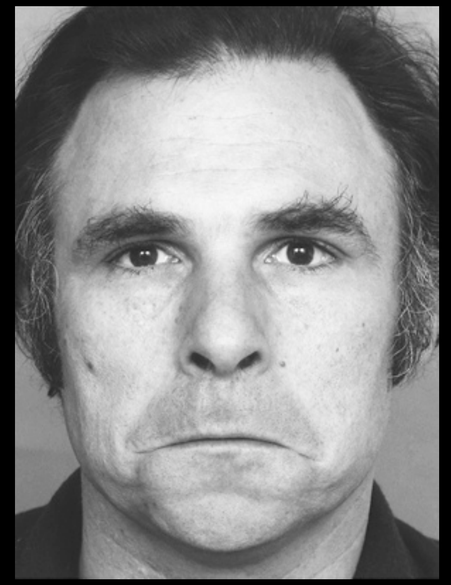
AU 14+23

Make a dimple in your cheek, squeeze hard, pressing your cheeks against your teeth. Tighten your lips. Make them thin and tense. Be careful not to press them together.



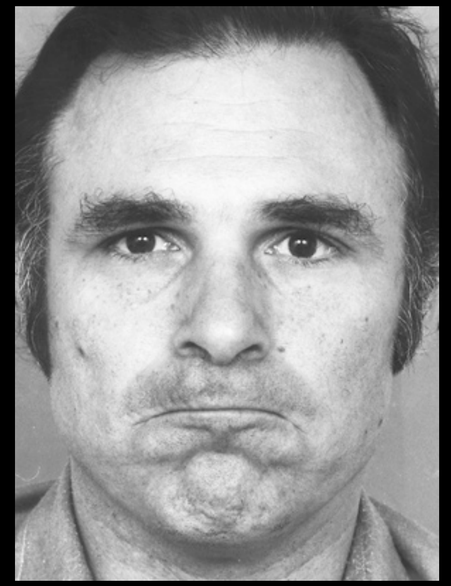
AU 15+23

Pull your lip corners downwards. Be careful not to raise your lower lip at the same time. Tighten your lips. Make them thin and tense. Be careful not to press them together.



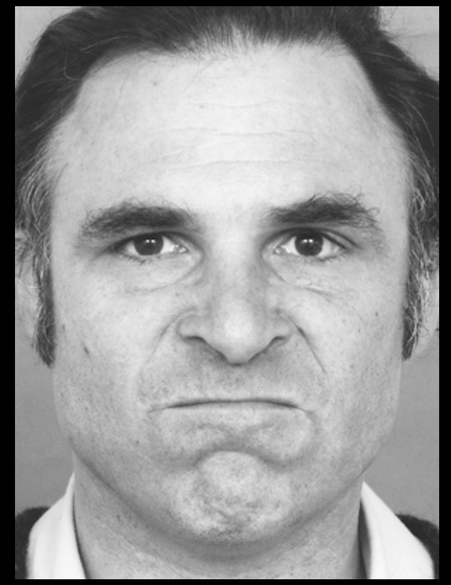
AU 17+23

Push your lower lip upwards and tighten your lips. Make them thin and tense. Be careful not to press them together.



AU 10+17+23

Lift your upper lip straight up to show your upper front teeth and push your lower lip upwards. Tighten your lips. Make them thin and tense. Be careful not to press them together or include nose wrinkling.

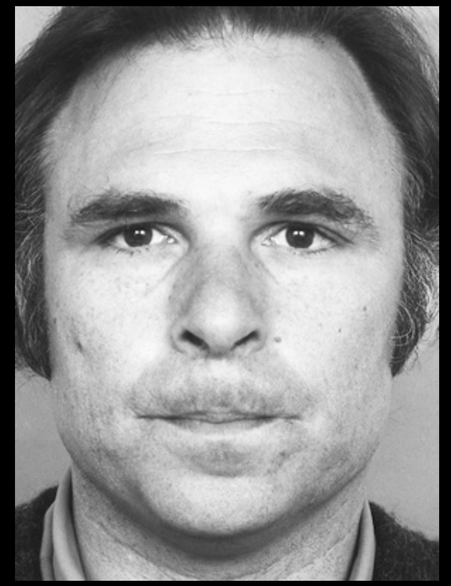


AU 12+17+23

Lift your cheeks without actively raising up the lip corners. Smile and push your lower lip upwards.

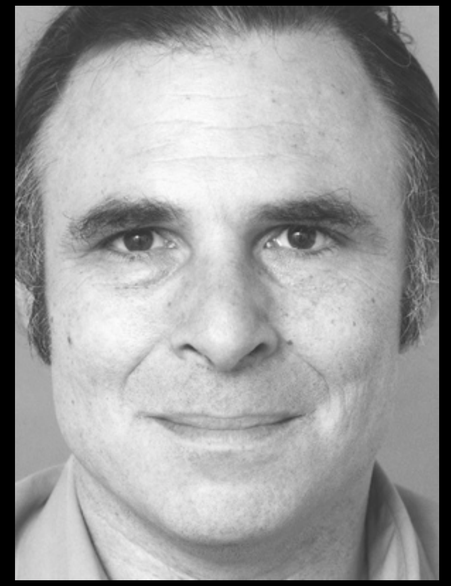
AU 24

The lips are severely pressed together, severely bulging skin above and below the red parts, with severe narrowing of the lips and wrinkling above the upper lip.



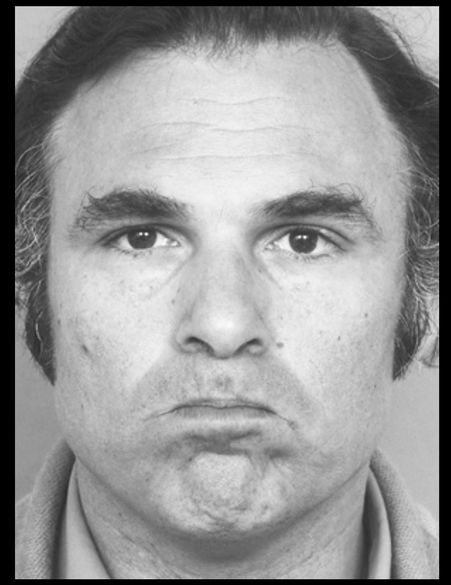
AU 12+24

Smile and press your lips together. Be careful not to push up with your lower lip in a hard fashion. Also be careful not to tighten your lip corners.

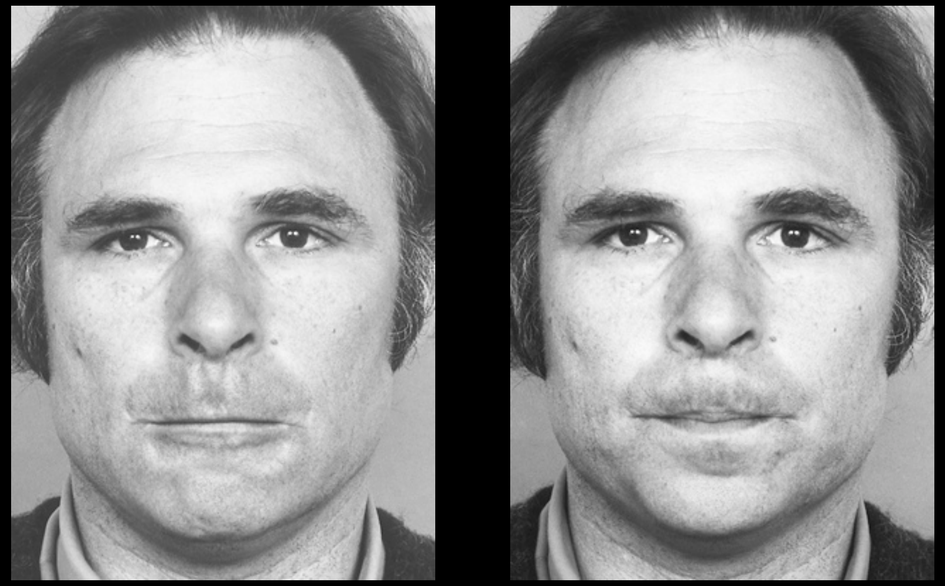


AU 17+24

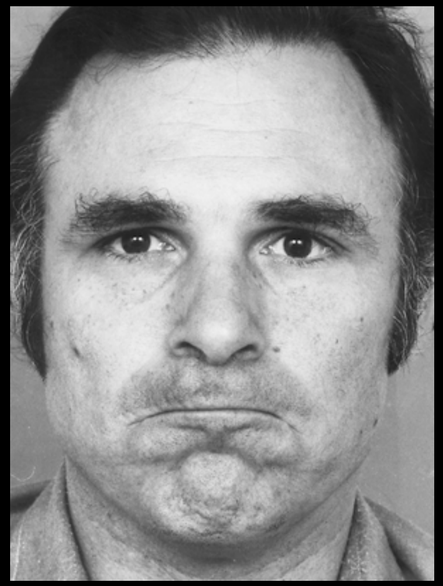
Push your lower lip upwards and press your lips together. Be careful not to push up with your lower lip in a hard fashion. Also be careful not to tighten your lip corners.

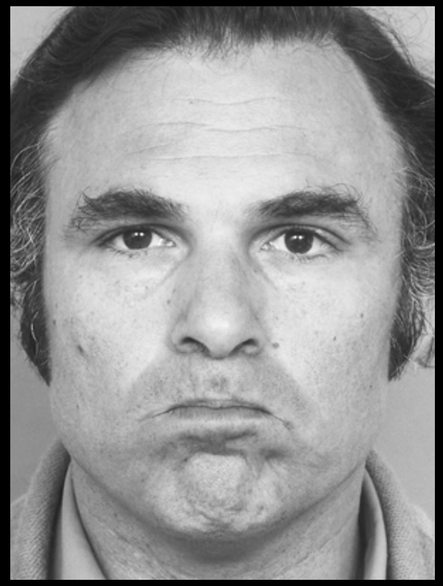


AU 23+24



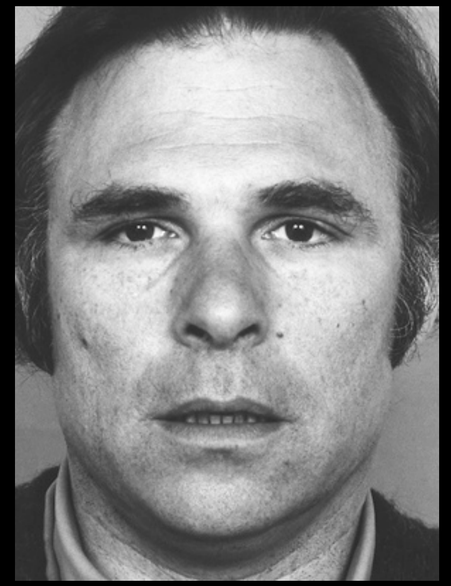
AU 17+23+24



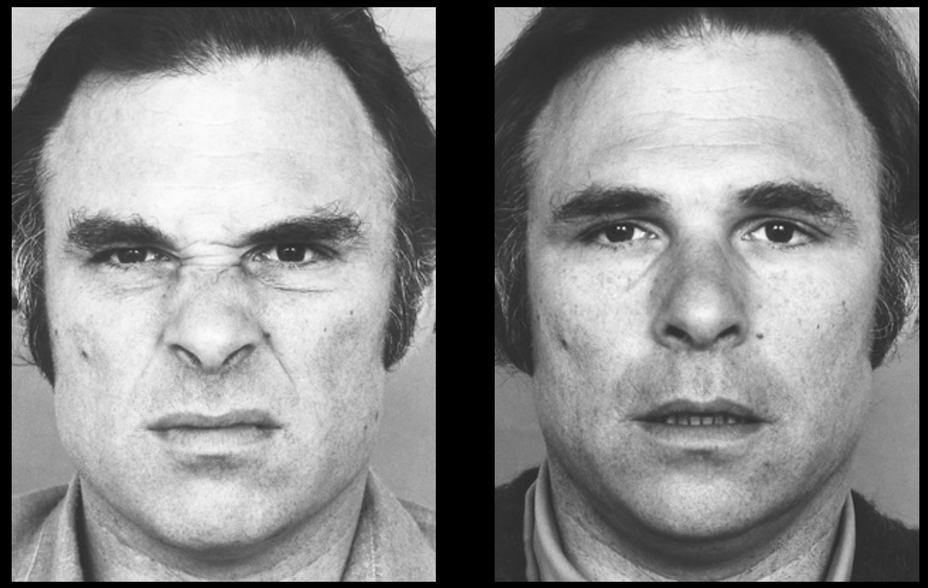


AU 25

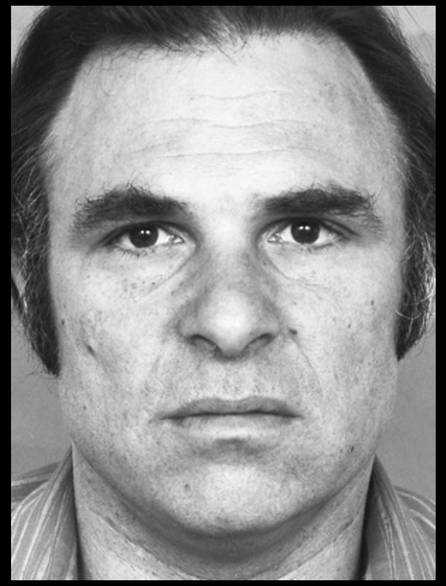
The teeth clearly show, and the lips are separated by about 2mm (not more than slightly greater than 2mm). Nothing suggests that the jaw has dropped even though the upper teeth are not clearly visible.

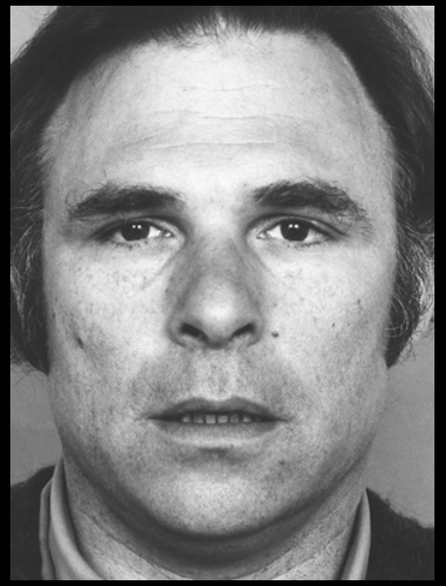


AU 9+25

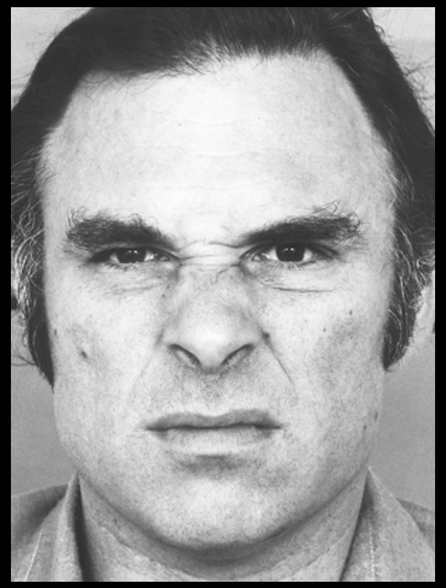
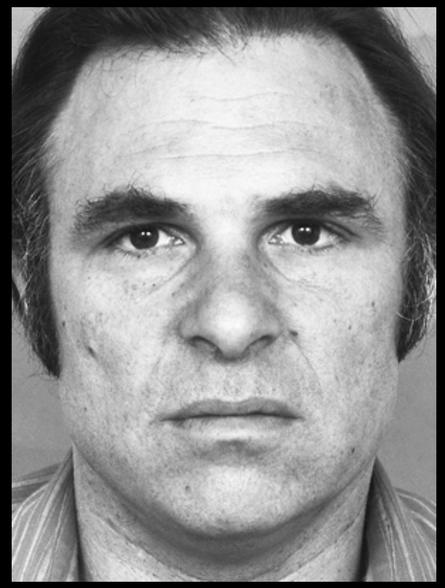
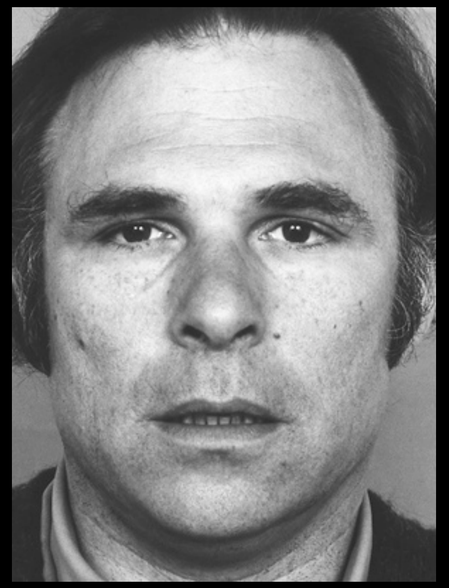


