PERCEPTION AND RECOGNITION OF COMPUTER-ENHANCED FACIAL ATTRIBUTES AND ABSTRACTED PROTOTYPES

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I, Philip John Benson, hereby certify that this thesis has been composed by myself, that it is a record of my own work, and that it has not been accepted in partial or complete fulfilment of any other degree or professional qualification.

Signed: Date: 4 September 1992

I was admitted to the Faculty of Science of the University of St. Andrews under Ordinance General No. 12 on 23rd November 1987 and as a candidate for the degree of Ph.D. on 1st October 1989.

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To my Mother and Father,

and to Rona

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Abstract

The influence of the human facial image was surveyed and the nature of its many interpretations were examined. The role of distinctiveness was considered particularly relevant as it accounted for many of the impressions of character and identity ascribed to individuals. The notion of structural differences with respect to some selective essence of normality is especially important as it allows a wide range of complex facial types to be considered and understood in an objective manner.

A software tool was developed which permitted the manipulation of facial images. Quantitative distortions of digital images were examined using perceptual and recognition memory paradigms. Seven experiments investigated the role of distinctiveness in memory for faces using synthesised caricatures. The results showed that caricatures, both photographic and line-drawing, improved recognition speed and accuracy, indicating that both veridical and distinctiveness information are coded for familiar faces in long-term memory.

The impact of feature metrics on perceptual estimates of facial age was examined using 'age-caricatured' images and were found to be in relative accordance with the 'intended' computed age. Further modifying the semantics permitted the differences between individual faces to be visualised in terms of facial structure and skin texture patterns. Transformations of identity between two, or more, faces established the necessary matrices which can offer an understanding of facial expression in a categorical manner and the inherent interactions.

A procedural extension allowed generation of composite images in which all features are perfectly aligned. Prototypical facial types specified in this manner enabled high-level manipulations to be made of gender and attractiveness; two experiments corroborated previously speculative material and thus gave credence to the prototype model.

In summary, psychological assessment of computer-manipulated facial images demonstrated the validity of the objective techniques and highlighted particular parameters which contribute to our perception and recognition of the individual and of underlying facial types.

I. The Human Face

The human face is the richest and the most variable source of visual information pertaining to an individual's identity, gender, beauty, age, ethnic group and culture, and as some would have it, personality and character. It's appearance and development has been charted throughout history by historians, writers and poets, painters, musicians, anthropologists, biologists, anatomists, physiologists, psychologists, and surgeons alike.

As a releaser and communicator of information, the capabilities of the face outstretch any other 'organ' known to mankind. Such as it is, it has been the subject of considerable attention in both scientific and pseudo-scientific realms. Literature has been saturated with references alluding to it's many properties, societies grappling to understand and formalise the many aspects and implications of it's appearance. The importance placed upon an individual's visage has stimulated much work of merit. Conversely, many untruths have been propagated, and dogmatically pursued to the point of genocide.

The ensuing sections (II and III) examine these multifarious issues from two viewpoints, namely:

- the perceptual and recognition psychologies of facial attributes;
- the specification of computer software models and associated toolsets for the purpose of quantitative and qualitative manipulation and measurement of facial parameters and the perceived impact thereof.

Each perceptual effect is presented as a critique of the relevant anthropological and socio-psychological criteria; computer synthesis is applied to images of faces, and perceptual evaluations are made; in discussion, the effectiveness of the transformations is assessed, and extensions to the methodologies are examined.

This section continues with a narrative on specific contemporaneous issues in face and facial attribute perception and recognition.

1.0 Issues in Face Perception and Recognition

Object recognition must in general address a number of themes common to their perception and neural coding. Most significantly, the task performed so apparently effortlessly by the cortical visual system of matching and processing the retinal image of a real-world object to a stored conceptual representation is one which has yielded many artificial, and biologically plausible solutions. These models of visual recognition and strategies of perceptual processing and associated boundaries have evolved slowly as new experimental evidence enlightens the research community. Much is now understood about how the visual appearance of objects from numerous categories, animate and inanimate, changes under naturally occurring conditions such as perspective view, direction and sources of illumination, elastic and inelastic deformation, amplitude, and contextual relationships. Particular classes of body may only be affected by a subset of these transformations, others by a different subset. Faces are clearly affected by all such mutabilities.

The ability to place one instance of a particular object within a generic category depends on two general principles (Rosch 1978):

- the function of a visual object category system is to provide maximum information with the least cognitive effort;
- the higher nature of the appearance of an object is dealt with as structured information rather than arbitrary or unpredictable attributes.

The objective categorisation of a stimulus requires that it can be considered not only correlationally equivalent to other stimuli but also different from other stimuli not in the same category. The same argument may be applied at a much lower level in considering the microstructure of an object or organism; fine-grain properties are subsequently used to provide more detailed and perhaps subjective information. Thus the infinite differences which exist amongst similar stimuli may be reduced to a behaviourally and cognitively usable order; in most instances it is quite sufficient to determine that a ball is a ball and not a face, where differentiation beyond a certain point becomes irrelevant. A method by which category membership may be determined involves the reduction of an object's appearance to that of an abstracted basic level as Rosch *et al.* (1976) demonstrated, eg. 'bird' being more identifiable than 'robin'. Averaged or generalised notions of objects are both appealing and cognitively practical (Marr & Nishihara 1978; Warrington & Taylor 1978; Palmer, Rosch & Chase 1981; Marr 1982; Humphreys & Riddoch 1984, 1985; Valentine & Bruce 1986b; Humphreys & Bruce 1989:52; Bruce *et al.* 1991; Benson & Perrett 1992a). It is not unreasonable that a degree of cortical specialisation would have evolved as a result of the demands of processing large numbers of similitudinous stimuli in an environment where detailed discrimination is of paramount importance.

Psychological and neurological investigations have revealed a wealth of evidence that there exists specialised routes of information processing dealing with the facial image and it's memories in man (Bauer 1986) and monkey (Perrett, Rolls & Caan 1982; Harries & Perrett 1991; Heywood & Cowey 1992). Systematic psychological studies of large numbers of normal human subjects have shown that computation of the facial percept occurs in parallel (as opposed to serial, eg. Ellis 1986b, 1986c), where particular attributes are processed at distinct levels in an hierarchy feeding forward to other stages in the visual system (Ellis 1975; Hay & Young 1982; Bruce & Young 1986; Bruce *et al.* 1987; Ellis, Young, Flude & Hay 1987). Neuropsychiatric case studies of human patients have also demonstrated how such a specialised system can be selectively compromised often causing bizarre, fascinating, and perplexing deficits (eg. *Capgras' symptom* (doubles, replacements of people normally close to the patient: Capgras & Reboul-Lachaux 1923; Berson 1983; Christodoulou 1986), *Frégoli's symptom* (delusional misidentification, hyper-identification, interference at a personal level: Courbon & Fail 1927; de Pauw, Szulecka & Poltock 1987), and *intermetamorphosis* (extrapersonal physical interchanges, Courbon and Tusques 1932; Bick 1986; Ellis and Young 1990). Particular atrophied areas in the higher visual pathways can not only affect the processing of facial images (and perhaps their memories, Etcoff, Freeman & Cave 1991), but also the perceived structural organisation and recognition of many other classes of familiar objects (de Haan, Young & Newcombe 1987; Perrett *et al.* 1988; Young & de Haan, 1988; Young, Hellawell & de Haan 1988; Milner *et al.* 1991).

As a specific instance of phenomenal object, the human face can assume a bewildering variety of manifestations. Even so, the inherent visual heterogeneity poses a number of interesting problems, not least of which is that faces are very much all alike. Consider that, under normal circumstances, we will be presented with a two- or three-dimensional ovoid whose internal features consist of two eyes situated in static orbit lateralising the upper end of a nose below which can be found an articulate slit with the ability to rapidly change shape in order to annunciate, consume, and expel; intra- and extra-cutaneous factors interact constantly to produce a highly complex holistic signalling apparatus. The dimensions of such features and their spatial relationship differs within reasonably predictable constraints; skin colouration may differ radically, but within a given ethnic group it is predominantly invariant; prevalence of facial hair is restricted to three areas, the constitution and visual characteristics of which can vary considerably. Yet we as perceivers are able to distinguish between many thousand instances of such (face) objects with remarkable accuracy, even to the extent of being able to recognise minute anomalies in the form and pattern of behaviour of one individual.

Our familiarity with the visual pattern which comprises the human face (eg. Harmon 1973; Sergent 1986a) is one which is reinforced throughout our lives. The circumstances of encounter with novel and known instances of faces are ones in which we actively and often subconsciously perform the operations of identification, association, knowledge updating, and coding. We are more proficient at remembering new instances of faces than any other category of object (Freedman &

Haber 1974) and that familiar faces are dealt with better than unfamiliar ones in the same paradigm under experimental conditions (Klatsky & Forrest 1984).

The question then of how a biological system should approach the task of discriminating between the homogeneity of the face class and the interpretation of the internalised signals is one which merits due and careful consideration. Because of our inherited reliance through the development and our intense experience of faces, Goldstein & Chance (1981) have suggested that we are able to access a number of consistent dimensions which facilitate perception and memory. Repeated exposure to members of a particular class of objects, especially human faces, serves to develop frames of reference and with them the organisation of efficient methods of access which permit fine discrimination on the basis of diminutive physical nuances. It is these slight differences which are responsible for so many of our 'first impressions'. Formalising and even verbalising them is often an impossible task (Liggett 1974: 156; Benson & Perrett 1991a, 1992b).

1.1 Representing the Face

Artistic interpretation has allowed the human face to subsume considerable stylistic representations. This in itself has been sufficient impetus for observers to have begun to contemplate the reasons for our desire to depict ourselves in such diverse manners through portrayal and as highly interactive social creatures.