AU 10+25



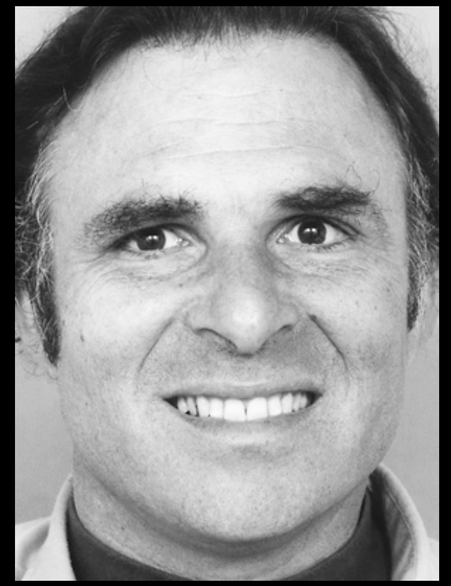


AU 9+10+25

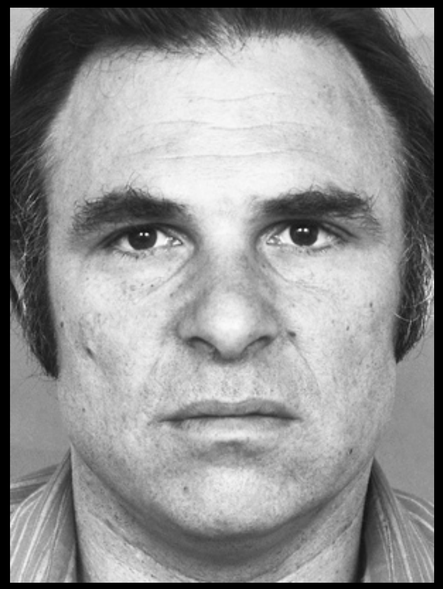
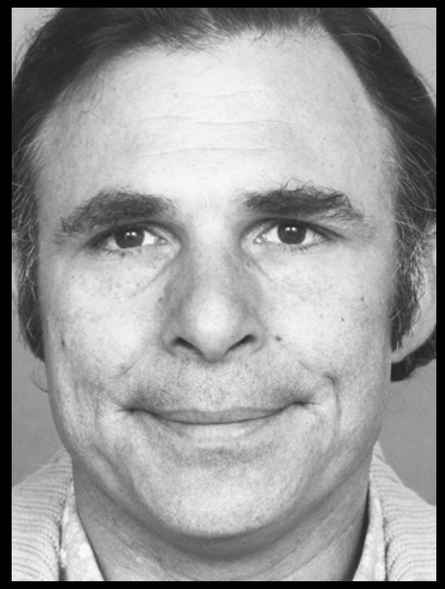
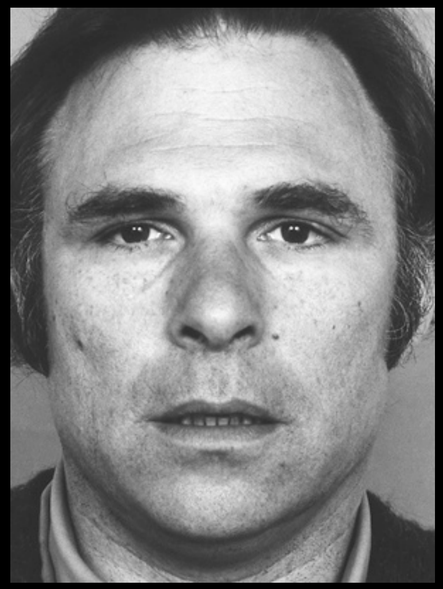




AU 10+12+25

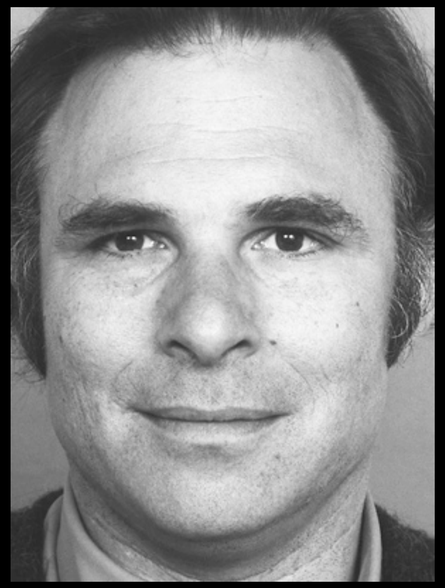
Smile and lift your upper lip straight up to show your upper front teeth but be careful not to include nose wrinkling.

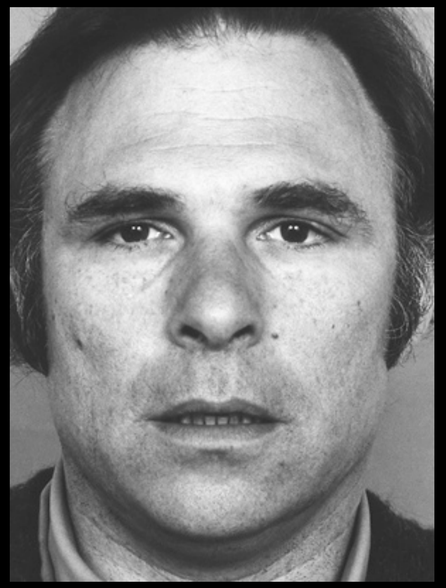


AU 10+14+25

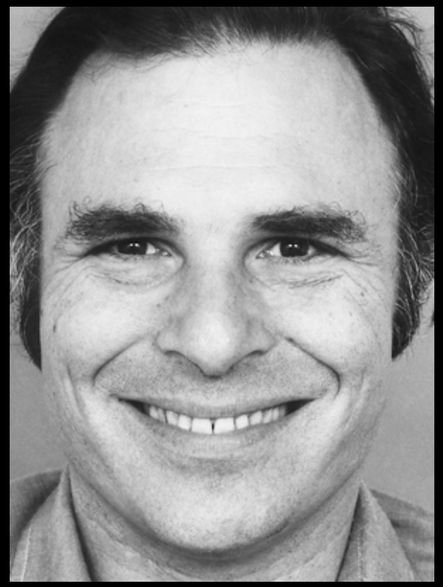




AU 12+25



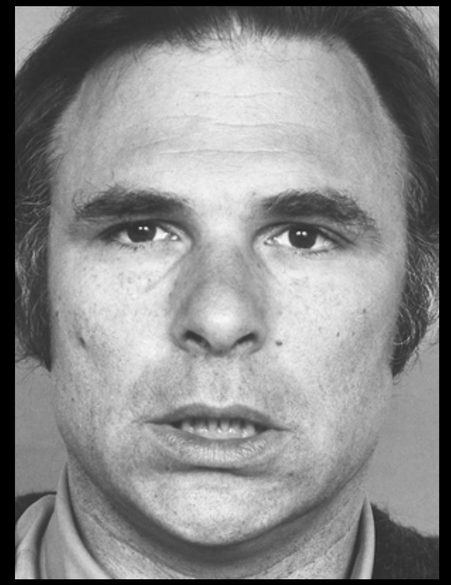


AU 6+12+25



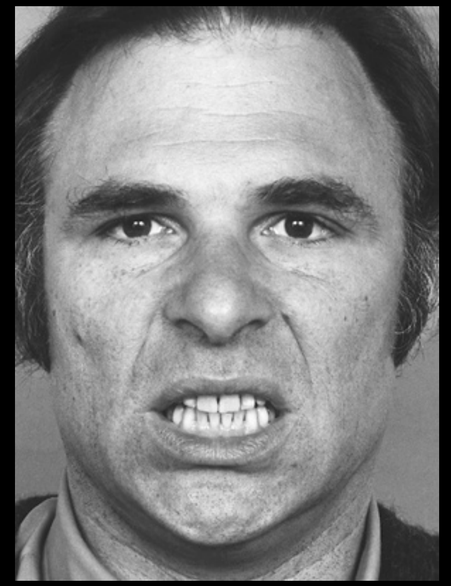
AU 16+25

Pull down the lower lip to reveal the gum line and a little more.



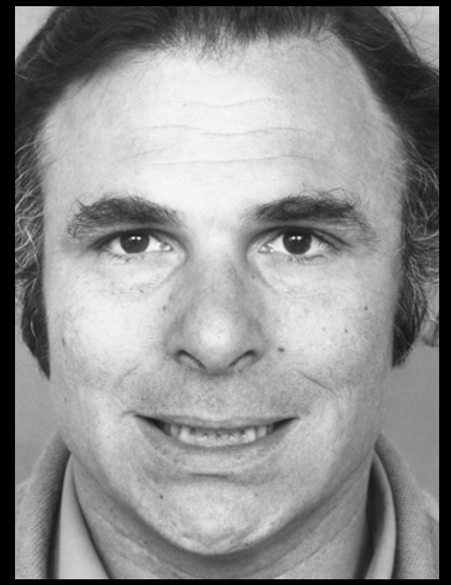
AU 10+16+25

The upper lip is raised severely. The lower lip is pulled down a maximum amount with lip and chin skin stretching laterally and downwards and flattening of the chin boss and other signs of 16 at a maximum.

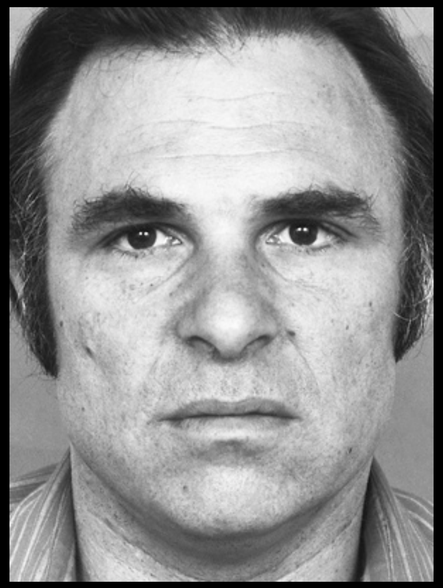
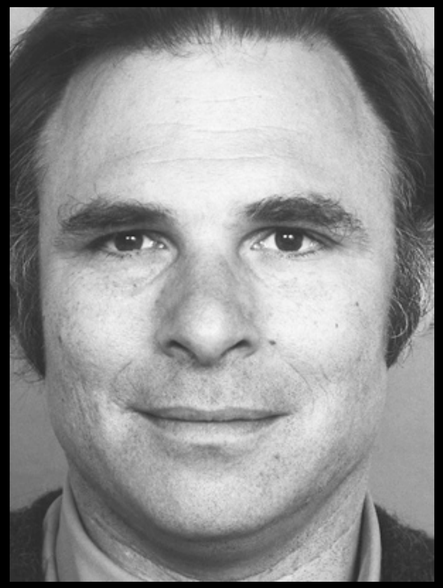
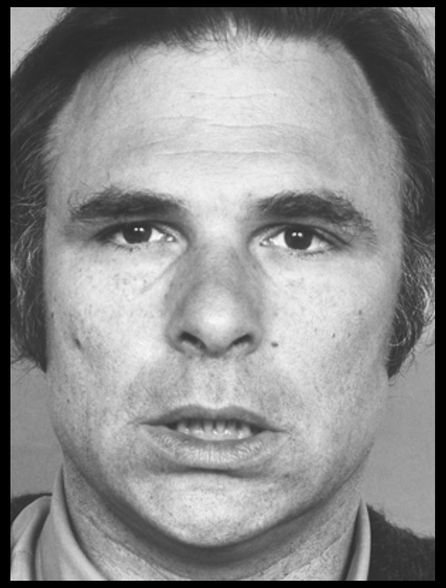


AU 12+16+25

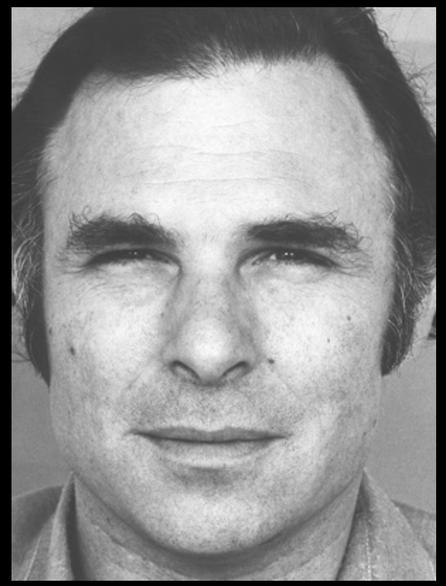
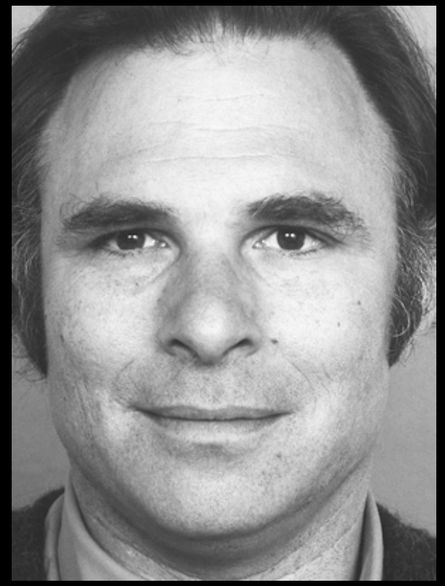
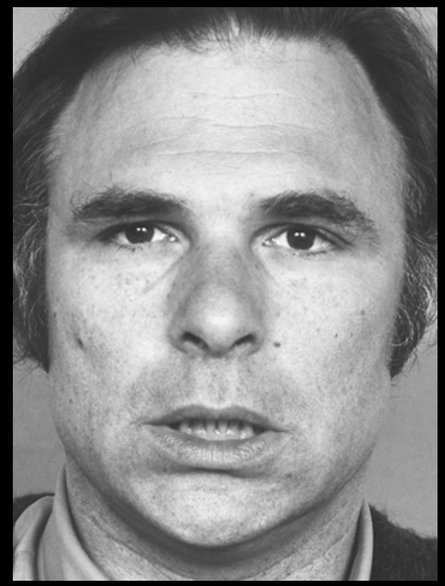
Smile and allow your lips to part. Lower your lower lip to show your lower teeth.



AU 10+12+16+25

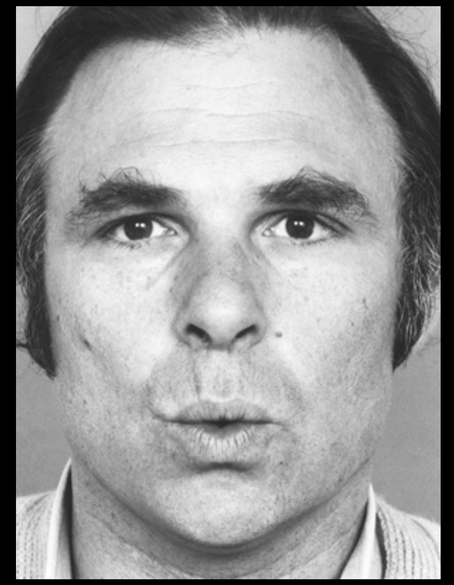




AU 6+12+16+25

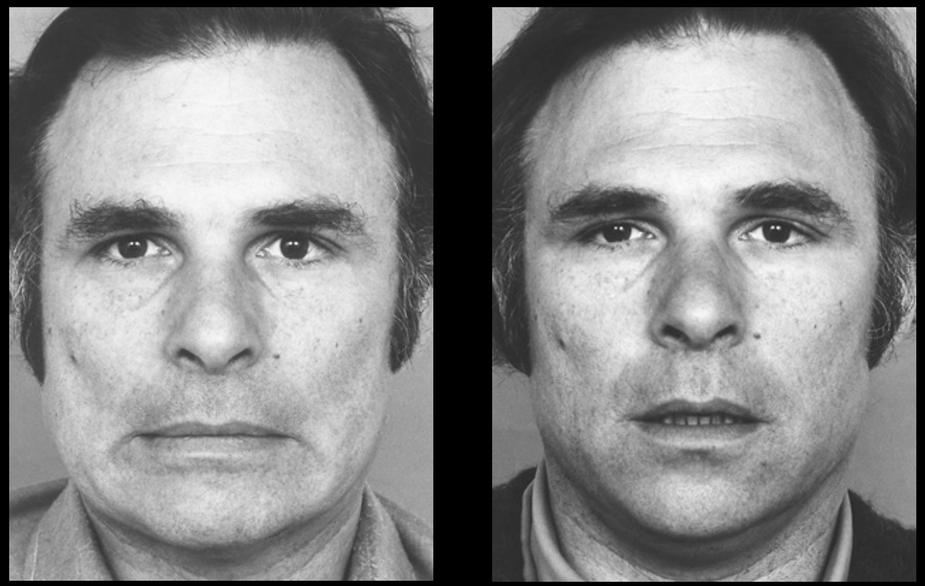




AU 18+25

Purse your lips and pucker-up as if for a kiss. Speak the word “fool”, holding your lips in the vowel position, then spread your lips apart.

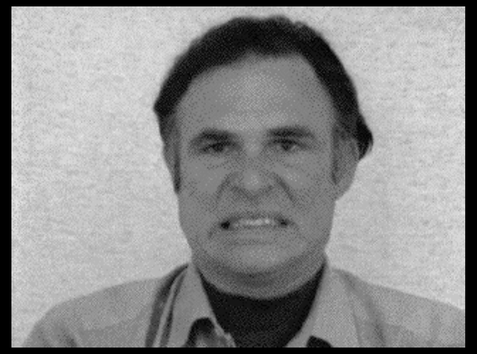


AU 20+25



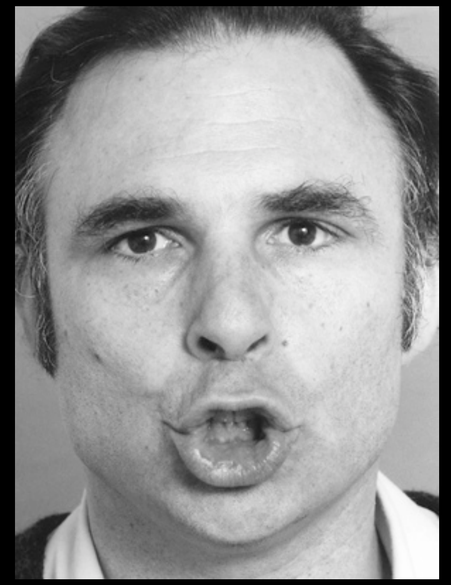
AU 10+20+25

Raise the upper lip so center of upper lip is drawn straight up, the outer portions of upper lip are drawn up but not as high as the center. Push the infraorbital triangle up, to cause the infraorbital furrow to appear, or deepen. Widen and raise the nostril wings, and pull the lips back laterally to elongate the mouth.

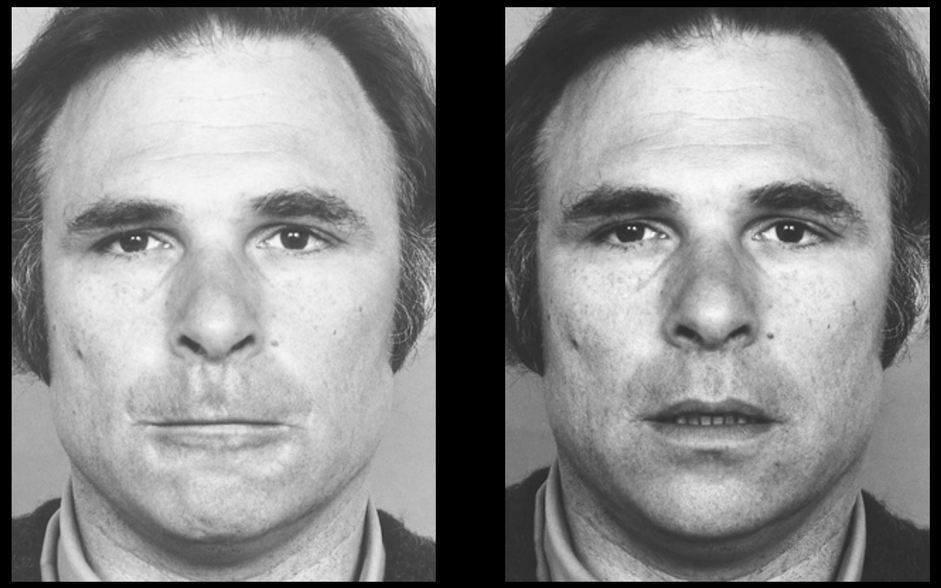


AU 22+25

Funnel the lips, turn outward, and thrust forward maximally, pulling the corners towards the philtrum, exposing extremely more red parts, the teeth, and gums, and the chin boss is flattened.

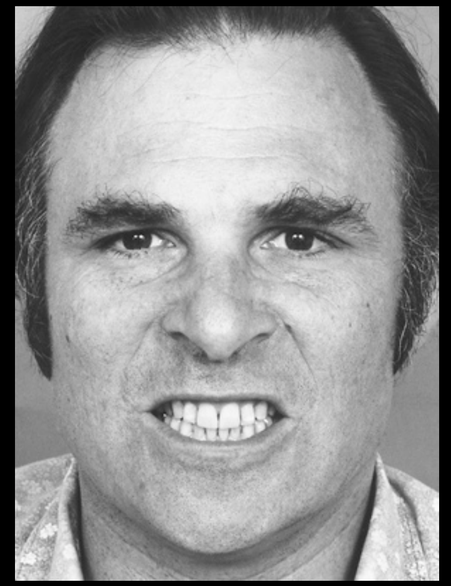


AU 23+25



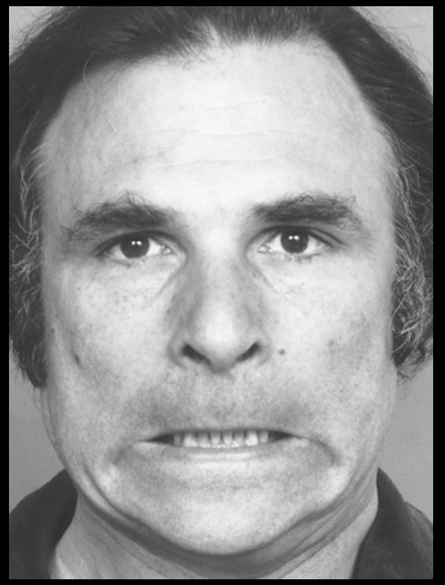
AU 10+23+25

Raise the upper lip and while holding this, tighten the lips.



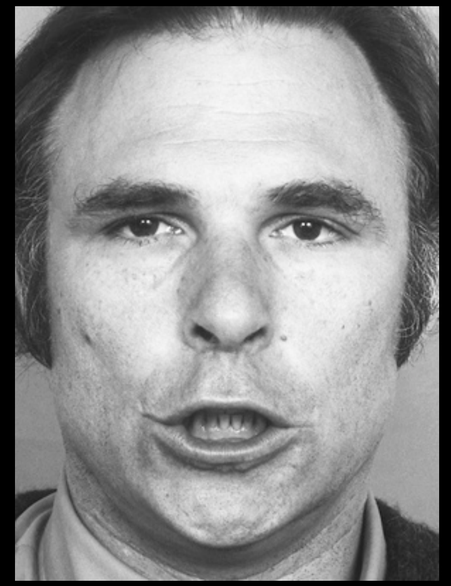
AU 20+23+25

Pull the lips horizontally back. Elongate the mouth pulling the skin beyond the lip corners laterally, so that the cheek area adjacent to the lip corners becomes flattened.



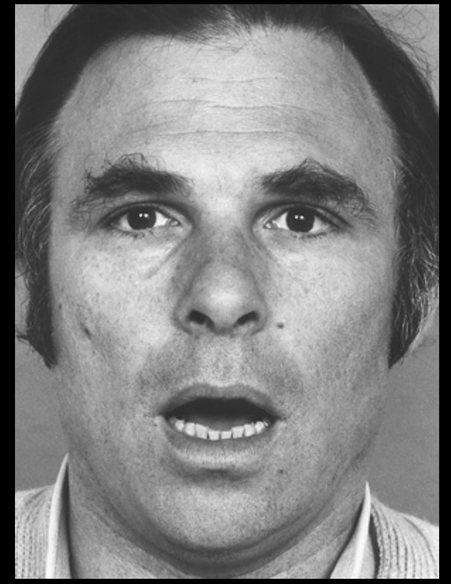
AU 22+23+25

Funnel your lips outwards. Speak the word “flirt”, accentuating the movement you make with your lips. Tighten your lips. Make them thin and tense. Be careful not to press them together.



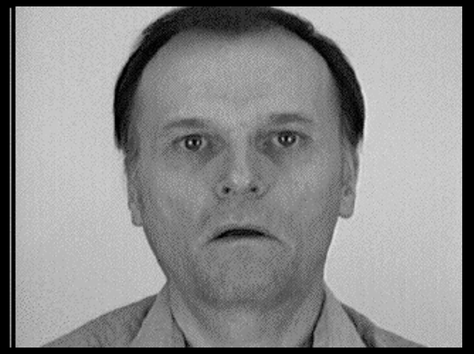
AU 26

The jaw is lowered about as much as it can drop from relaxing of the muscles. The lips are parted to about the extent that the jaw lowering can produce.

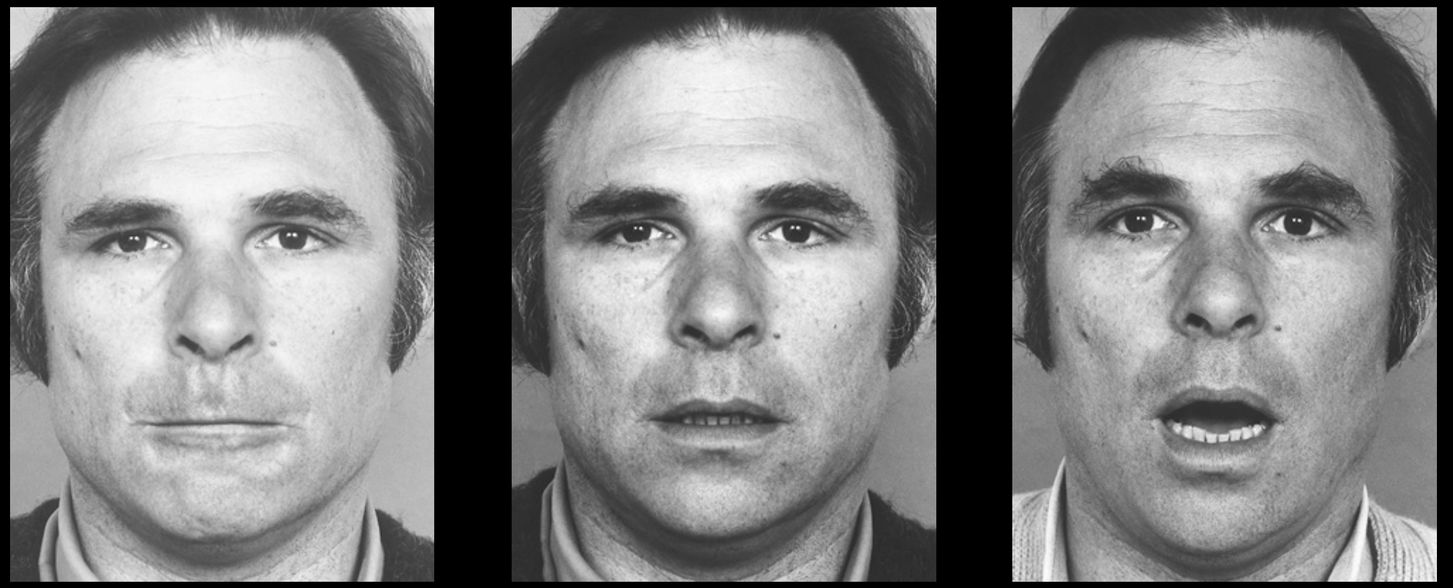


AU 25+26

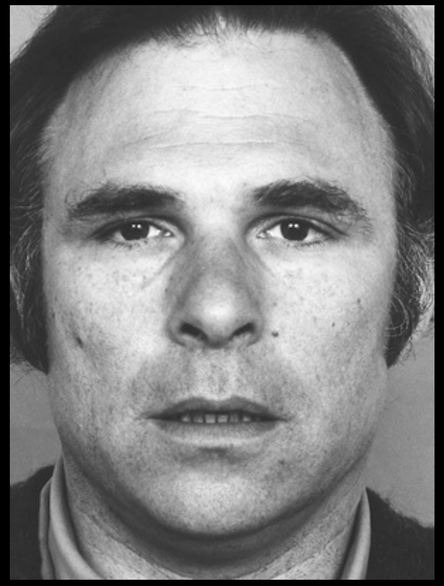
Relax your mouth and let your jaw fall open; do not pull or force your jaw open. The lips should be parted.