Historically, sculptors, painters, zoologists and anthropologists have concerned themselves with the notion of head and facial ideals, using the rough anatomical correspondence between head and body size to their expressive advantage. This preoccupation is manifest in the works of art, literature, and social thought of their age, and has influenced a great variety of subsequent works. Our vulnerability in perceiving images of the self and others has provoked rather than inhibited curiosity and experimentation with representation and media.

Comparatively recently the work of the C16 Italian artist Giuseppe Arcimboldo (1527-1593) drew attention to the power of complex allegorical portraiture (Hulten 1987a, 1987b). His paintings and drawings of 'composite heads' realised the potential of such imagery to make statements about the elegance of the human physiognomy and indirectly challenge the character of his peers (Figure 1.1:1). His canvases depict human heads whose features are represented by thematic objects substituted in an harmonious and purposeful manner; every imaginable component was constructed from fruit, vegetables and plants, fish, land animals, books, mechanical components, kitchen utensils, and all manner of human figures themselves. Conversely, Cacciari (1987) notes:

> "A diabolic inversion of this harmony would occur if a flower, an animal, or a stone were to be composed of human faces. Alchemical transformation has a predetermined and irreversible direction: it passes from the apparently chaotic multiplicity of natural forms to the true Aurum (gold) of the sages..." (p280)

Although Arcimboldo's works remained almost undiscovered for some three-and-a-half centuries, his legacy survived to exert considerable influence on a number of C20 artists (eg. René Magrite, *Le Viol* (1934); Salvador Dalí, *Paranoiac Figure* (1934-35)).

The cumulative effect of these early abstract and surrealist works greatly shaped the philosophies of writers and illustrators to come. The following section describes how a number of distinct disciplines have developed and interacted to produce what is now a highly familiar and emotive vehicle for the communication of critical ideals as carried by the human face and body.

Figure 1.1:1

GIUSEPPE ARCIMBOLDO (1527-1593): *Vertumnus - Rudolf II*, c.1590. This piece and others inspired many artists to reconsider their portrayal of the human head and face.

1.2 Caricature: Genesis, Graphic Art, and Political Iconography

An historical perspective of the development of cartoon caricature from C16-C20 Europe is described together with the influence of national and international war and socio-political influence on developing media systems as a means of rapid communication in society. An examination of stylistic trends and experimentation in depicting faces in portraiture to this end is also presented. The impact of caricature and its survival to the modern day has merited scientific consideration, the psychology of which is reviewed and discussed separately in section 2.0.

> **caricature** *n.* 1. a pictorial, written, or acted representation of a person, which exaggerates his character traits for comic effect. 2. a ludicrously inadequate or inaccurate imitation: *he is a caricature of a statesman.* ~*vb.* 3. to represent in or produce a caricature of. [C18: from Italian *caricatura* a distortion, exaggeration from *caricare* to load, exaggerate]
>
> Collins English Dictionary, 2nd Edition
> London: Collins, 1987

The century following the Napoleonic and revolutionary wars saw several generations of people moving into the major cities of Europe as a result of developing technological and commercial conditions. This resulted in considerable economic and social difficulties for these new immigrants. By means of 'gesture' the mutually unknown populous sought to communicate with each other. C17 Le Brun authored works on physiognomy (Le Brun 1698) and it is here that the language of gesture has its roots. Theories of this phenomenon were subsequently examined by amongst others the Swiss pastor, teacher, poet, and physiognomist Johann Caspar Lavater (1741-1801) in the following century. The first post-Greek work on the subject had been published in 1272 (*De Hominis Physiognomia*) by Frederick II's astrologer Michael Scot. In this he attempted to give physiological bases to facial forms and expressions; the explanations were of a magical and occult nature, and it was not until Lavater's *Physiognomische Fragmente zur*

Beförderung der Menschenkenntniss und Menschenliebe (Lavater 1775-78) and *Essays on Physiognomy: designed to promote the Love of Mankind* (1772; see Lavater 1780) that the subject was separated from its hopelessly confused association with the white magic of 'judicial astrology'. So powerful was the art of social gesture, that it became a significant feature in Restoration theatre especially during the C19, and at that time was also being displayed in pen and ink portrait and caricature by the popular and dedicated newspapers of the time.

The physiognomists of the day believed that there was a direct relationship or correspondence between a person's inner self and their physical appearance. That is to say, the outward *character* of a person was revealed by such factors as colour of eyes and hair, shape and arrangement of features, manner of speech, facial expression, etc. In studies of literature, character description implies composite portraits, leitmotivs, symbolic physical features, and so on; critics, however, have objected to character description indicating the tediousness of the long drawn-out portrait (Petsch 1942), or complain of the difficulty of visualising a person that has been described (Maugham 1952). Nonetheless, character description plays a significant role in written work. This approach to understanding should be contrasted with that of the phrenologists, who were concerned with the relationship between bumps on the surface of the head and qualities of the owner's character (*organology*, *cranioscopy*, *phrenology*). The geatest exponents of the science were the Viennese physician Franz Josef Gall (1758-1828), and his former student Johann Georg Spurtzheim (1776-1832); together they embodied their ideas in *Anatomie et Physiologie du Systême en Gênéral et de Cerveau en Particulier* (1810-19) which became the reference text.[1] They believed that the brain consisted of a distinct number of organs or 'centra' which would develop to different degrees in different people. The extent of these growths would be reflected by corresponding swellings on the skull which could be seen and felt from outside the head. There were well-, under-, and over-developed bumps.

[1]Gall and Spurtzheim were by no means the innovators of inferential phrenological studies. Spurtzheim (1815; Nash, 1966) refers to several previous authors, including Charles Bonnet (1764), and Sömmering (1791).

The notion of physiognomic normality emerges from rather unwonted work.[2] The C18 Dutch physiognomist Pieter Camper differentiated higher and lower forms of vertebrates, and his work was heavily influenced by the work of both the German painter and engraver Albrecht Dürer (1471-1528) and Lavater. Camper approached the problem of the separation between man, quadrumana, and other mammals by using the *facial angle* (Camper 1791) which he intended to make clear distinctions between the crania and hence intelligence of monkeys, orangutans, Negroes, Kalmucks, and Europeans (Figure 1.2:1). He compared the facial angles of the other faces with that of what he considered to be a representative European skull. Camper concluded from his studies that the *normal* (desirable) facial angle for European men lay between 70 and 80°. Anything less than this figure was an indication of barbarism, and anything higher belonged to the realm of fantasy or diseases such as hydrocephalus. The validity of such work was disputed and many of the findings discredited, although the German anthropologist and ardent monogenist Johann Friedrich Blumenbach did little to discourage such notions. He believed that all non-white races were essentially degenerations of original Caucasian stock, and thus appealing to Europeans he suggested that it was better to be Caucasian rather than a member of any other race.

Curtis (1971) documented the trials of the Irish at home and in America by Victorian England. "Paddy" - the stereotypical Irish Celt of the mid C19 - was considered to be different from Englishmen. So much so that both men and women were rendered in such journals as *The Graphic* (1869) and *Puck* (1877) transformed from harmless drunken peasants to dangerous simianised creatures, often the 'cause' of agitation, rioting, unrest, etc. Derogatory comparisons of the "white negroes" (sic) were made with the Chinese, Maoris, Aborigines, Hottentots, and Sudanese; in less than a century (1840-90) the Irishman had become a monstrous Celtic Caliban capable of any crime the cartoonist cared to imagine, moving on

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[2]Although it is convenient to regard phrenology as an essential part of the Lavaterian era of physiognomy, this is not tantamount to saying that those who accepted phrenology also subscribed to the principles of physiognomy, or vice-versa. Phrenology has its own laws, its societies, and its journals, and it was jealous for independence as a science in its own right.

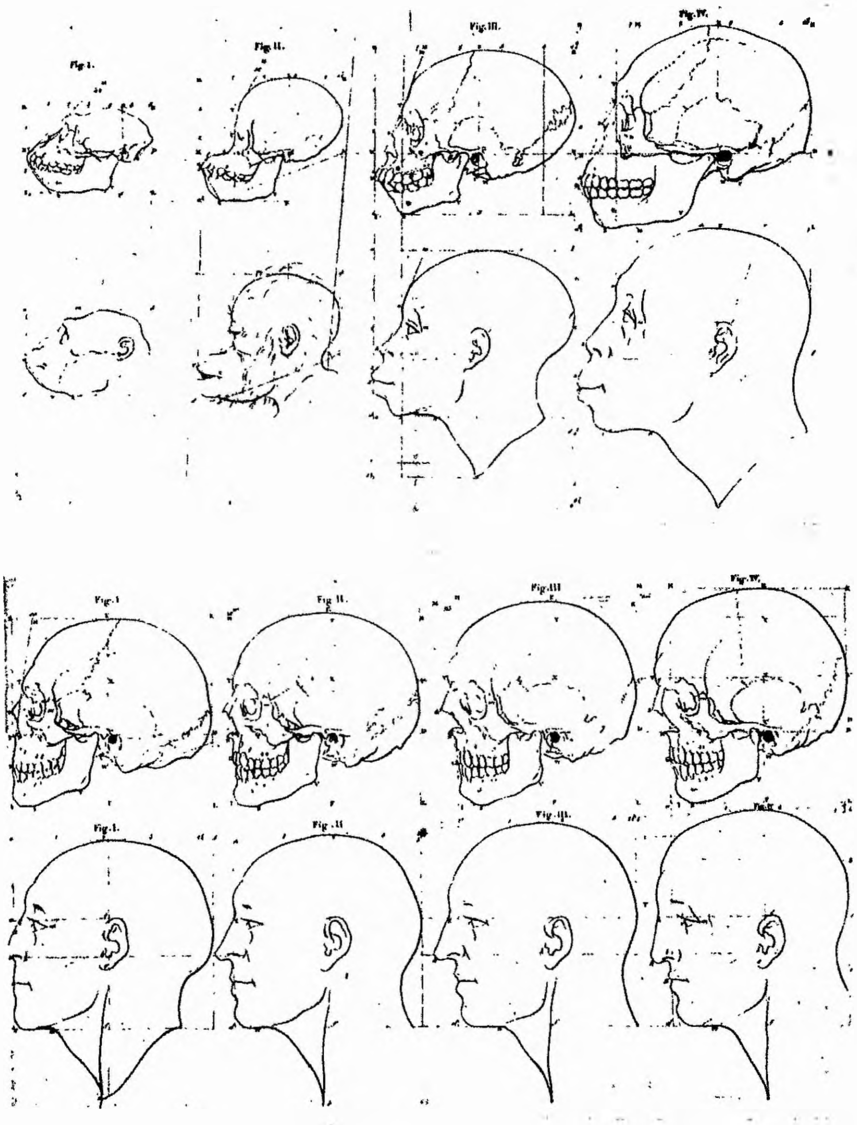

Figure 1.2:1

CAMPER, from T. Cogan (Ed.) *The Works of the Late Professor Camper on the Connection between the Science of Anatomy and the Arts of Drawing, Painting, Statuary*, 1821 (reprinted from Curtis 1971).