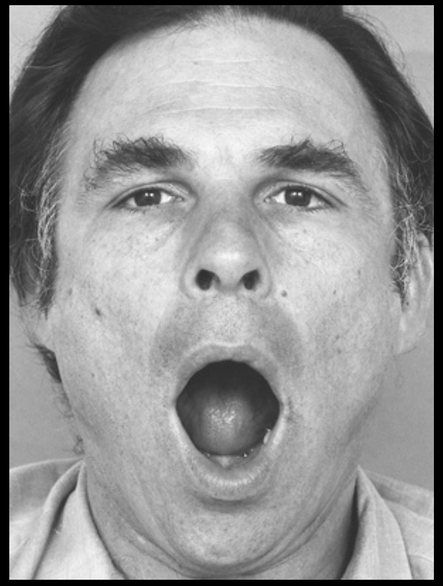


AU 23+25+26

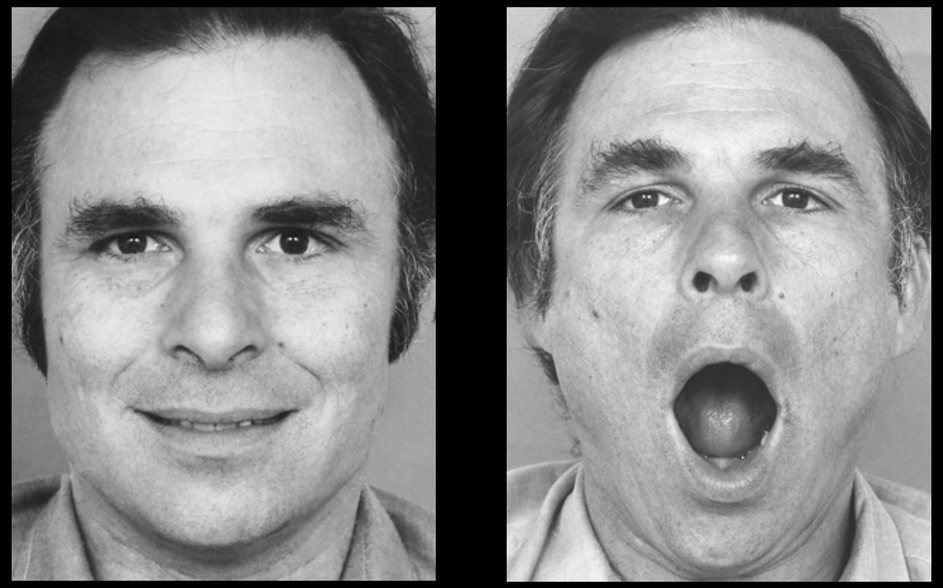


AU 25+27

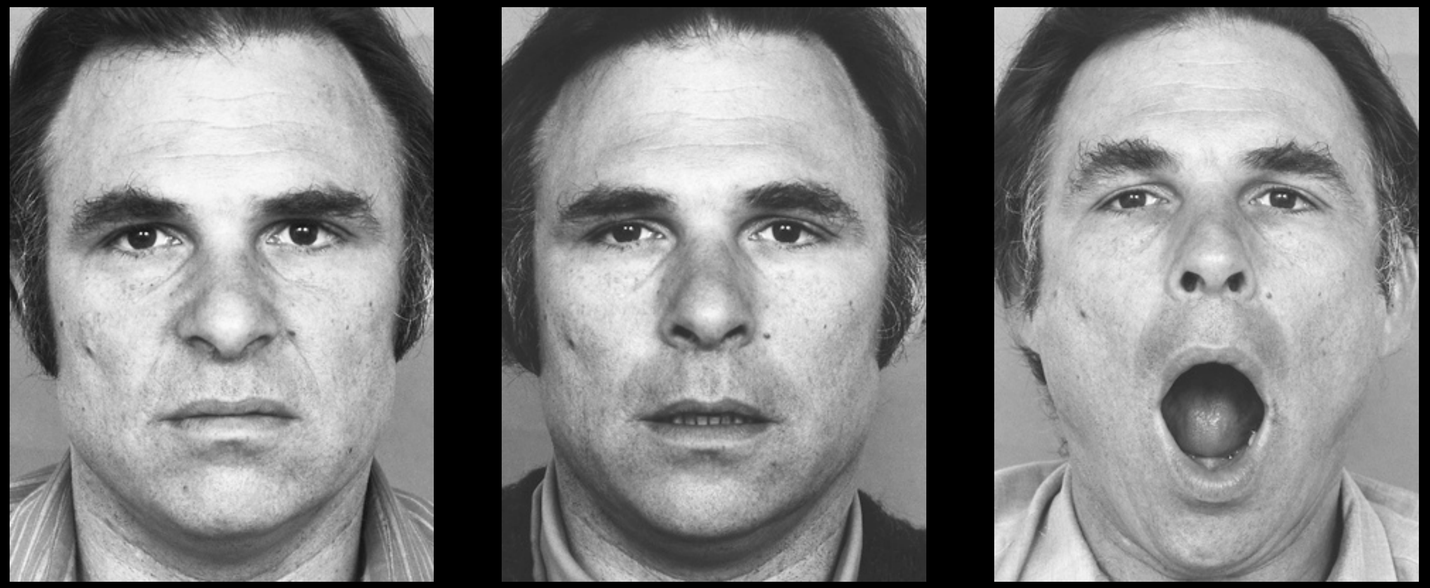




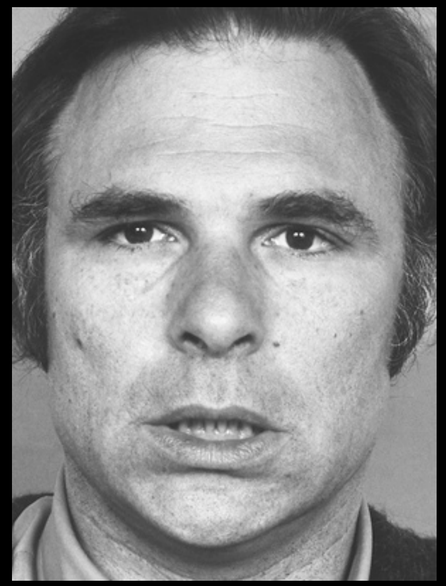
AU 12+25+27

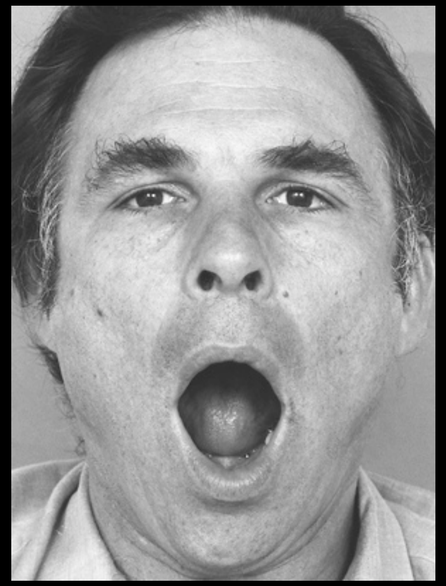


AU 10+25+27

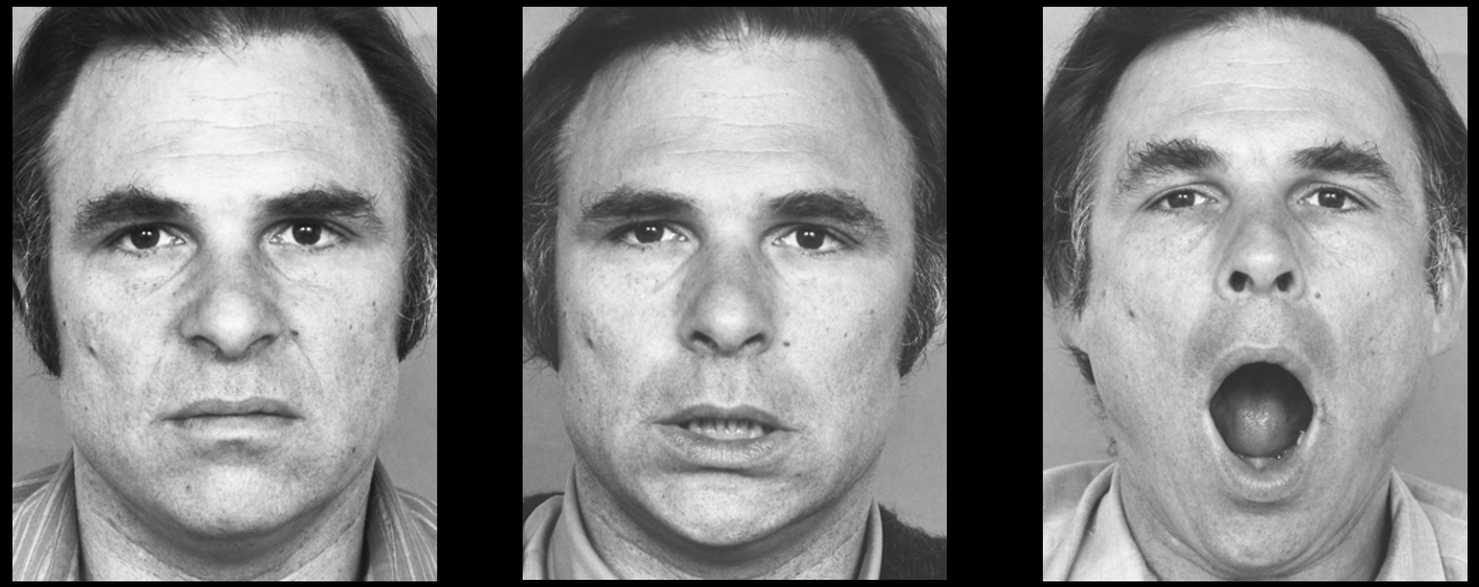


AU 16+25+27

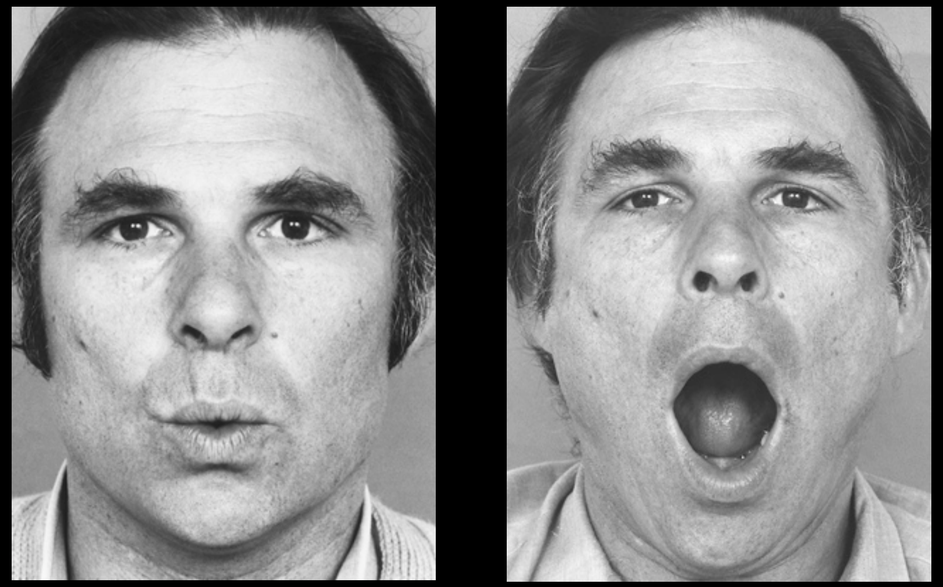




AU 10+16+25+27

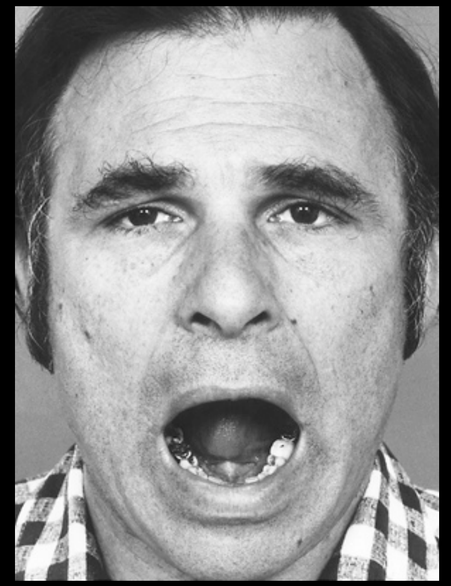


AU 18+25+27



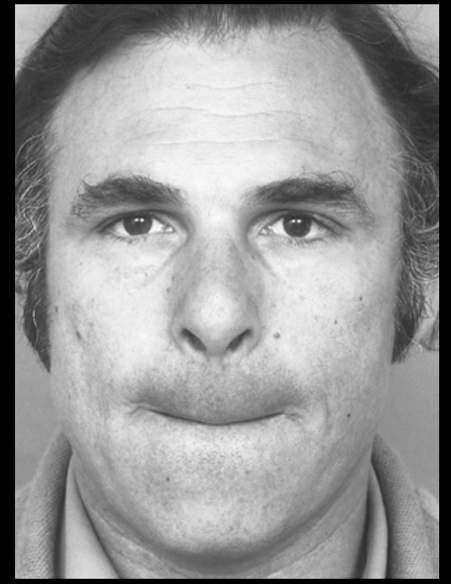
AU 20+25+27

Lip corners are maximally pulled down to form an curved inverted-U shaped. Push up the lower lip relax muscle to allow the lips to part.



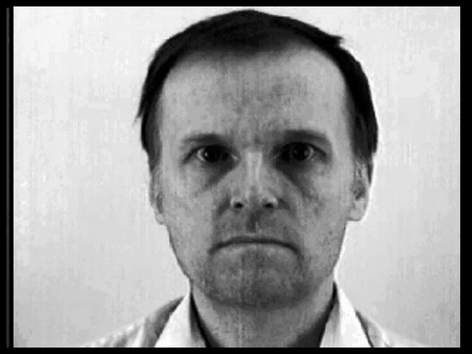
AU 28

The lips are rolled into the mouth over the teeth and the red parts just disappear, and there is severe stretching of the upper and lower lip as skin is pulled into the mouth.



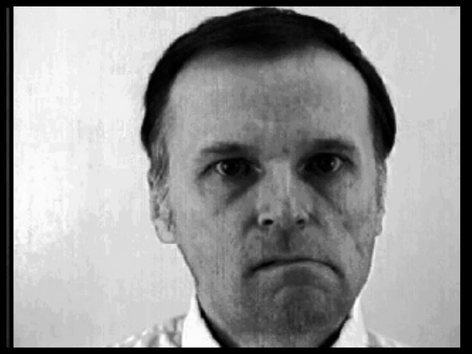
AU 29

Thrust the jaw.



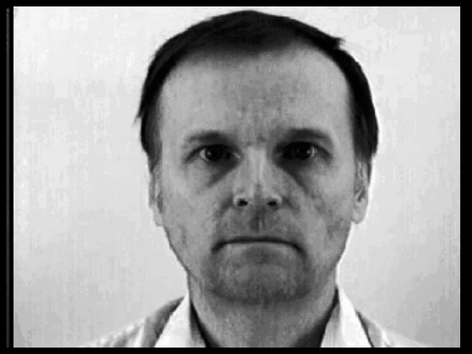
AU 30

Move jaw sideways.



AU 31

Clench the jaw.



AU 32

Bite upper and lower lips.

AU 33

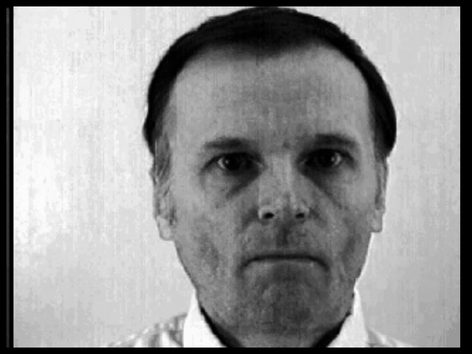
Puff out cheeks, allow air to escape from the mouth.

AU 34

Keep mouth closed and puff out cheeks.

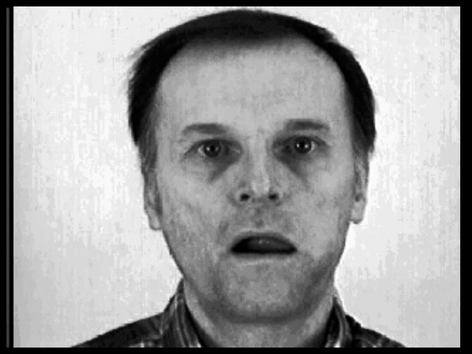
AU 35

Suck cheeks into mouth.



AU 36

Bulge: open mouth, push tongue against inside of mouth.



AU 37

Lip wipe: lick lips with tongue in one direction.

AU 38

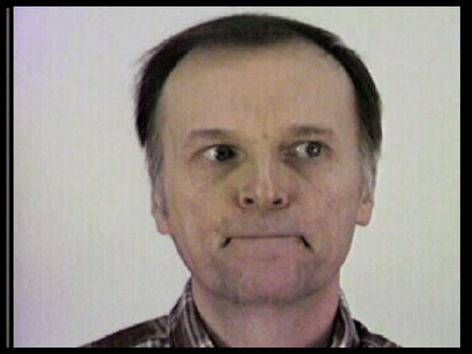
Nostril Dilator

AU 39

Nostril Compressor

M61 + M62

Eyes move to the left + right



M63 + M64

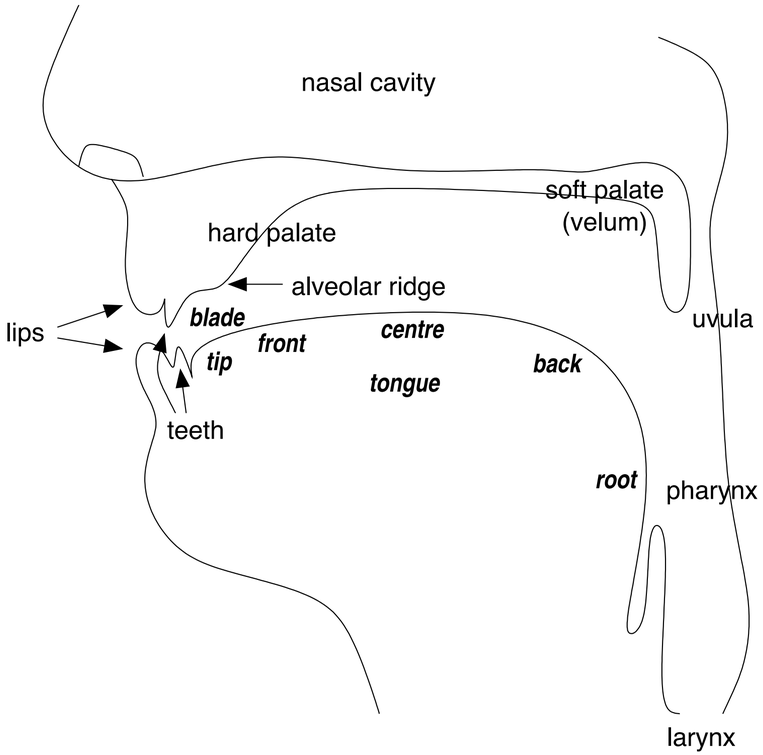
Eyes up + down

Eyes Around

Please “roll” your eyes around

Describing a Speaking Face

- AU 50 = Speech?
- Phoneme - smallest meaningful unit of acoustic speech



	IPA symbol	Example		IPA symbol	Example
Vowels	i	lead	Consonants	p	pin
	ɪ	lid		b	bin
	e	led		t	tin
	æ	lad		d	din
	u	food		k	could
	ʊ	good		g	good
	ʌ	cut		f	fan
	ɒ	cot		v	van
	ə	about		θ	thin
	ɜ	church		ð	that
	ɔ	caught		s	sue
	ɑ	lard		z	zoo
Diphthongs	eɪ	bay		ʃ	shoe
	aɪ	buy		ʒ	vision
	ɔɪ	boy		tʃ	chew
	ɑʊ	loud		dʒ	gin
	əʊ	load		m	my
	ɪə	pier		n	no
	ɛə	pear		ŋ	sing
	ɔə	pore		l	lie
	ʊə	poor		r	rye
				j	yes
				w	wet
				h	hat

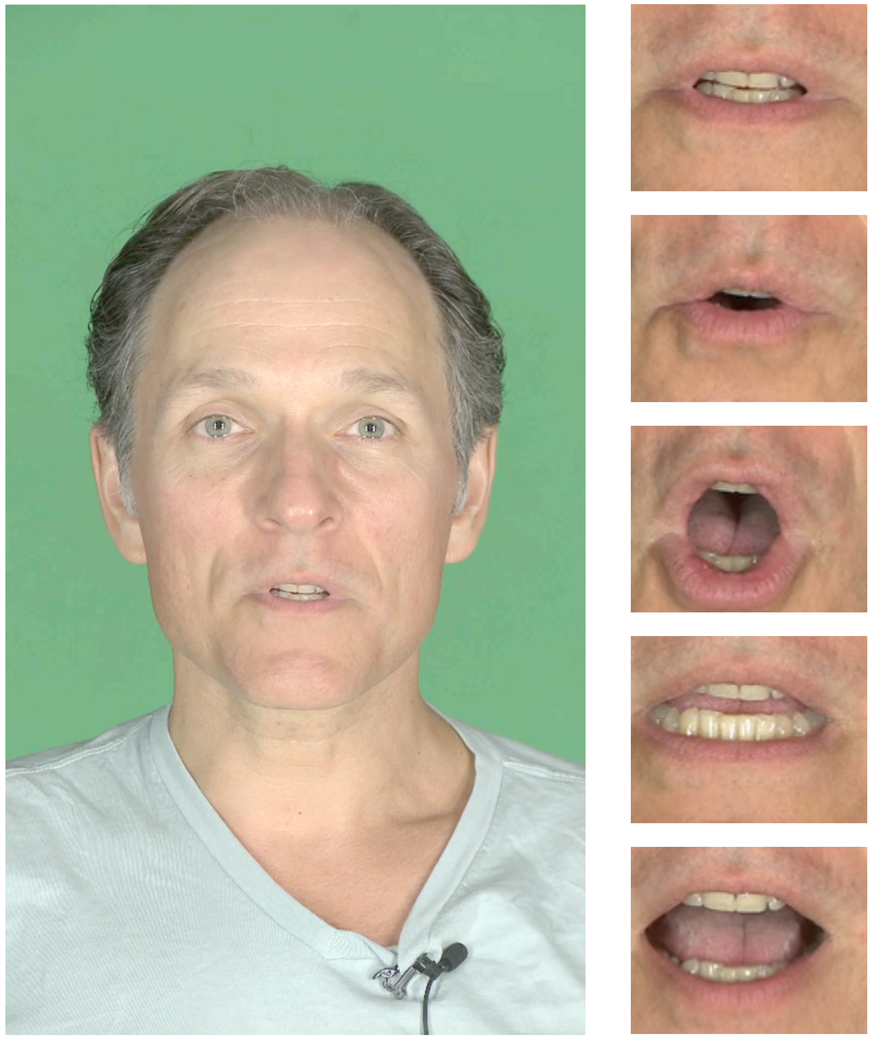
Table 2.1: IPA symbols for the phonemes used in RP English transcription with examples of their use.

Visual Speech Units?

Author		Visemes									
Binnie [28]		/p,b,m/	/f,v/	/θ,ð/	/t,d,s,z/	/ʃ,ʒ/	/k,g/	/w/	/r/	/l,n/	
Heider [107]		/p,b,m/	/f,v/	/k,g/	/ʃ,tʃ,dʒ/	/θ/	/n,t,d/	/l/	/r/		
Finn [90]		/p,b,m/	/θ,ð/	/w,s/	/h,k,g/	/ʃ,ʒ,tʃ,j/	/f/	/v/	/y/	/z/	/t,d,n,l,r/
Owens [173]	/ɑCɑ/:	/p,b,m/	/f,v/	/θ,ð/	/ʃ,ʒ,tʃ,dʒ/	/k,g,n,l/	/w,r/	/h/			
	/ʌCʌ/:	/p,b,m/	/f,v/	/w,r/	/ʃ,ʒ,tʃ,dʒ/	/t,d,s,z/					
	/iCi/:	/p,b,m/	/f,v/	/θ,ð/	/ʃ,ʒ,tʃ,dʒ/	/t,d,s,z/	/w,r/				
	/uCu/:	/p,b,m/	/f,v/	/θ,ð/							
Walden [218]	BT:	/p,b,m/	/f,v/	/θ,ð/	/s,z,ʃ,ʒ/	/w/					
	AT:	/p,b,m/	/f,v/	/θ,ð/	/ʃ,ʒ/	/w/	/s,z/	/r/	/l/	/t,d,n,k,g,j/	
Erber [80]	NH:	/p,b,m/	/t,d,n/								
	SHL:	/p,b,m/	/t,d,n/	/k,g/							
	PL:	/p,b,m/	/t,d,n/								

Table 2.3: Some of the proposed homophenous phoneme groupings. Note: For the Owens entry, the context in which the consonants were presented are shown. For the Walden entry, BT indicates before training and AT after training. For the Erber entry, NH indicates subjects with normal hearing, SHL indicates subjects with severe hearing loss and PL subjects with profound loss.

Real Speech: Coarticulation – Context Matters



/k/

/t/

Visual Coarticulation

[1] Michael M. Cohen and Dominic W. Massaro. Modeling coarticulation in synthetic visual speech. In N. M. Thalman and D. Thalman, editors, Models and Techniques in Computer Animation, pages 139–156. Springer Verlag, Tokyo, 1993.

Describing Faces

- Faces deform non-rigidly with **complex** controls
  - But, not that many to span the space?
- **No simple representation**: *Is there one?*
  - Rig creation - what are the common controls?
  - Re-targeting performance capture (model-based)
  - Generalised person-independent tracking models
  - Expression analysis
- **Implementation**
  - Blendshapes / Matrix / Linear
  - Deformer / Nonlinear
  - Simulation

Parameterising Faces

Common Facial Parameterisations

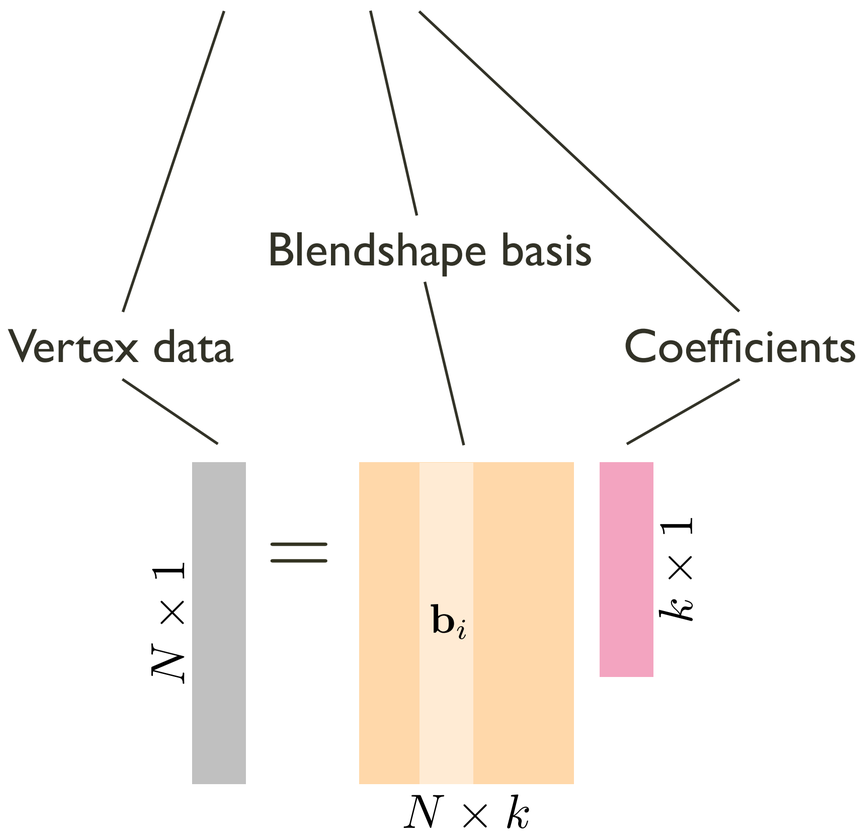
- Divined
  - Hand tuned rig (blendshape/deformer/interpolated) Often FACS derived (Ekman) — **32+ => 300+ => 1000+**
  - Muscle based deformation — **32+**
- Learned
  - Data driven basis (e.g. linear PCA) — **~30**
  - Piece-wise linear (e.g. PCA) — **~100**
  - FEM model — **39 + 1,080,000?**
- Re-targeted Model — **1?**

Blendshape FACS Models

Blendshape Models

$$\mathbf{x} = \mathbf{Bc}$$

$$\mathbf{x} = \sum_{i=1}^{k} c_i \mathbf{b}_i$$



Blendshape Models

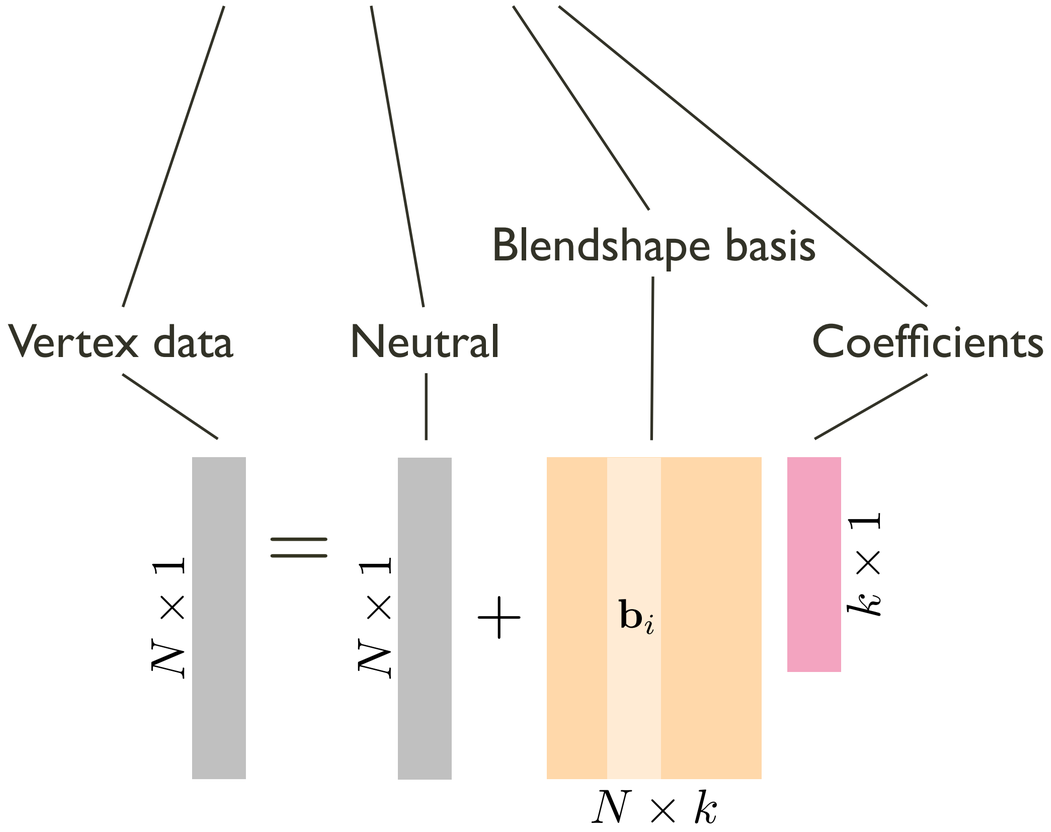
$$\mathbf{c} = \mathbf{B}^{-1}(\mathbf{x} - \mathbf{x}_0)$$

$$\mathbf{x} = \mathbf{x}_0 + \mathbf{B}\mathbf{c}$$

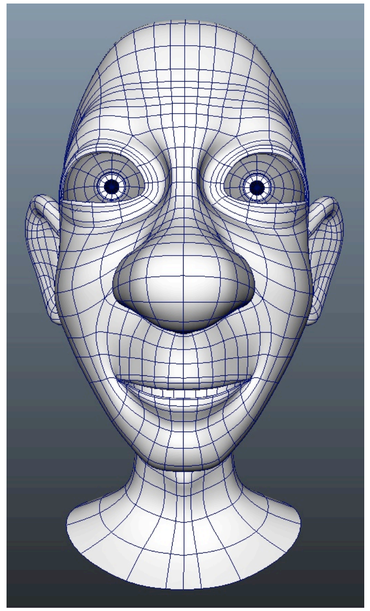
$$\mathbf{x} = \mathbf{x}_0 + \sum_{i=1}^{k} c_i \mathbf{b}_i$$

Basis may not be orthogonal?