The facial angle is formed by the intersection of 2 lines; the 1st diagonal or vertical from the forehead to the foremost point of the front teeth, the 2nd horizontally from the external auditory meatus (ear hole) to the nostrils. The angles (upper extract from the top, left to right) are I, tailed monkey, 42°; II, orangutan, 58°; III, Negro, 70°; IV, Kalmuck, 70°; and (lower image) I, European, 80°; II, Grecian bust, 90°; III, Roman bust, 95°; IV, a case of hydrocephalus, 100°.

This work, and others of the period, perpetuated myths about ideals and intelligence in races of man. However, it is clear evidence that the physiognomists were judging their peers using some notion of a norm.

from chimpanzee to orangutan to gorilla. These acutely prognathous characters conveyed the "swinishness of the multitude, especially the primitive instincts of the politicised 'mob'" (Curtis 1971). A decidedly porcine influence followed affecting the cheeks, mouth, and nose, reflecting a peasant economy and diet reliant on pork. Demands for the termination of British rule completed the prototyping of the stereotypical Paddy, appearing in the press as snub-nosed, big-mouthed, hyperprognathous gorillas and orangutans (Figure 1.2:2).

A psychological code of a person could be described, as writers such as Honoré de Balzac (de Balzac 1833-46; Hunt 1959) often did, by examining the categories into which facial and body features fell. Such a code would not only facilitate an accurate artistic representation but would also be sufficient for others to accurately and immediately recognise the depicted character. Combining physiognomic codes for particular features would thus permit character generation, eg. the crooked nose of a street fighter, phlegmatic eyebrows, and the mouth of a sensualist could easily be a formula for the face of a criminal. Thus by reading the elements of such a code, the nature of a stranger could be understood. Coping in an environment of strangers seemed to become manageable through the 'science' of physiognomy and stylised caricature.[3] Lavater himself showed a fondness for caricature, and included several drawings in his *Fragmente* (Lavater 1775-78) with a view to maintaining his belief that we should adopt an attitude of love and understanding when looking at the physical defects and deformities depicted. His regard for the work of William Hogarth (1697-1764; 1833a, 1833b), one of the great early caricaturists, is clear in his warning to parents that children should be aware of the harms of vice on their appearance in later life (Figure 1.2:3). Caricature, was the means by which artists such as Hogarth, and George Cruikshank (1792-1878; 1826) portrayed the character and identity of individuals, themes, and characters.

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[3]Modern novelists still use the principles of physiognomy to convey to their readers the essence of their character's personality before the plot has developed far enough to reveal their real nature. The "tall, dark stranger" euphemism has many interpretations.

Figure 1.2:2

JAMES WALES, detail from *An Irish Jig*, Puck, 1880 (reproduced from Curtis 1971).

From 1840-1921, constant reference was made in the humorous sections of the press to Irish Celt physique as Caliban, "The Missing Link", and *The Origin of Species*.

Figure 1.2:3

WILLIAM HOGARTH (reproduced from Tytler 1982). A crowd of dissolute revellers showing distorted faces and deformed bodies, participating in a drunken brawl, leads to the admonition that parents should give their children about the harmful effects of vice on the appearance. A number of the characters portrayed here are taken directly from other pieces by the artist.

The chaotic society in which these Europeans lived required the imposition of order and a sense of cultural conscience, an arbiter, if they were to meet the goals of the new progressive industrial systems. It could be said then, that gesture and caricature are candidates for such arbitration. The reason being that to present the masses with a notion of a stable character and personality would lay the foundations of a successful society and culture.

The physiognomist's attempts to analyse personality traits comes from ostensibly fixed forms of appearance such as skin colour, eye separation and attire. Darwin's (1872) work during this period constantly resorts to some kind of permanent fixed type of emotion which underlies all others. As a stranger's mask could be a reliable guide to his temperament (for those who required this) so the artists' 'portraits' became relied upon in the popular press. The dominant codes in a sketch could freeze a personality onto a fixed and recognisable form.

There are three distinguishable strands in caricature as Wechsler (1982) calls them:

- portrait charge [how it is constructed visually];
- allegorical interpretation of public events;
- social caricature.

Feature exaggeration, whether as extra- or retrograde enlargements, would be applied by the caricature artist to features of a subject's face or body according to whether they were considered to be characteristic of that person. Such exaggeration often has a satirical message in, for example, the tradition of human-animal analogies used as physiognomic codes for human character/psyche.[4] A caricaturist stressing the owlish eyes and small pointed

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[4]Throughout literature, physiognomy has also been referred to as *podoscopy* and *metaposcopy* (origins unknown). Many notable authors have made liberal use of the ideas it professed, including Cardano (1659, *Fisionoma Astrologica*), Thomas Hill (1588, *The Contemplation of Mankind*), Thomas Wright (C17, *The Passions of the Minde in Generall*), William Shakespeare, Samuel Johnson, Milton, Dryden, Giambattista B. della Porta (1586, *De Humana Physiognomonia*; 1627, *Of Celestial Physiognomy*), John

nose of the French statesman and historian Louis Adolphe Thiers was not merely finding a successful formula thus rendering the antics of a public figure humorous, but also commenting on Thier's political personality: his advocation of sharp-sighted wisdom - the owl's traditional attribute.

Nations, factions, and abstractions such as Death, Peace, War and Diplomacy, are often represented by single figures with recognisable characteristics (see Jensen 1975). In such cases there is frequently an element of humour in the punning and guessing involved in the task of deciphering the metaphysical codes. In addition, the traits of Folly, Greed, and Lechery alleged to be rife in the Army, Medicine, and Politics (irrespectively) were frequently supplemented by the relatively simple humour of marital status (eg. traditional role reversal seen in hen-pecked husbands dominated by burly housewives), the drunkard, the fool, and the eternally preposterous and ridiculous spectacle of *the Foreigner* as fodder for the English. Around 1786-87, colonial artists kindled nascent Australian caricature, and in its first few decades was dominated by the portrayal of phenomena as entities (characters and physical objects) as opposed to the exaggeration of the physical characteristics of public figures. Such allegorical statements are very scarce today.[5]

Caricature is not restricted to making a statement about individuals, but also about different societies to locally, nationally, and (through media technology) globally distributed audiences. To be successful, caricature had to develop a fervent and rapid communicative vocabulary, exploiting the graphic limitations of its means of reproduction, a fact which still pervades today's impoverished images (see Seymour-Ure 1975). Social caricaturing is the satirical presentation of typical characters in everyday situations. It is thematically affiliated with *genre* painting which by definition portrays types

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Evelyn (1697, *Digression concerning Physiognomy*), Kant (*National Physiognomies*). Leonardo da Vinci also sketched different heads and faces and was obviously concerned about the particular traits and characteristics of their would-be owners (see Liggett 1974).

[5]Real people were often drawn as portrait characters using lithographic or pen and ink techniques; by virtue of this the printed representations were very much like cartoon characters, accurately sketched, although Mahood (1973) disagrees with this as she makes no reference to the work and significant influence of the French caricaturists of the time on the transported British stock (in London, caricatures appeared around 1785 in the *Humorists' Magazine*, and later in *Punch, Or the London Charivari* circa 1850).

rather than individuals and domestic situations rather than (often glorified) historical events.

Thus, caricature can be seen to have developed through a two-fold tradition:

- *physiognomics* in the classification of people into character types (cf. genres) according to outward appearance (physiognomical measurements can be traced back to Aristotle in the C4 BC; according to the Hippocratic school of physiology, facial features provided infallible clues to the somatic and pneumatic qualities of man);
- *pathognomics* in the interpretation of changing emotions by facial or body expressions (cf. Darwin 1872; and more recently, eg. Allport 1924; Izard 1971; Ekman, Friesen & Ellsworth 1972; Salzen 1981).