Coefficients are often constrained to be positive

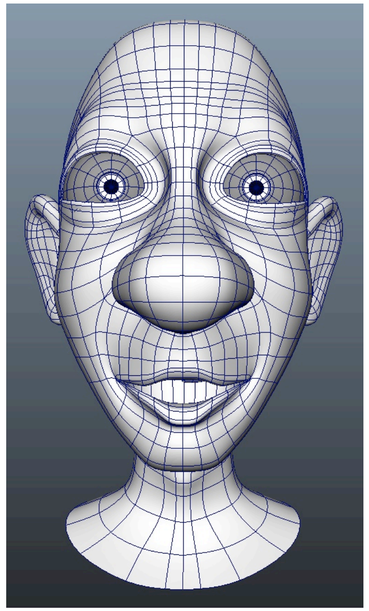


Blendshape Models

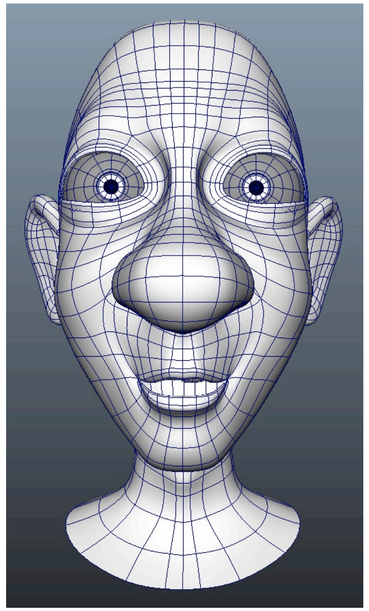


neutral

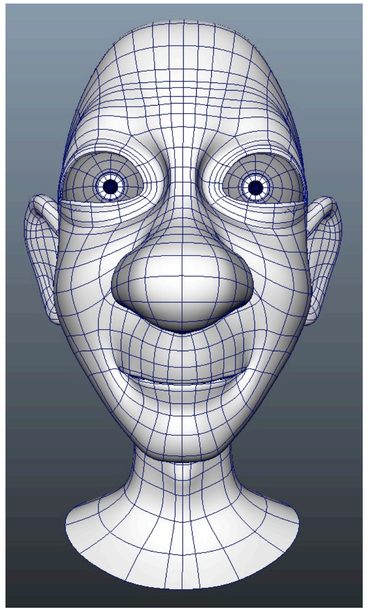
+



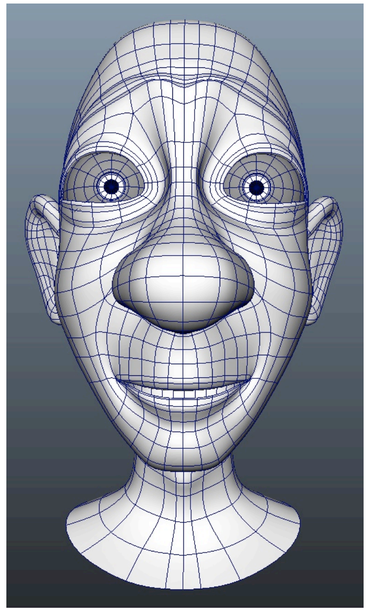
mouth-center-open



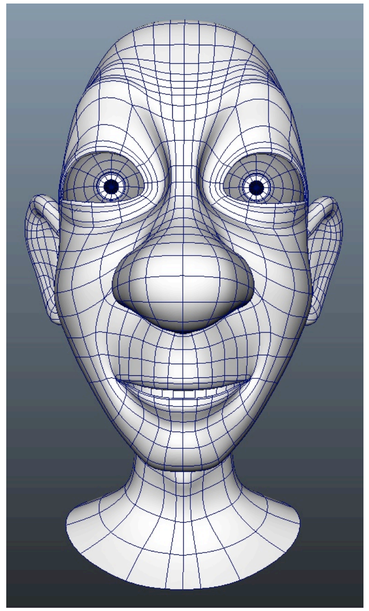
mouth-corners-in



mmm



inner-brow-up

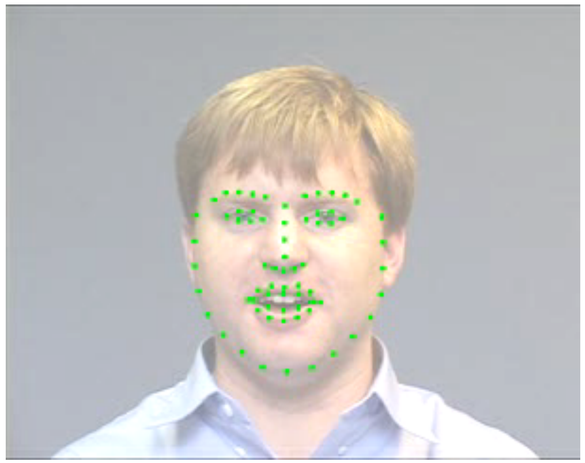


brow-excited

Blendshape FACS Models

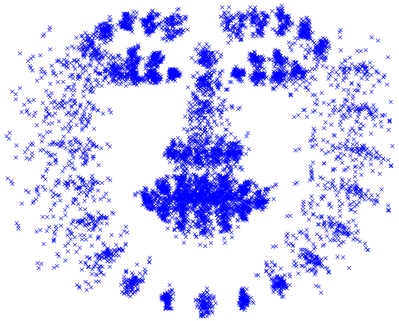
- Modelling: Rig complexity increases *exponentially* with realism?
- Modelling: Parameter interdependence - not often orthogonal?
- Modelling: Difficult to evaluate for correctness
- Animation: Space of deformation has many *monsters*?
- Retargeting: Parameter parallel
- Solving: Optimisation can have many solutions?
- Interpretation: Intuitive, generalises?

Learned Linear Models: PCA



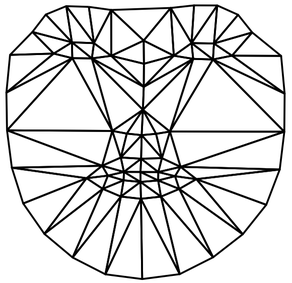
Hand labelled training data

Procrustes

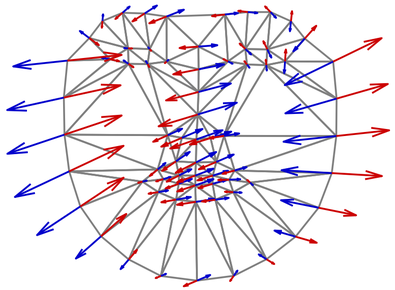


PCA

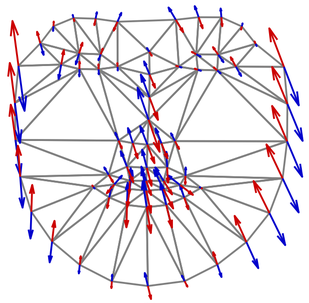
Shape Model



$\mathbf{s}_0$



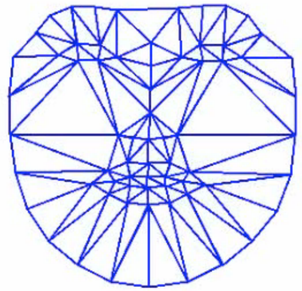
$\mathbf{s}_1$



$\mathbf{s}_2$

Modelled Deformation

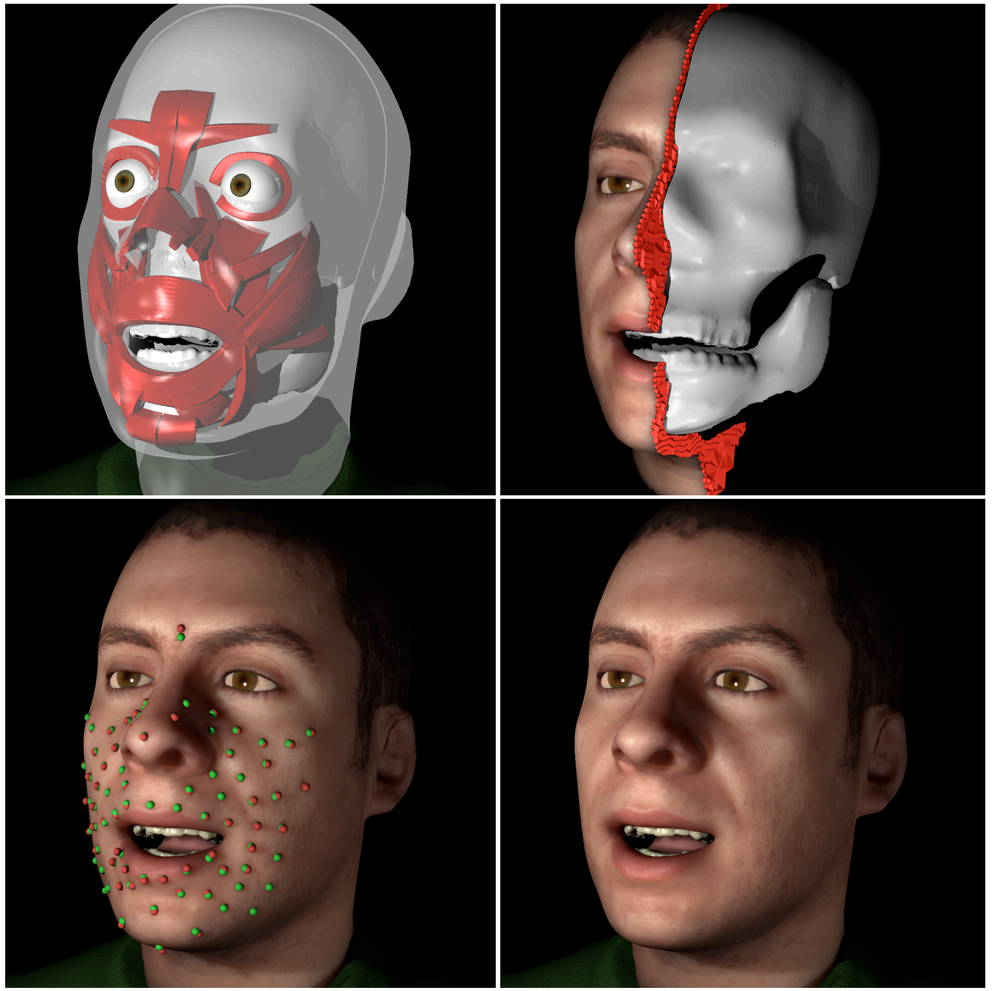
$$\mathbf{s} = \mathbf{s}_0 + \sum_{i=1}^{n} p_i \mathbf{s}_i$$



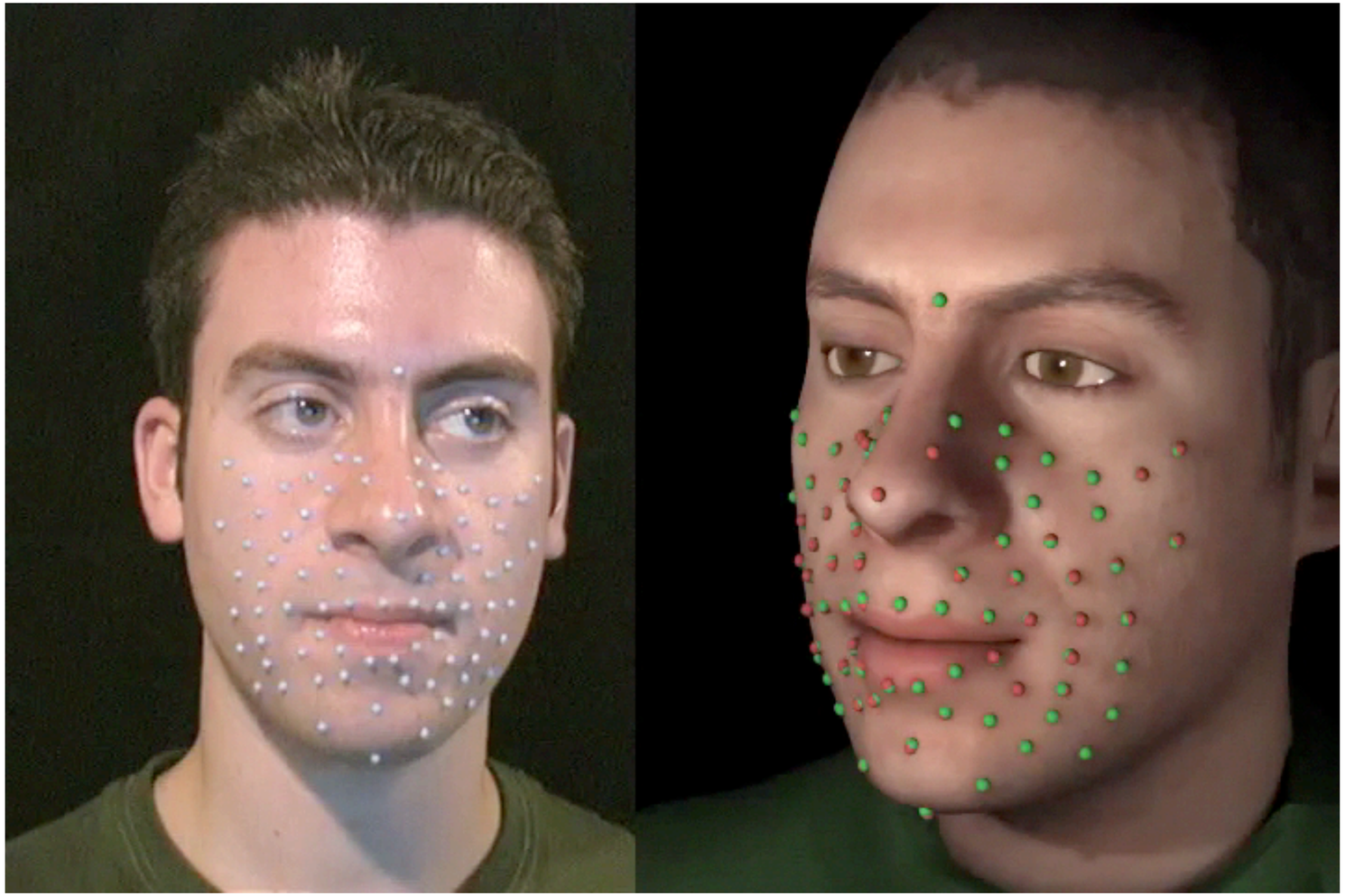
Learned Blendshape Models

- Modelling: Hand label data, PCA/FEM etc.
- Animation: Difficult to include artistic direction?
- Animation: Parameter space very unintuitive. Different interface?
- Animation: Model space manipulation also unintuitive?
- Solving: Linear solution
- Retargeting: Hard, not parameter parallel
- Retargeting: Replace means, CCA, content-based...
- Interpretation: Unintuitive, does not generalise

Anatomical Muscle-Based FEM Simulation



Automatic Determination of Facial Muscle Activations from Sparse Motion Capture Marker Data. Sifakis, Neverov, Fedkiw. Siggraph 2005.



Captured markers: red. Simulation: green
32 muscles

Anatomical Muscle-Based FEM Simulation

- Modelling: Very involved (Visible Human, MRI, FEM)
- Modelling: Difficult to debug or modify?
- Animation: Hits the uncanny valley? How to get it right?
- Animation: Artistic direction?
- Retargeting: Parameter transfer? Re-solve?
- Solving: GN + constraints. 8min/frame
- Interpretation: Intuitive, does not generalise?

Retargeting: Performance Driven Facial Animation

Spot-on Emotions

Remember what was said before about the dots on the black leotards to pick up body motion? You're probably wondering how they capture the actor's expressions. You're also probably wondering why they're wearing strange-looking cycling helmets with mini cameras pointing at their faces.

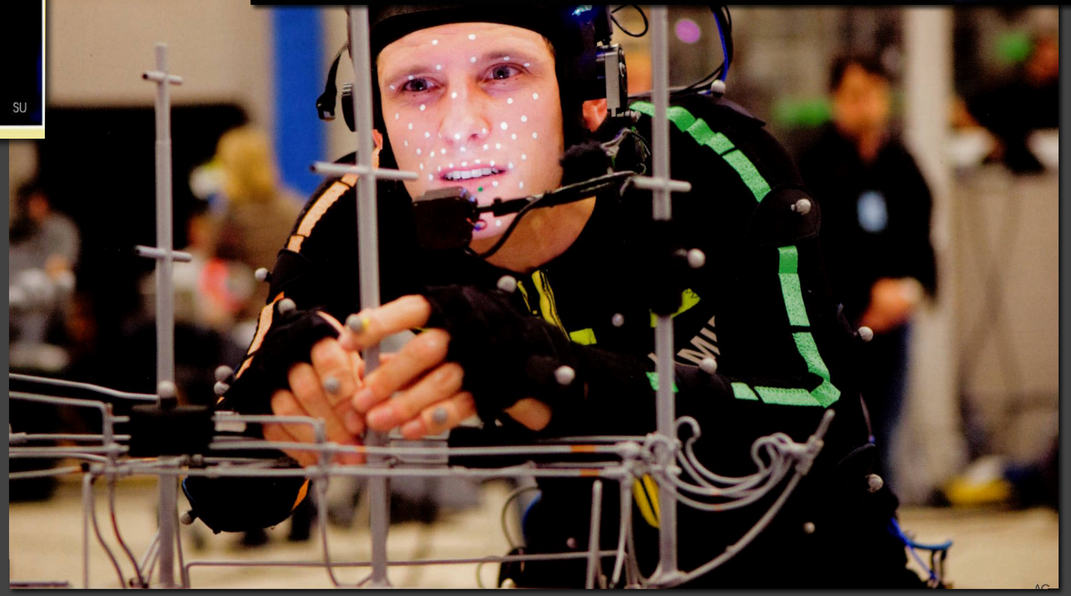
I asked Weta Digital Animation Supervisor Jamie Beard to explain what the dots were all about.