It is quite astonishing to read of the depth of belief in physiognomic science held by Lavater (1789: 242) for example:

> "Skillful and very experienced surgeons have in their physiognomy a particular *dominant trait*, which comes from an habitual movement of raising the upper lip - which can be attributed to the effort they make to resist the impression caused by the sight of suffering and pain which they have before their eyes during major operations."

and

> "Our gait and deportment are natural only in part and we generally blend with them something *borrowed* or *imitated*. But even these imitations and the habits they make us contract, are still results of nature and enter into the primitive character." (my italics)

Physiognomy had been derided in the past; a century passed after Lavater's formalisation of the science before consensus of opinion again made it's mark. The French philosopher and novelist Denis Diderot's (1713-84)

Encyclopédie was finally published between 1745-72 (Diderot 1875-77) and contains the following definition (also cited in Vauvenargues 1929):

> "*Physiognomie... etc.: Physiognomy* [feminine pronoun] (Moral). The physiognomy is the [physical] expression of character; it is also that of the temperament. A stupid physiognomy is one which expresses only the complexion, a sort of hearty temperament, etc. But one should never judge anyone by his physiognomy. There are so many elements mingled together in the human face and bearing as to lead to confusion, not to mention the accidents which disfigure the natural features, thus preventing the inner man from manifesting himself, such as smallpox, thinness, etc."[6]

Although allegory and the application of the animal dimension can be traced back to engravings of 1519 (Urs Graf, *The Soldier's Return*) and 1523 (Lucas Cranach, *The Donkey-Pope of Rome*, and *Monk and Donkey*) it was not until the rise of the press in the revolutionary phase of the C19 that the caricature made its mark. The humble printer became accuser and critic of the establishment. The French poet, Charles Pierre Baudelaine, wrote of the popularity of press illustrations covering the extensive work of French 'artists' Vernet, Pigal, Daumier, Charlet, Monnier, Grandville, Gavarni, Trimolet, Travies and Jacque, and also non-nationals such as Cruikshank, Goya, Hogarth, Pinelli and Brueghel. As an author, his often macabre imagery made him the ideal literary exponent of the insolent talent of such artists, in particular Philipon and Daumier.

Charles Philipon and his collaborators worked on the first caricature journal *La Silhouette* which appeared in Paris between 1829 and 1831. At that time, they founded the two most important caricature papers *La Caricature* and *Le Charivari* (meaning a loud clatter of pots at the windows of unpopular people) which dominated social and political comment for a full 30 years. By the early 1830's, caricature was a means of delivering

[6]Compare this point of view with Diderot's later works in which Lavater's immediate influence provoked such statements as "a painter who is no physiognomist is a poor painter" (Diderot 1796).

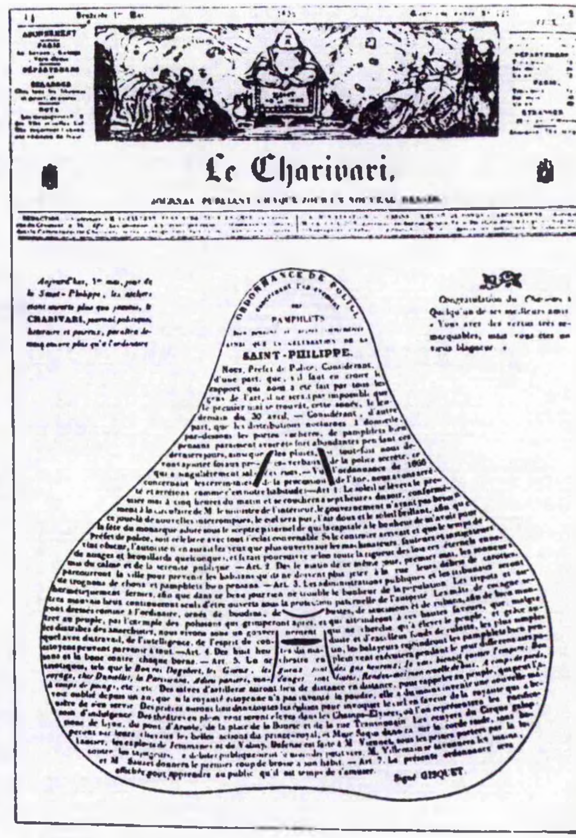
political discourse particularly adapted to the social and technical emergence of mass daily illustrated newspapers. Caricature became a visual commentary of its time whose vehicle was the human figure. It was a vernacular art drawing on the expressive conventions of historical and contemporary methods of painting, whilst unhampered by the precepts of academic teaching. Censorship in revolutionary France became official in 1835 after several years of failed attempts to ban certain illustrators' work and newspapers. The censors feared political images more than words, and they themselves became the target of caricature by Grandville (in *The Censors*) that year. The pressure of prosecution on the caricature press provoked the artists into employing more ingenious uses of their talents, forcing the traditional visual repertoire to yield indirect political and social meaning (Wechsler 1982).

Philipon invented the singularly most famous and effective political emblem, the *poire* (pear), as a representation of the repressive King Louis-Philippe. Not only was Louis-Philippe overweight in matching the shape of a pear, but additional reverence for this iconoclastic statement is in the colloquial use of poire, meaning fat-head. In time, the pear came not only to refer to the monarch, but also all those who seized the opportunity to become rich under his gargantuan regime. Censorship failed to regulate even the most apparently benign use of said fruit in press illustrations, the caricaturists showing increasing dexterity and cunning in circumventing the latest legislation. *La Caricature* printed the court judgment against Philipon in the typographical form of a pear (Figure 1.2:4). Four years later, the government forbade the caricaturists to draw *any* pears, who had in the interim been enjoying their devious game.

The antecedents of *Mr Punch* appeared in French papers shortly after, Mayeux (1830-33), Macaire (1835-38), Ratapoil (1850-52), and Prudhomme (1852-70). Each were satires and/or allegory on the current political situation, although Prudhomme was declared apolitical due to the aftermath of the Franco-Prussian war in 1871. Monnier, the artist, eventually became caricatured as Prudhomme himself, unlike Daumier whose flexibility ensured his freedom of expression in the press.

LES POIRES,

Vendues pour payer les 6,000 fr. d'amende du journal le *Charivari*.



Le Charivari.

SAINT-PHILIPPE.

Figure 1.2:4

Left: PHILIPON, 'The Pears', *Le Charivari*, 1831 (in Philippe 1982). Philipon reduced King Louis-Philippe of France's head in systematic stages, gradually reducing distinctiveness and emphasising shape.

Right: (Philippe *ibid.*). An account of the legal ordinance against Philipon was published in the shape of a pear, *Le Charivari*, 1835, as further protest against the government's reaction to the above publication by censoring references to pears.

Human metamorphosis has often been taken further than the perfect simplicity of deforming Royalty into a piece of fruit (see Gould 1975). Comparison with animal physiology is not uncommon, the resulting image still bearing a reasonable resemblance to the original visage (see Figure 1.2:4); body form often suffers the most, as with the ex-New Zealand Prime Minister Sir William Fox, this often by virtue of surname.

At the turn of the century, Max Beerbohm (1913, 1921, 1958, 1978) began to produce caricature illustrations and artwork in a rather different vein. Much of his considerable work dealt with romantic and affectionate portrayal of the Edwardian upper-class. The humour in his images is entirely different from most comic cartooning seen before, simultaneously respectful and gross. Beerbohm's work is a classic example of the often limited repertoire of *types* at the artist's disposal. His figures are consistently tall, often gaunt, and always well dressed in pressed suits, or are monuments of obesity; politicians are old, and postured. Head size varied considerably. Many of his portraits concentrating on that feature, the image completed with a miniature torso and legs.

Diurnal cartooning continues very often in times when 'personalities' are scarce; the media seems to adopt a preference for 'mass' over 'class'. Certainly in political terms, caricaturing rides the wave of public opinion, and in many cases through editorial bias is demonstrably responsible for such changes as the general public succumbs to media communication. The events of civil unrest and consternation and national warfare generate unprecedented volumes of graphic art worldwide which is developed and manipulated for both public and political use. Raising national spirit is a simple matter of manipulating personal pride. Caricaturing the 'opposition', at whatever level is applicable, compounds and serves to bolster people's feelings (Bowlt 1975; Behrendt 1975). As sentiment runs high, caricature can be seen to range from intelligently subtle and informative, to iconography which under any other circumstances in particular countries would itself be tantamount to war. The results can be viciously effective if the correct facts are known within the literate communities (Figure 1.2:5).

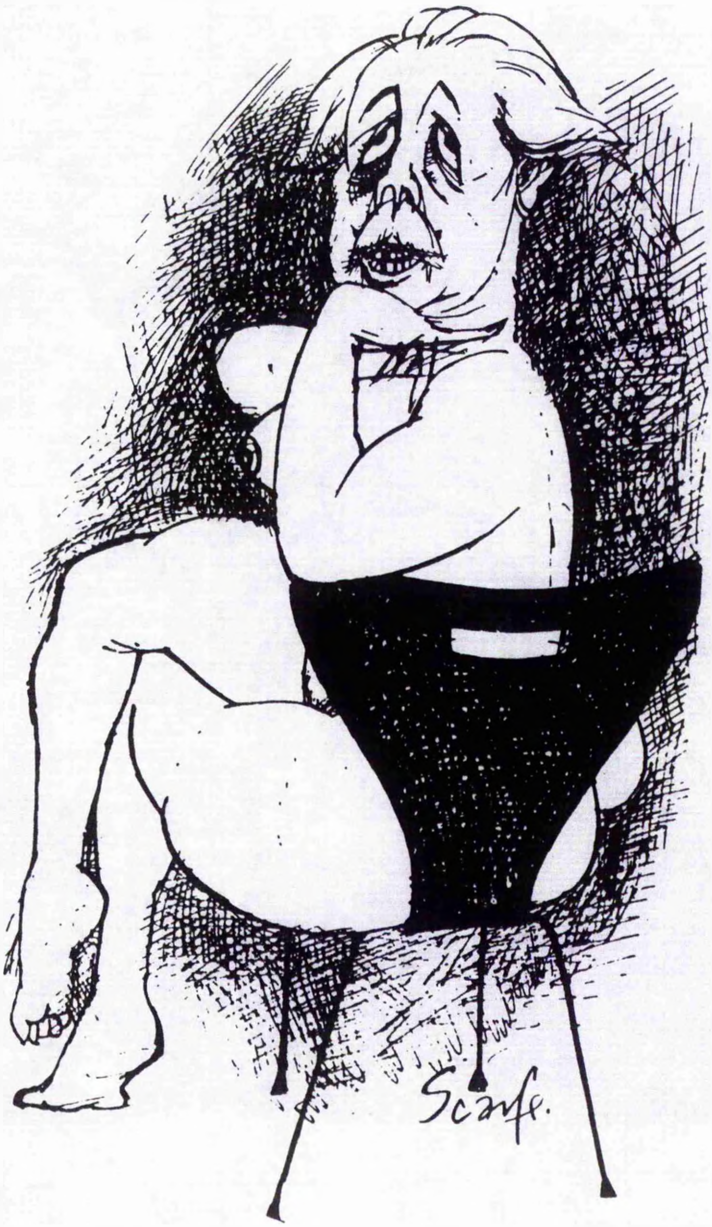


Figure 1.2:5

GERALD SCARFE, 1963. Associations are often made in direct and indirect ways. Here, the figure's pose is clearly recognisable as that of the model Christine Keeler who, with Member of Parliament John Profumo, caused public outrage and political embarrassment for the then Prime Minister Harold Macmillan.

"Those damn pictures", as 'Boss' Tweed called them, can often conjure more vivid memories of particular events than newspaper headlines.

Throughout caricature history, several public figures have received much attention from national and international press. Such media scrutiny can arise for a number of reasons including politics, social conscience and awareness, corruption, and stature. The latter is of considerable interest as it eludes to certain figure types, characters who's physiognomic codes lie within domains which the caricaturist is able to manipulate to humorous and satirical effect. As humans, we rely on recognition of *faces* in close social interaction. A person may be recognised through one or more particular features which distinguish them from others, those features which are characteristic of their physiology and personality. To this end, a distinguishing feature is one which is not commonly shared amongst other people of the subject's genre. Some aspect of that person which makes them readily identifiable. A person who does not possess distinguishing personality features or traits will not be identified as easily. Consequently the tractability of someone's caricature is moderated by their distinctiveness.

For the above reasons, Richard Milhous Nixon (U.S. President from 1969-74) received almost obsessive attention from caricature artists especially during the reelection campaign in 1972. In 1972-73, what became known as the *Watergate* scandal projected him into a critical public eye. In America, he suffered the privilege of Presidential shame and disgrace as the details of his Administration's sanctioning of political burglary seeped into the national press.[7]

Nixon was the cartoonist's dream. He was easy to draw, and with a little imagination the cartoonists were able to exploit his persona. As the crisis developed, the artist's pen became more powerful and devastating (Perkins 1975; Goldman & Hagen 1978; Philippe 1982). It is hardly surprising that the escalation of events took their toll, the already characteristic 5 o'clock shadow, widow's peak and sagging jowls became stronger references to his actual appearance. (Nixon had earlier attempted to transform his physical appearance using makeup and hair dyes.) Even with

[7] America, in 1860, saw the first caricatures of Abraham Lincoln as a presidential candidate. It was not until many decades later that his assassination was lampooned in the press. Even today, we still see often metaphorical reference made to the event, modern politicos cast in the leading role.

such few and seemingly innocuous facial features depicted, we are still able to identify the character, sometimes without contextual knowledge (Figures 1.2:6 and 1.2:7).

In 1974 Nixon resigned from office. His successors, Gerald Ford (1974-77) and Jimmy Carter (1977-81), caused serious problems for the political caricaturists. James Trelease (in Perkins 1975) said of Ford:

> "He is what we call a 'nobody'. That is, there is nothing distinguishing about his face. If he robbed a bank the teller would be hard pressed to come up with a description. Outstanding ears? Nose? Hair? Clothes? Nothing!
>
> "...His smiling face already has proved to be more recognizable than his serious expression. It may, in fact, become his broad toothy trademark. But not until we cartoonists do a lot of work at our work."

The American commentator and artist Jules Feiffer declared Carter a "cartoonist's nightmare" (Philippe 1982):

> "...while most leaders, throughout the ages, seemed larger than life, Carter was much, much smaller."

Such comments relate the issue of familiarity which many caricaturists relate; it seems that until the advent of political scorn or public disdain the artist must rely upon their visual impressions of their targets. Ronald Reagan (1981-89) was eminently caricaturable, not least because of his manipulated role as President. He too suffered scandal during office, in what became known as *Irangate* - the 'unconstitutional' supplying of arms and funds to Iran - and received his just deserts from the press. His successor, George Bush, again confounded the political cartoonists.

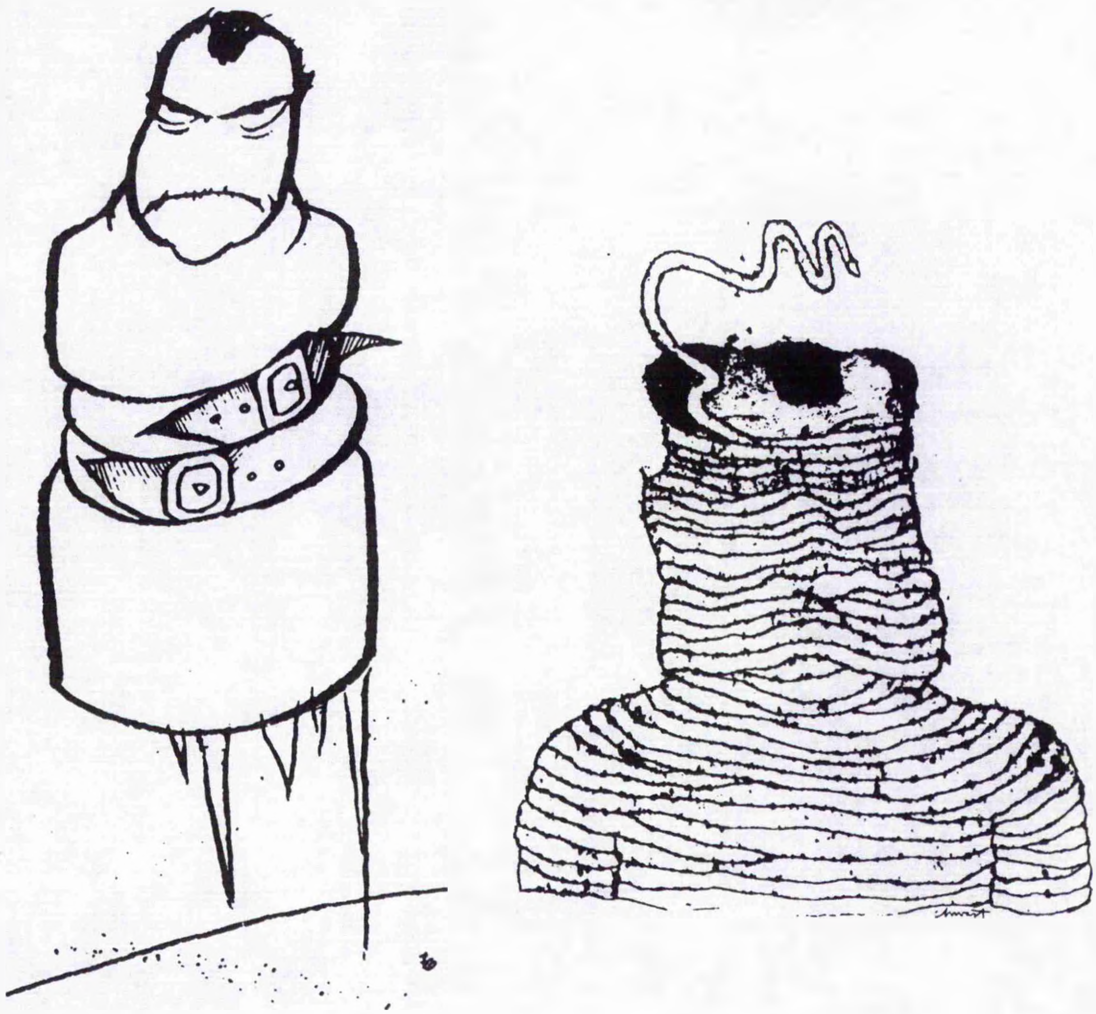


Figure 1.2:6

Left: ROBERT OSBORN, illustration from 'Missile Madness', 1970 (pre-Watergate crisis) (Philippe 1982).

Right: SEYMOUR CHWAST, 'The Nixon Mummy', *Op-Ed Page, New York Times*, 1973 (during Watergate) (Philippe *ibid.*).

The more frequently caricatured a character in the national press, very often the less visual information is required to facilitate identification. In representational and psychological studies by Perkins (1975) and Goldman & Hagen (1978) much is made of the consistency with which artists of the time rendered particular features of Nixon's face. The full-face view shows his nose as potentially flat and bulbous, however, in three-quarter and full profile the outward length of the nose increases dramatically and has a seamed tip; such an exaggeration, if incorporated 'correctly', is likely to aid recognition. Osborn's image is devoid of nose, although the hairline and sullen mouth are still very much Nixon's. In Chwast's illustration only the hair is visible but we extract additional information from the outline of the face showing heavy jowls.

Figure 1.2:7

REPRESENTATION OF DISTINGUISING FEATURES. Left: Adolph Hitler recognised the importance, for a political figure, of simple, easily remembered, personal marks of distinction. He successfully exploited the infamous trio of moustache, forelock, and salute. Centre: a truly minimalised representation of Hitler. Right: techniques such as this which were prevalent during the second World War have been adapted for the purpose of humorous reference (from Milligan 1974).