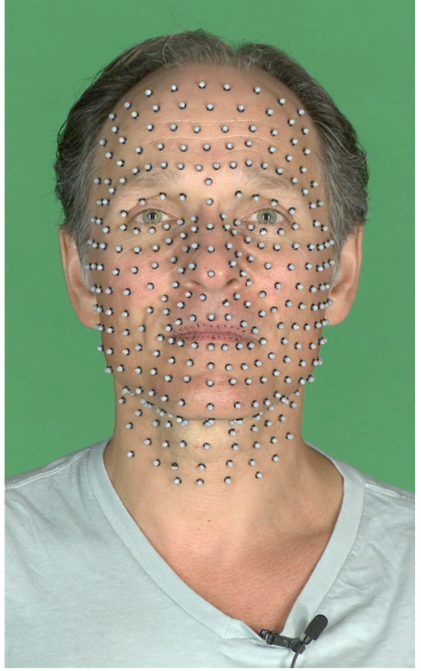
'The dots are a set of markers placed specifically to reflect the motion of 12 major muscle groups of the face. It's not simply a random array of dots. Those dots represent those muscle groups that in turn replicate emotions — two major sets to read eyebrow motions, some more around the corners of the mouth, and so on.

'When the actor emotes, the dot motion is picked up by a camera attached to the helmet they're wearing. This information is fed into a piece of facial-tracking software which is piped into our computer-generated character's digital face. This digital face has the same muscle groups as the actor, so whatever the actor's face does, our digital model face does too.'

Jamie Beard
Weta Digital Animation Supervisor

Right and below: Actor Andy Serkis pulls a variety of expressions inspired by original Hergé panels. These are then applied to a rough digital model of Captain Haddock.

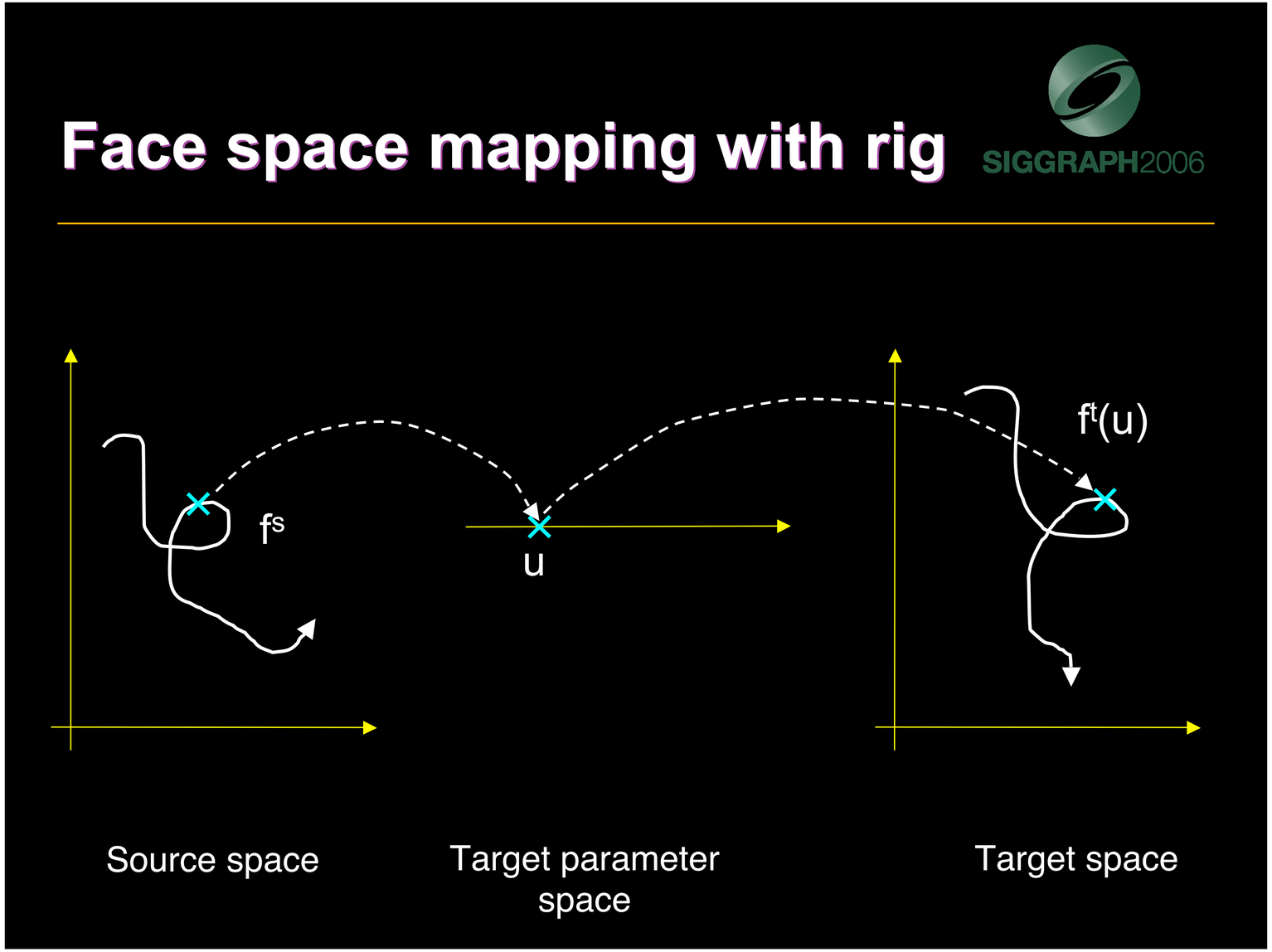




Tracking

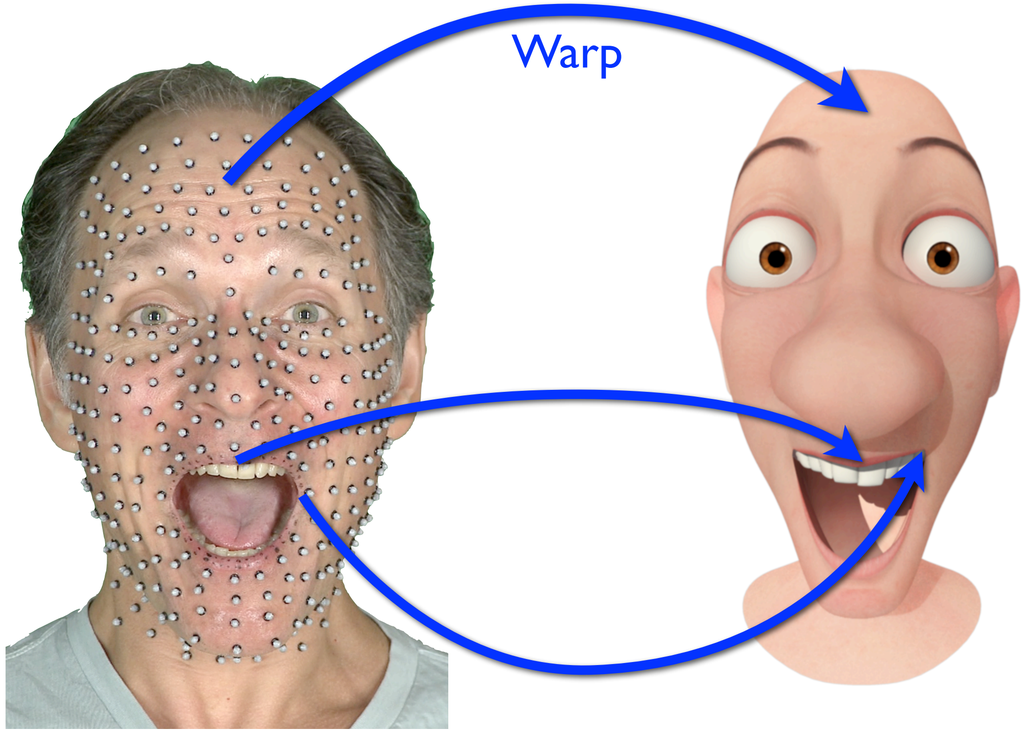
Retargeting

Retargeting

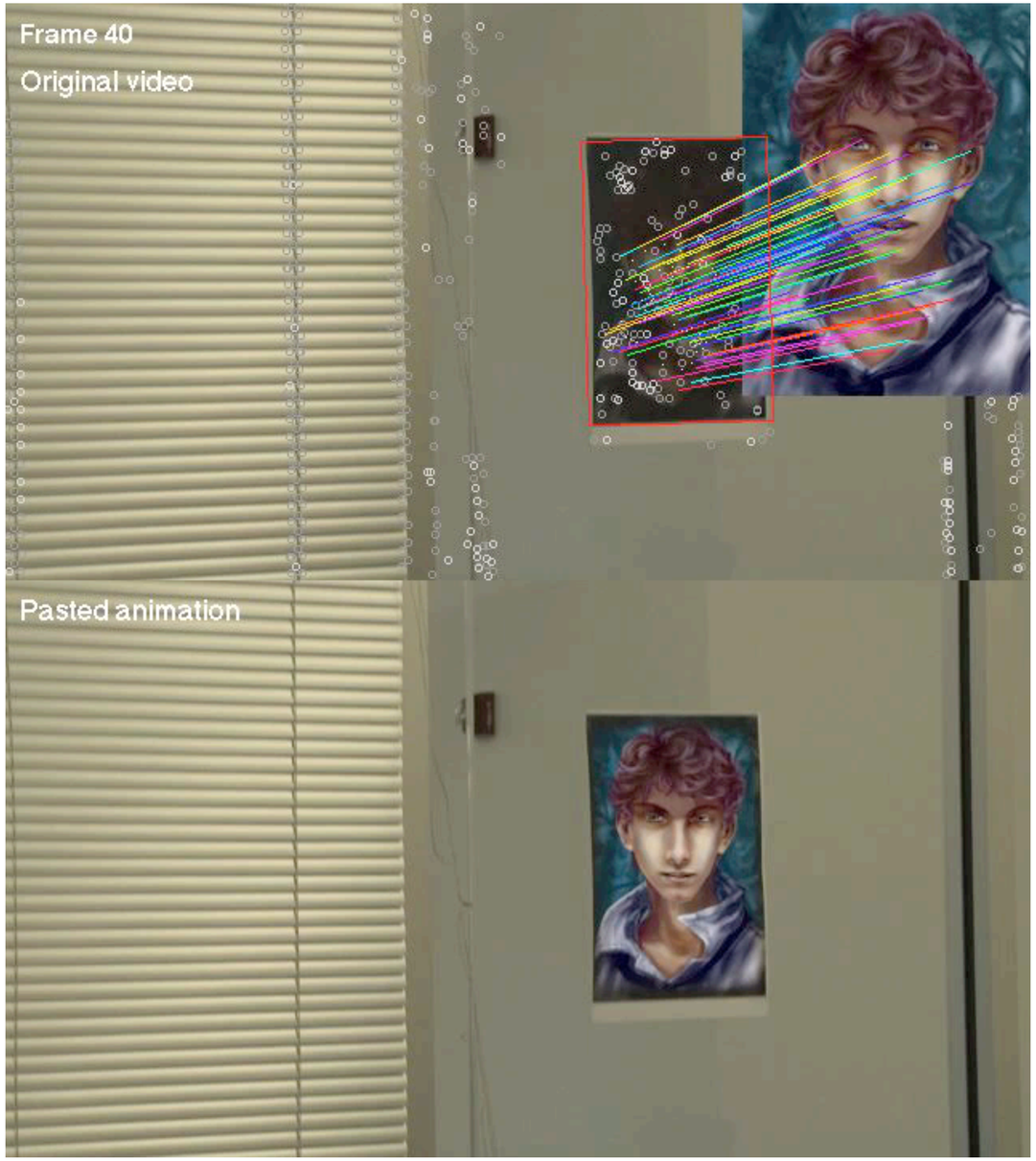


[1] F. Pighin and J. P. Lewis, editors. *Performance-Driven Facial Animation*. SIGGRAPH Course Notes, 2006.