Eastern bloc and in particular socialist-governed countries do not dare satirise their political leaders for fear of recrimination although much has changed since the calls for Democratic rule in mid-1989. However, the West delights in this practice. Ex-Soviet President Leonid Brezhnev as an hirsute diplomat due to the unusual bushiness of his eyebrows, and the traditional Western beliefs about Russian weather; reformation ex-premier Mikhail Gorbachev often has the birth-mark on his forehead portrayed as some coherent pattern. The 'Hammer and Sickle' of the old order is a favourite of Central Television's *Spitting Image* series (in this instance a distinguishing feature became an icon). This programme has mutated caricature into life-sized animated foam puppets; their articulatory capabilities, through voice characterisations, have added yet another significant dimension to the art. The series not only satirises politicians (former Prime Minister Margaret Thatcher portrayed as a suited man, Reagan's memory problems and absent-mindedness taken to the extreme), but also royalty (Prince Charles' truly auriculated caricatures), sports personalities (boxer Frank Bruno and snooker's Steve Davis' intellectual capacities), and even 'the man in the street' (based on regional traditions, mannerisms, and accents). So successful have the series' been, a few of the real characters, whilst privileged to be moulded in the programme, are content to admit their enjoyment. In the West, it is the historical birthright of public figures "to be exposed to public ridicule and although they may not always like it, in Winston Churchill's words: '...they are quite offended and downcast when the cartoons stop. They wonder what has gone wrong, they wonder what they have done amiss'." (Victoria & Albert Museum 1984).

The emotional states of both countries and individuals is also frequently remembered in caricature: loss in combat depicted as the tears of a nation flowing into the bloodied seas of battle; tears of laughter flowing like water from a fountain from the Opposition ridiculing a disgraced Politician both make reference to weeping eyes but clearly bias a reader towards two very different viewpoints. Figure 1.2:8 demonstrates the artist's power in conveying a confused maelstrom of emotional conditions to the reader leaving little if anything to their imagination.

Figure 1.2:8

RALPH STEADMAN, an illustration from H.S. Thompson, *Fear and Loathing in Las Vegas*, (Thompson 1982).

The exaggeration of expression in emotion can often lead to more recognisable images; depicting the facial response to one or more somatic experiences is the clearest intimation of such a constitution. The difference in perception between spontaneous and posed expressions as reviewed by Ekman, Friesen & Ellsworth (1972) indicates that surprise, fear, sadness, and happiness are less accurately recognised in the spontaneous condition while for forced (posed) expression of happiness, surprise, fear, sadness, anger, and disgust/contempt accuracy improved significantly (see also Salzen (1981: 141) for a review).

Satirical iconography is sustained by its topicality; the graphics have proved its ability to express an essential inherent truth, even when it disguises its immediacy. The consensus of adulation of caricature art has succeeded over the centuries in alerting attention to local and global matters, bringing together an often disparate public. Philippe (1982) notes:

> "The vitality of political prints is a good barometer for the political and cultural climate. Graphic art flourishes at periods of crisis in the established order and of questioning of 'the rules of the game' ...The kicking-off point is the destruction of so-called personality. Visual irreverence springs up at the first breaching of the wall."

The advent of film and television bears witness to caricature in a different dimension. The very nature of comedic performance in these media has done much to extend theatrical performance to a point where in many cases the humour is 'forced' upon us; weak characterisations are justified in terms of our recognition of the exaggerated roles, mannerisms, dialogue, context, and embellishment of attire and facial appearance. What we experience in such broadcasts is nothing more than everyday occurrences which have been twisted and distorted according to the fantasies of writers and directors. Sarcasm in oratory can be delivered under the aegis of caricature; comedy is caricature, and vice versa.

1.3 Summary

It has been suggested that because of the visual and structural complexity of the human face a great number approaches have been adopted in an attempt to discover both the meaning and cognition of its lineament. The prevalence and maintenance of caricature can be understood in terms of an historical perspective on the mechanisms by which it has developed and is represented.

The achievements of a variety of disciplines have been given empirical and theoretical credence through psychological analyses of the mechanisms which gave rise to these perceptions and beliefs in the first instance. In the following sections (particularly 2.0, and 3.0 through 3.1.4), the matter of attribution of an individual's identity commensurate with the signals of their facial characteristics is accordingly surveyed and promoted.

II. Toolset Description

A series of computational tools are described which have been used to manipulate digital images of faces. The basis of the deformation model is a vector geometry manipulating the differences between measurements of two facial images. Distortion algorithms alter the configural and textural geometry of images automatically. Complementary utilities support the rendering tool providing a high-level interface to each category of facial transformation.

This section describes the specification and methods governing the production of the base image warp. Section III extends the model in simple steps to accommodate a number of visual transformations and their perceptual psychology.

2.0 A Caricature Generator

Faces as replicable objects on paper and canvas constitute a class of object which has confounded even the most notable of artists. For this reason, the face and head has been used as a seal of authenticity on currency (Gombrich 1959) and stamps (Rose 1980; Ellis 1986b). Nothing, it is suggested, would be harder for the forger to imitate than precisely the right expression even though the depicted heads were artistically almost insignificant.

Part of what we do in recognising someone is to look for the 'minimum clues' which belie identity, some features being more important than others. Accurate recognition of familiar individuals is still possible when, for example, only low spatial frequencies (eg. 10 cycles per vertical dimension of the image) are present in the image (Harmon 1973; Harmon & Julez 1973; Perkins 1975; Fiorentini, Maffei & Sandini 1983; Hübner, Rentschler, & Enke 1985; Watt 1988, 1991) indicating that particular fundamental features and their spatial relationship on the surface of the face are significant and useful. The invention of portrait caricature presupposes the theoretical discovery of the difference between likeness and equivalence (Gombrich 1959). Despite the stroke of an artist's pen creating a wealth of feature changes in a caricature, the 'whole' of the image remains remarkably similar. As was shown in Figure 1.2:4, we accept the possibility of an alternative representation of King Louis Philippe as a pear. For Gombrich this is the secret of good caricature:

> "... it offers visual interpretation of a physiognomy which we can never forget and which the victim will always seem to carry around with him like a man bewitched." (Gombrich 1959: 291)

In this sense, caricature can be said to be a measure of the artist's success.

Perkins (1975) also believes caricature draws from two fundamental concepts, *exaggeration* and *individuation*. Exaggeration would seem to be a meaningful concept only in a system of representation where it is also possible to indicate some notion of truth. Individuation requires that the cartoon remains true to the subject's physiognomy which implies that mere exaggeration distortion is insufficient for caricature. In a sense, caricature can be seen to be the exaggeration of the deficits of an individual's physiognomy, ie. exaggeration for individuation's sake.

Line-drawings, as a general rule, contain less information than photographs of the same object (Davies, Ellis & Shepherd 1978). In the former, main features of the image will be delineated and the degree of detail will vary according to the amount of texture and highlighting lines, etc. Traditional caricature portraiture has employed manual line-drawing techniques. Even with such impoverished (see Figure 1.2:6) and exaggerated representations of real people we are still able to quickly recognise the character depicted.

It is proposed that successful caricaturing depends on a number of factors, namely

- who the person is, our familiarity with them, and their profession;
- the distinctiveness of particular features of that face;
- which features are exaggerated and the degree to which this is done;
- the artist's style and bias;
- sociopolitical climate (current affairs and public sentiment).

The relative importance of the roles played by identity, familiarity, and facial distinctiveness are assessed experimentally in the remainder of section II.

As individuals, only the faces of people who are familiar to us can be recognised in caricature (cf. Rhodes & Moody 1990). While it is possible to exaggerate details for an unfamiliar face the exaggeration will not make the face more familiar or recognisable. By contrast, the more 'famous' the face, the more exaggerated, distorted and impoverished the caricature representation of that person can be. Under varying conditions we may have become very familiar with expressions, mannerisms, apparel, etc. of that person and hence more perceptually tolerant of distortions in their appearance.

There is a high degree of concordance amongst caricature artists as to which features of a person's face should be exaggerated or minimised. It has been noted by Goldman & Hagen (1978) that although this is the case, the amount of distortion afforded to these 'key' features (see Perkins 1975) varies quite strongly across artists, and is also significantly affected by public sentiment towards the individual.

The decision as to which features to caricature and which to leave unmodified would seem to be based upon a comparison with what the artist considers to be an average or normal face. Only those features which deviate from the norm are exaggerated. The choice of norm against which to compare the target face must presumably be based on some consideration of age, sex, race[8] and even occupation since there are stereotypes for the

[8]Brennan (1985: 174) noted, however, that she often considered the best caricatures to be generated by comparing a target face with a slightly inappropriate norm.

appearance of individuals with different professions (Klatzky, Martin & Kane 1982); pop stars look young and are brightly dressed, and civil servants look old and are suited.

The definition of caricature as

> "...a symbol that exaggerates measurements relative to individuating norms" (Perkins 1975: 7)

gives the basis for a formal experimental model.

The theory of computation underlying the generation of caricatures is to exaggerate the metric differences between a graphic representation of a subject face and some other similarly structured face, ideal or norm or "average" (Brennan 1982, 1985; Dewdney 1986). Such a norm is intended to correspond to a hypothetical model of a generic or average human face which, for the purposes of an cartoon or caricature artist, provides a basis for judging what is unique about a face. As has been noted, faces are such compelling objects that we frequently bear witness to their image in natural phenomena. The ability of caricature to encompass likeness with very few lines is reflected in Brennan's (*ibid.*) theory.

The notion of exaggerating feature dimensions in accordance with how much they depart from the norm was used by Brennan (1982) to produce computer-generated line-drawing caricatures. Brennan used a fixed number of points to delineate manually the features (eyes and brows, nose, mouth, hair lines, ears, jaw) of a stored digitised facial image to produce a database of *x-y* coordinates for features. The shape for an 'average' face was created by taking mean feature coordinates over a number different faces. Different averages were created for male and female faces. A caricature of a particular face was produced by amplifying differences in feature coordinates from those of the average face. This procedure has the advantage of not requiring the particular deviant characteristics to be explicitly defined by the operator. Since all feature deviations are similarly treated any deviations characteristic of the individual will be amplified. Secondly the transformation is global and extends to the areas between delineated features. Therefore the distortions will modify the configuration of features which itself may be a cue to facial identity (Haig 1984, 1986a, 1986b). Appendix I discusses the linearity of the caricature computation space versus the possible dimensions of perceptual space. Brennan controlled the degree of exaggeration and expressed it as a percentage increase or decrease in the distance between feature point coordinates in the original from those of an average face. For example if the tip of a nose in a target face was 70 vector units from the average position, this would be increased by 35 to 105 units by a +50% degree of caricaturing. An exaggeration of -50% would change the veridical face half way towards the average or norm (producing an anticaricature). For an exaggeration of -100%, the face would be 'normalised' and would have the same proportions as the average. Caricatures then, are produced by exaggerating all feature point deviations from the norm (Figure 2.0:1), and anticaricatures by diminishing all feature deviations.

Brennan (1985) notes that her system (Brennan 1982) is limited to caricatures of black-and-white line-drawings of faces. The availability of reasonably powerful hardware has allowed the extension of her technique to include photographic-quality digital images. It is worth noting that manipulations of digital images in terms of artists' impressions of caricature are possible using general utility imaging packages such as *Digital Darkroom* (Aldus, Edinburgh) or *PhotoShop* (Aptec, London); Figure 2.0:2 shows such a manipulation (finally rendered as a 1-bit image for *The Guardian* newspaper).

2.1 Continuous-tone Caricatures

Photographs give greater scope for including detail. Perceptually, the more information there is to be gleaned, the easier it is recognise the picture under stable viewing conditions. Accordingly, photographic caricatures may be more easily recognised than line-drawing caricatures. The purpose of the methods described here is to develop a means of automatically producing

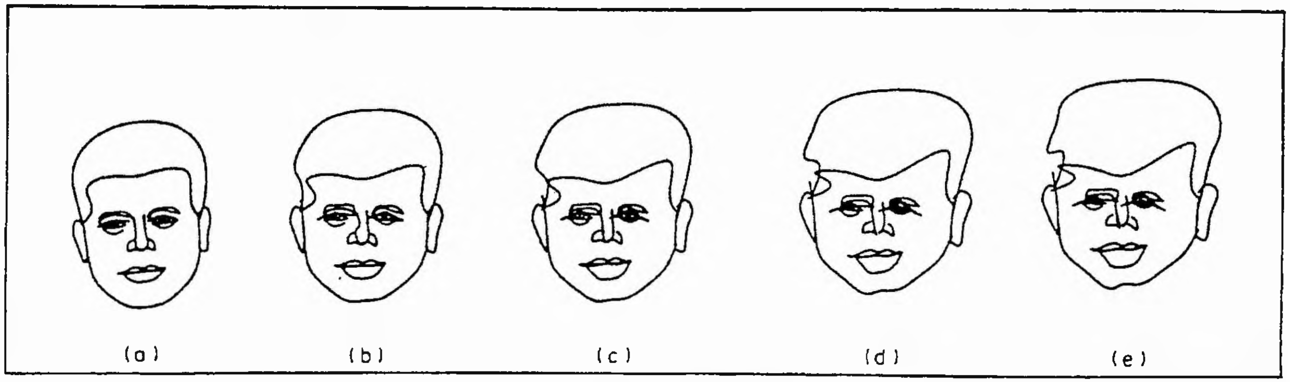


Figure 2.0:1

COMPUTER-GENERATED LINE-DRAWING CARICATURES (reproduced from Brennan 1985). (a) undistorted original, 0% caricature; (b) 50% exaggeration with respect to an 'average' face; (c) 100% exaggeration which Brennan (*ibid.*) considered the 'best' caricature in the sequence; (d) 140% exaggeration; (e) 160% exaggeration showing considerable overlapping and distortion of lines much as would appear in an artist's subjective caricature.

Figure 2.0:2

PETER CLARKE. Illustration from *The Guardian* (Clarke 1991). These caricatures were produced by the artist on a subjective basis. Using photomanipulation software on a Macintosh computer, Clarke is able to arbitrarily distort captured images according to his perceptions of the individual, digitally cutting and pasting them into a final collage for printing.

transforms (caricatures) of faces while maintaining the high fidelity detail present in original photographic images of faces. Brennan's model has been extended to allow the rendering of the line-drawing representations with photographic detail. 24-bit colour or 8-bit grey-scale images can be produced (Benson & Perrett 1991e). A four stage process is described below which transforms original portraits into continuous-tone caricatures.

2.1.1 Frame-Grabbing

The format of the original facial images may vary therefore a flexible image capture system is required. Photographic prints are mounted on the base of a camera rostrum illuminated with diffuse lighting and frame-grabbed into video store on an MS-DOS PC-based Pluto 2i 24-bit graphics utility processor using a JVC BY-110 video camera and RS-110 remote control unit. Images taken in this way have a maximum pixel resolution of 767 (x) by 576 (y), each pixel with up to 24 bits of colour definition. Individual frames from video tape are captured using a FOR-A FA-450P digital time base corrector connected to the Pluto graphics system.

Pluto image files are transferred to a UNIX-based Silicon Graphics IRIS 3130 24-bit colour workstation using a Local Area Network Ethernet file transfer protocol (*ftp*).[9] Pluto image files are run-length encoded on the green-blue-red bit planes; this data is preceded by a variable length header record containing colour table and image size information. To facilitate processing of image data each file is translated into a red-green-blue 8-bits-per-plane binary image sequence headed by 4 bytes specifying the x and y dimensions of the picture.

2.1.2 Feature Delineation

[9] PC/TCP implementation under MS-DOS is provided by `ftp` software (FTP Software Inc., Wakefield, MA) and Ethernet card (PCnic Ethernet Network Interface Card, IMC Networks Corp., Tustun, CA). UNIX provides TCP/IP as standard.

A set of 50 feature contours are manually delineated by overlaying a series of 186 marker points on an image of the face (see Figure 2.1.2:1). Each feature is described by a predetermined number of points (up to 13) which is identical for all faces processed by the system. Feature points follow those chosen by Brennan (1982, 1985), and Rhodes, Brennan & Carey (1987) except for additional detail around the eyes and mouth.

The edges of the image are automatically specified in order that the background surrounding the outline of the head can be included in the finished caricature. The 4 corners are noted and a number of equally spaced points along the horizontal (5) and vertical (3) boundaries are calculated.

The resulting coordinate data thus provides a veridical description of the target face. This information is used as the basis for an intermediary line-drawing caricature and as a reference frame for the mapping of pixel intensities to produce the rendered caricature.

Successful caricaturing depends on distributing the markers evenly along a feature edge or contour whilst still capturing the distinctive shape of the feature. For example, if points delineating the upper lip are spread unevenly with more lying to the right corner then the lip will become lop-sided in the caricature. Such potential distortions arising from inappropriate feature delineation are not visible in the veridical line-drawn sketch as features are simply represented by lines joining the delineation points. Interactive viewing of line-drawing caricatures does, however, highlight inaccuracies created in the delineation stage. These may be corrected by editing the locations of the feature markers in the database of points for that veridical image. Cheekbones show important structural information about the target face but are difficult to define (since the only cues to their position are subtle shadow and contour changes). They are more easy to specify in faces showing a smiling expression. Given this uncertainty the tessellation map (described below) does not utilise these points. ['Tessellation' is taken in this text to refer to individual tesserea in the plane, as well as the subdivision process.]