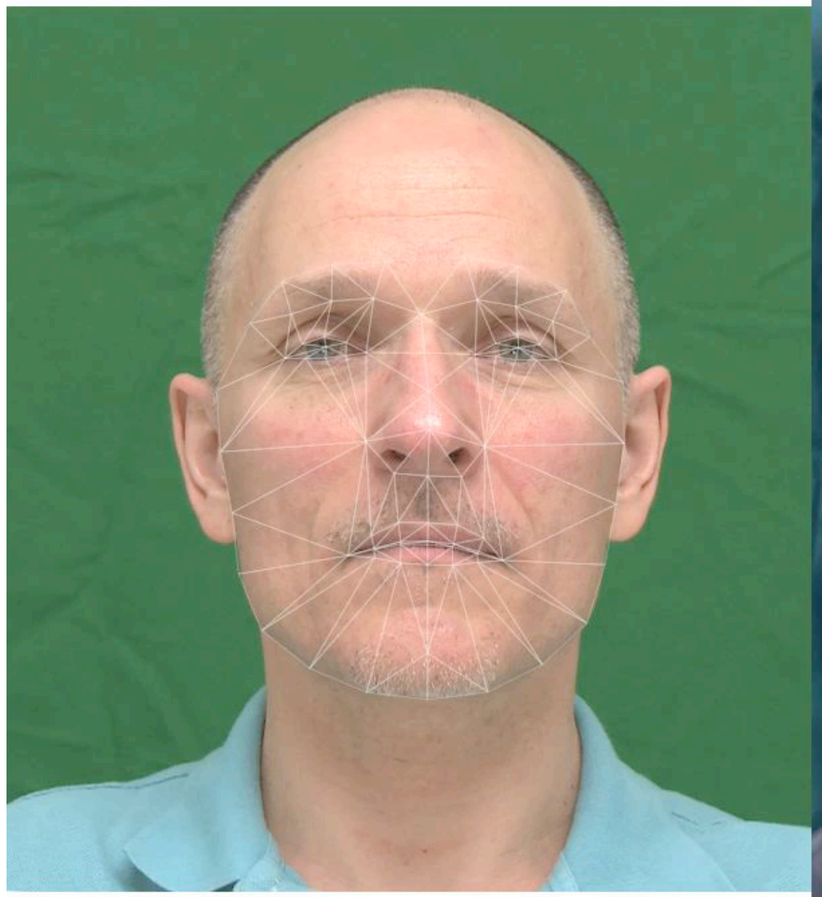
Retargeting

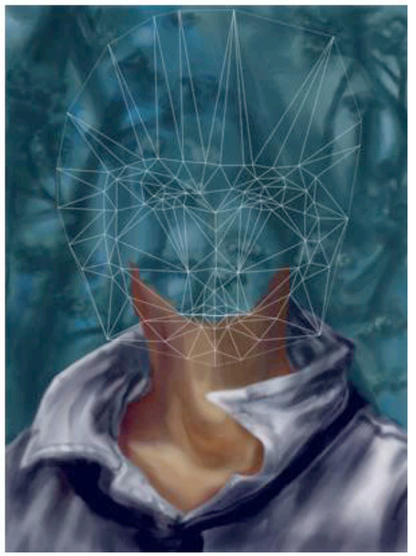


Geometric Retargeting

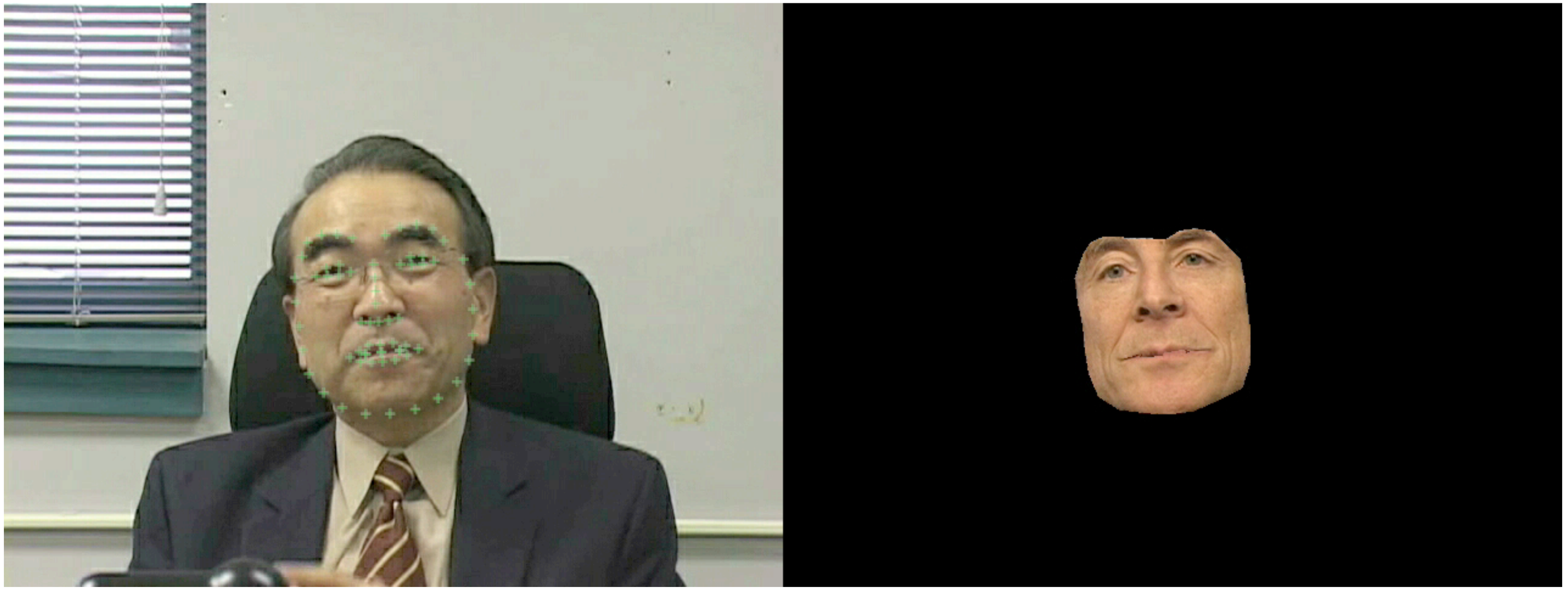


Geometric Retargeting

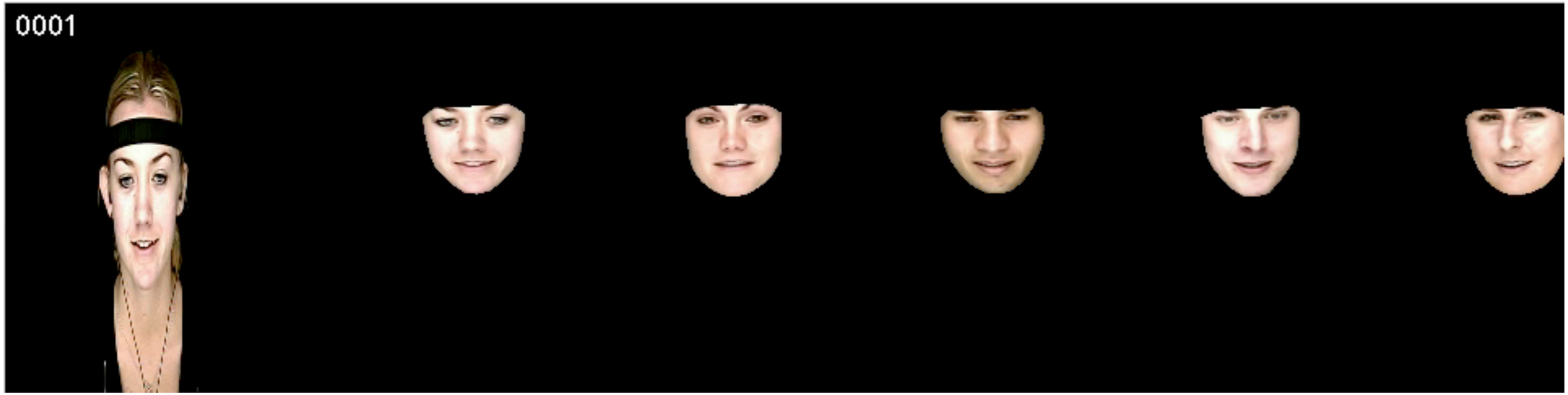




Data Driven Retargeting



Data Driven Retargeting

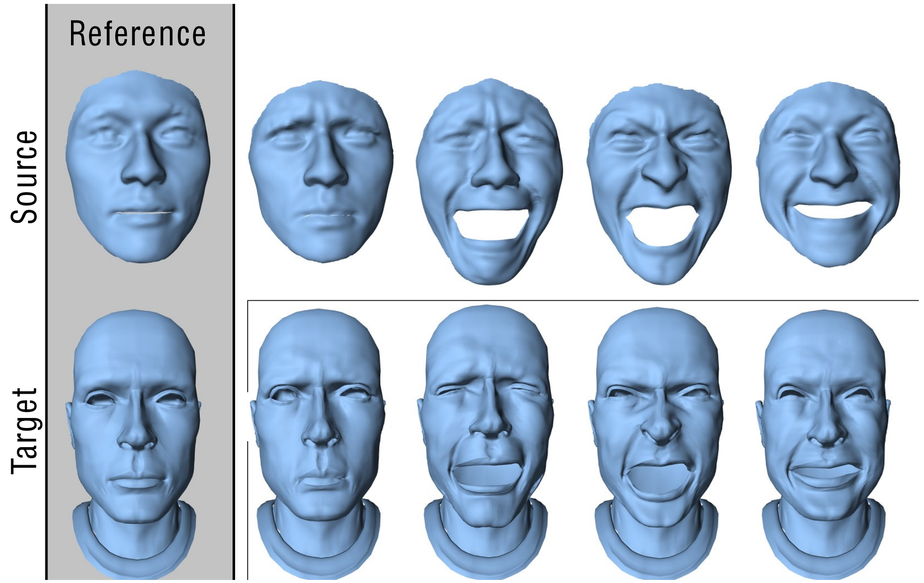


[1] Steven M. Boker, Jeffrey F. Cohn, Barry-John Theobald, Iain Matthews, Mike Mangini, Jeffrey R. Spies, Zara Ambadar, and Timothy R. Brick. Something in the way we move: Motion, not perceived sex, influences nods in conversation. Journal of Experimental Psychology: Human Perception and Performance, in press 2011.

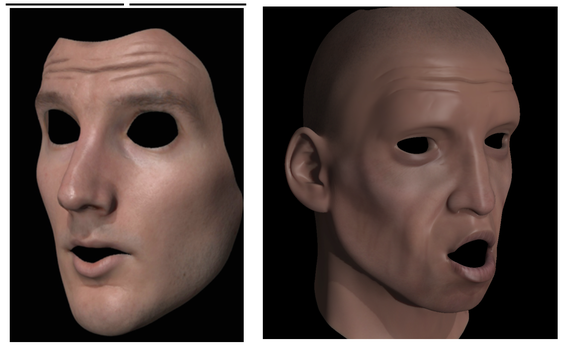
Geometric Retargeting

- Modelling: Only have to model neutral face?
- Animation: Dynamically often looks great
- Animation: Statically often very wrong
- Retargeting: Hand tuned to fix local scaling issues?
- Solving: Image warping
- Interpretation: None?

Geometric Retargeting



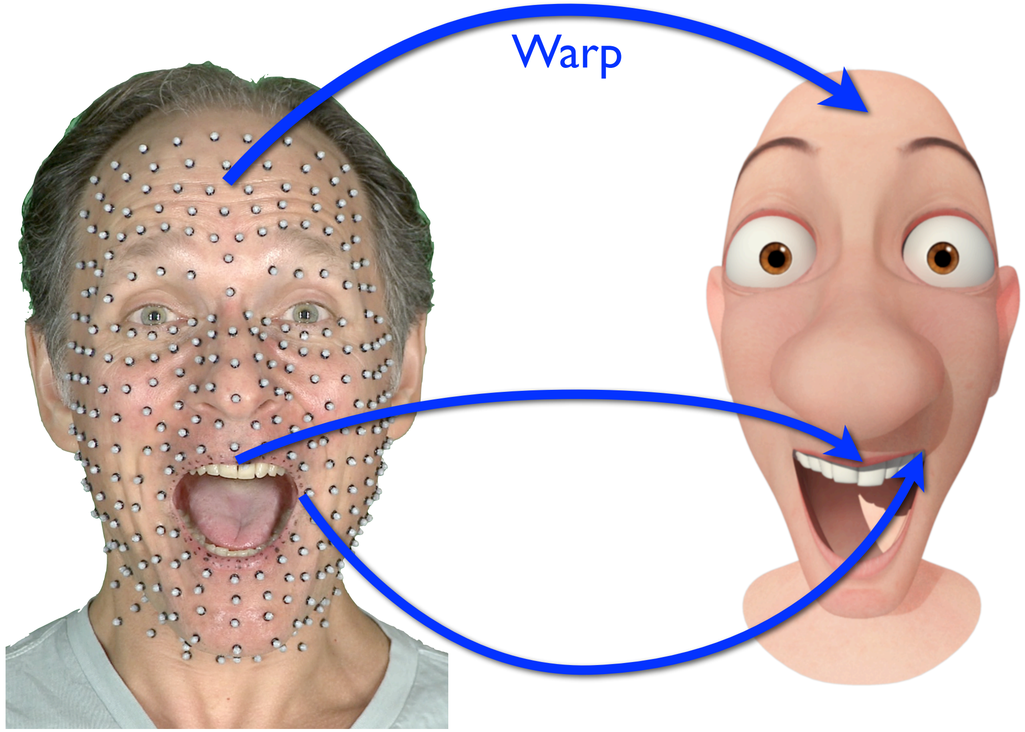
Sumner and Popovic, 2004

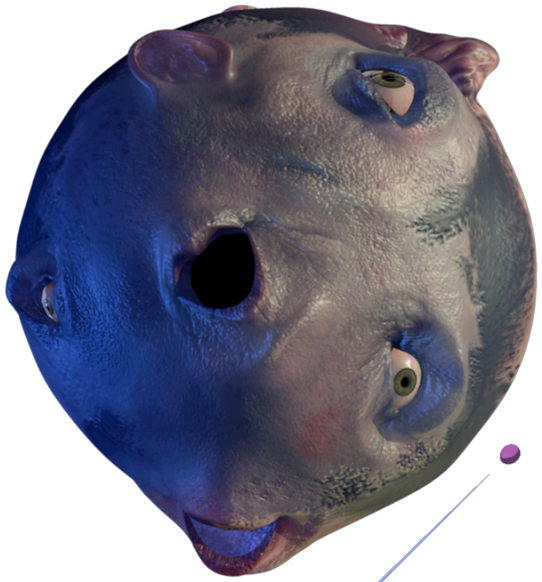


Bickel et al., 2008

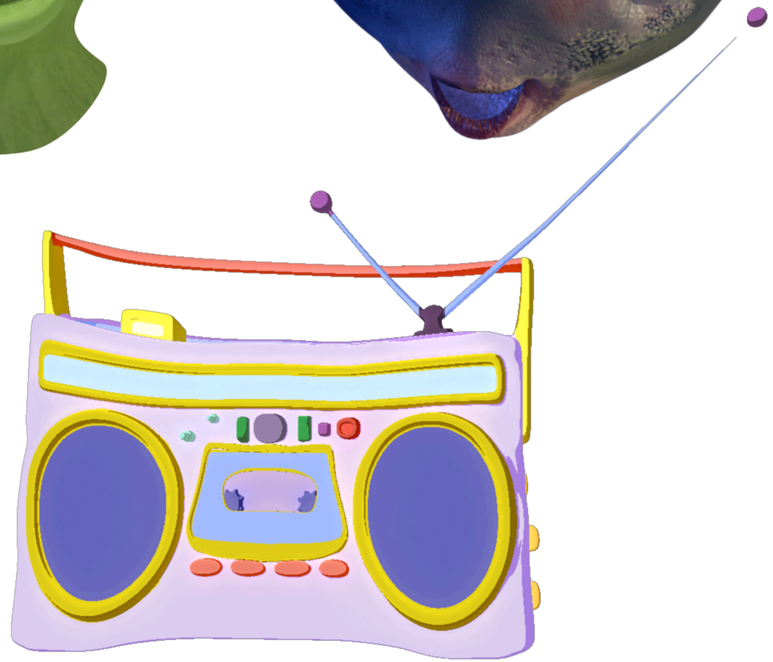
Weise et al., 2009

Retargeting





Parameter Parallel

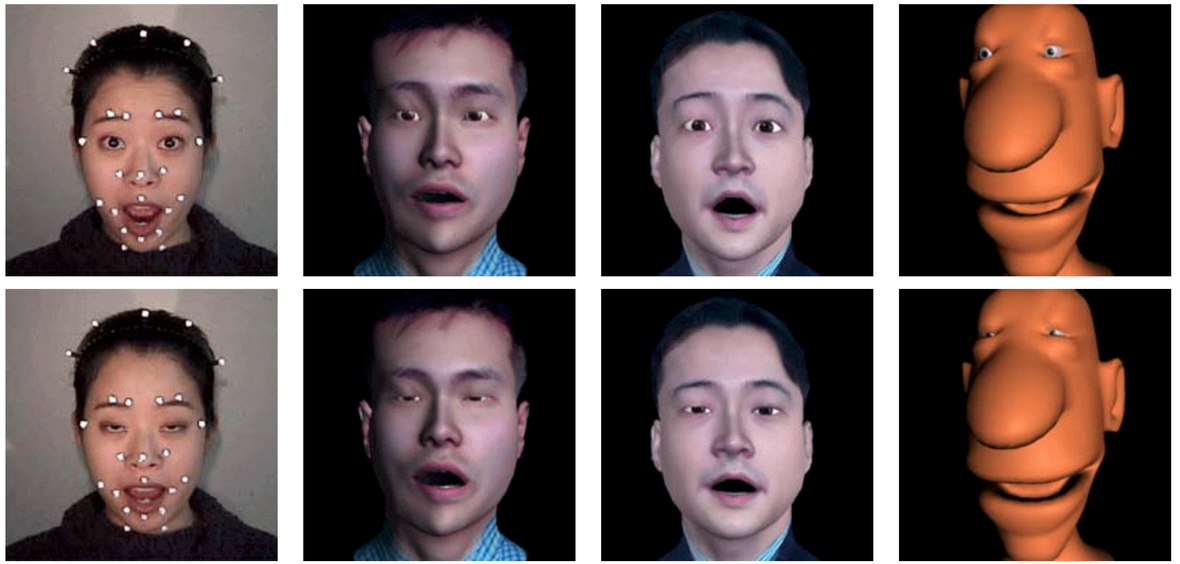


Parametric Retargeting

- Modelling: Have to implement all controls (Blendshapes?)
- Modelling: Rig complexity for realism is very high
- Animation: Can be intuitive to edit, depending on parameterisation
- Animation: Quality depends on ability to setup re-targeting
- Retargeting: Parameter parallel is simple!
- Solving: Often complex, depends on parameterisation
- Interpretation: As parameterisation

Parametric Retargeting

Chuang and Bregler, 2005



Choe et al., 2001

Curio et al., 2006

Interpolation

- RBF
- PSD
- Sparse multi-linear models