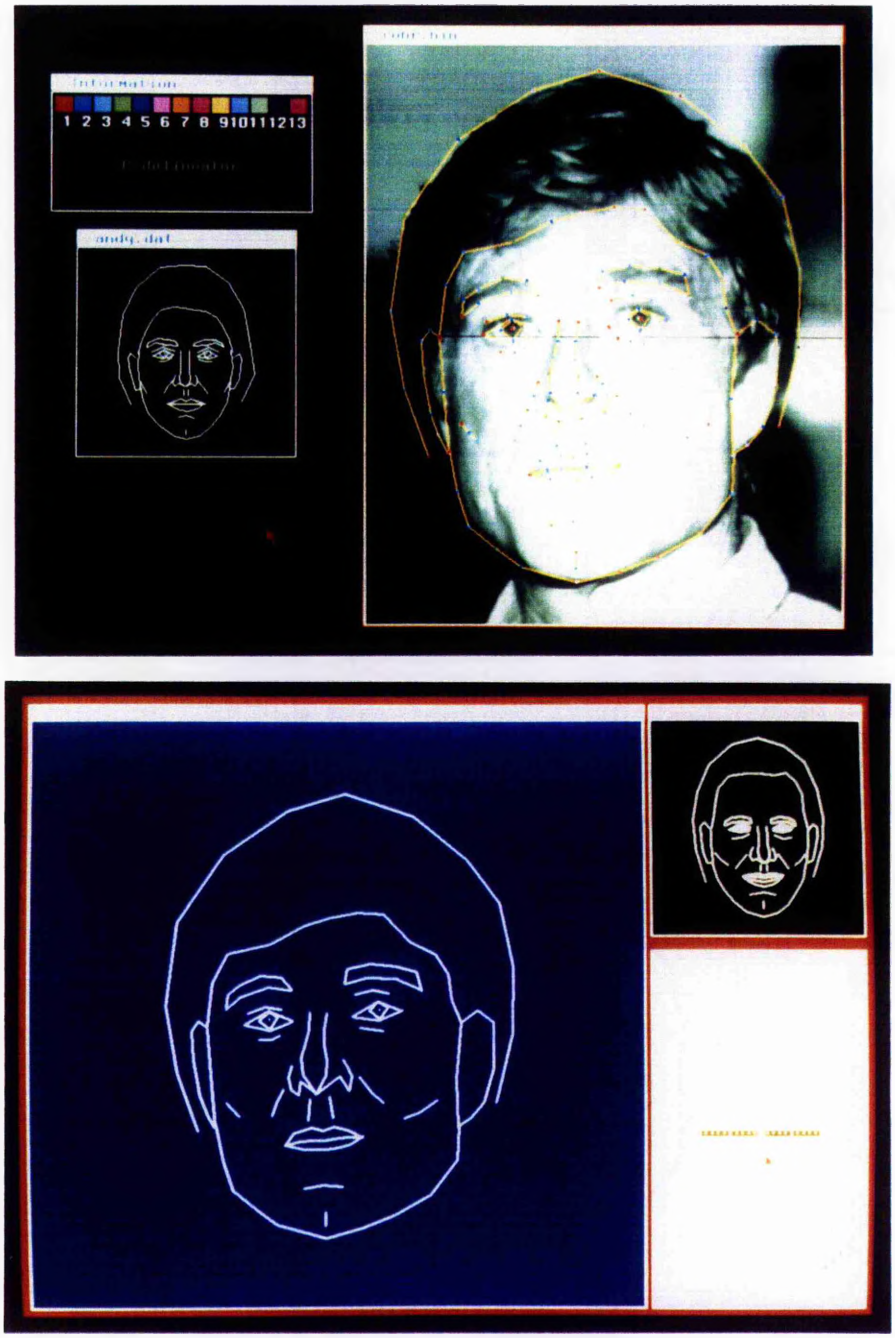


Figure 2.1.2:1

FEATURE DELINEATION. Top: 186 points are used to specify the Cartesian *x-y* locations of the main facial features. Colour-coded location markers are placed using the workstation mouse detailing a feature edge. Bottom: contiguous points around the source feature are joined by line segments to visualise an accurate line-drawing representation of the face.

2.1.3 Caricature Generation

Norms of feature positions for different ages and sexes are made by averaging data from several typical (≈10) faces of the same 'class'. To form a caricature of a given face, a suitable age and sex matched norm is selected for comparison. The position of the features delineated in the previous step are then interactively distorted. Each feature point in the veridical data set is compared with that of the norm and caricatures formed (Figure 2.1.3:1) according to a simple rule:

> *Wherever there are differences between feature point locations of the target face and the appropriate average face, exaggerate these by a specified amount.*

The user interactively alters the degree of exaggeration applied to each veridical point (see Figure 2.1.3:2) nominally in the range 0% to ±100%. Application of a positive distortion forms a caricature, whereas application of a negative distortion factor *reduces* all deviations between the veridical and norm and forms an anticaricature. Linear distortions are usually applied, but it is possible to apply others, eg. logarithmic or exponential distortion, to the vectors described by the distortions shown in Figure 2.1.3:1. Table 2.1.3:1 tabulates 7 different functions applied to an arbitrary sample of delineation data. An exponential distortion has the effect of more selective exaggeration; features close to the norm receive little or no distortion but larger deviances are considerably exaggerated.

Because of scale differences between the average (norm) and veridical (target) faces it is important to temporarily normalise the veridical data before generating a caricature data set. This may be done in several ways:

- ensure inter-pupilary distance is matched with the norm;

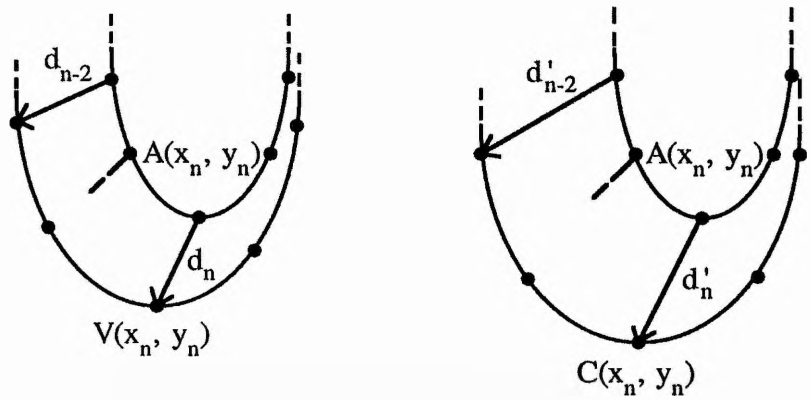


Figure 2.1.3:1

LINEAR CARICATURE EXAGGERATION. Exaggeration of features is performed by vector deformation of individual feature points (shown here for the points around the tip of the nose). Each point in the veridical image of the target face V is compared with the corresponding point in the average face A. Points in the caricature image (eg. $C(x_n, y_n)$) are produced by calculating the vector distance (d_n) between pairs of points in the veridical and average face ($V(x_n, y_n)$ and $A(x_n, y_n)$) and adding a fraction of that distance (eg. for a 50% caricature: $d'_n = d_n + 50 / 100 * d_n$).

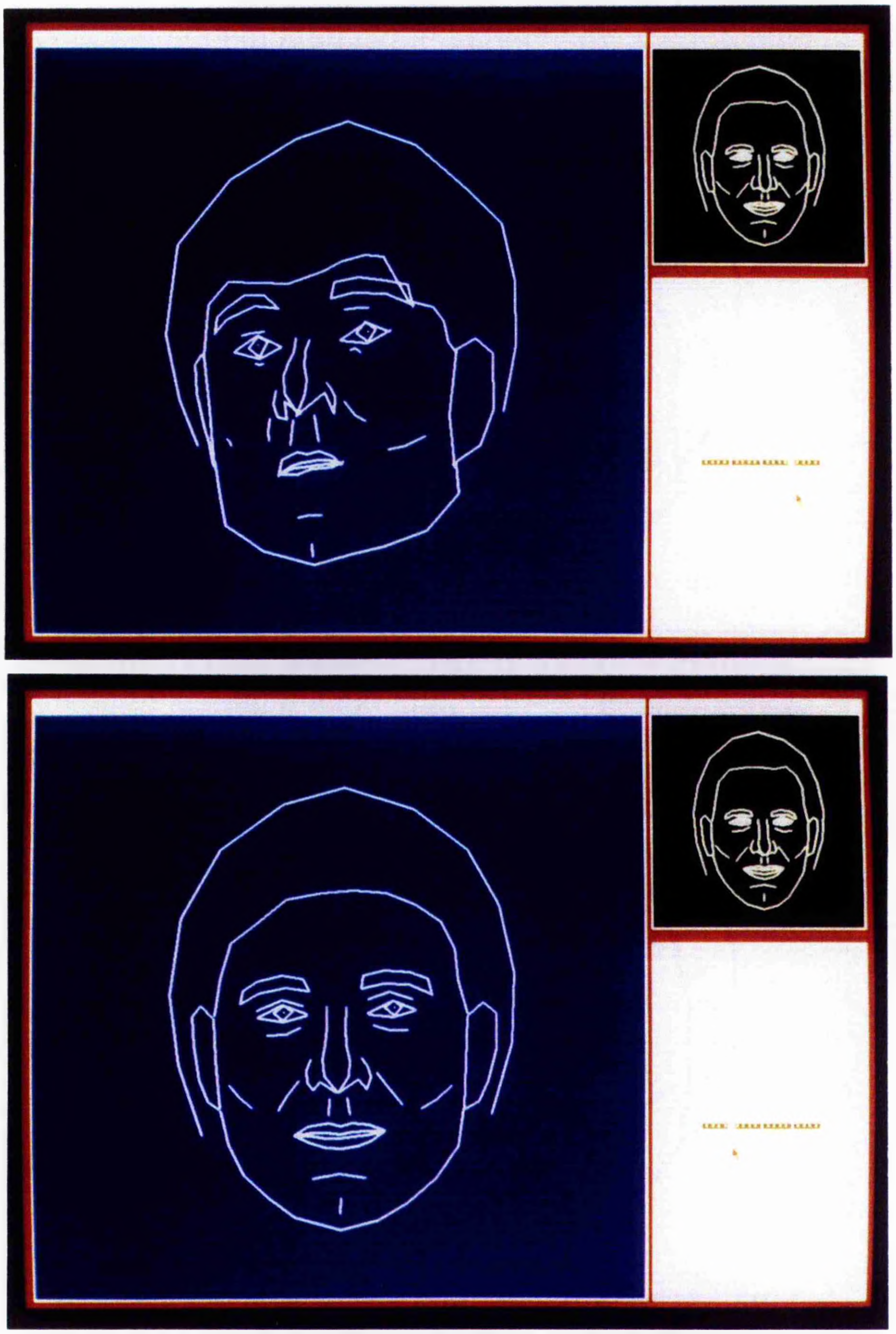


Figure 2.1.3:2

CARICATURE GENERATOR. Real-time exaggeration of the line-drawing veridical face is controlled through a graphical slider. Facial features may be represented by straight- or curved-line segments. Top: a 50% line caricature of Robert Redford. Bottom: the corresponding 50% anticaricature shown here as a straight-line drawing. In each case, the caricature is produced by referencing the normalised target face with a suitable 'average' face (upper right window).

diff	caric	linear	log	log2	log10	exp	exp2	exp10
0.321:	0%	0.321	0.321	0.321	0.321	0.321	0.321	0.321
	5%	0.337	0.378	0.403	0.346	0.390	0.383	0.426
	10%	0.353	0.435	0.485	0.370	0.459	0.446	0.530
	15%	0.369	0.491	0.567	0.395	0.528	0.508	0.635
	20%	0.385	0.548	0.649	0.420	0.597	0.571	0.740
	25%	0.401	0.605	0.731	0.444	0.666	0.633	0.845
	30%	0.417	0.662	0.813	0.469	0.735	0.696	0.949
	35%	0.433	0.719	0.895	0.494	0.803	0.758	1.054
	40%	0.449	0.776	0.977	0.518	0.872	0.821	1.159
	45%	0.465	0.832	1.059	0.543	0.941	0.883	1.263
	50%	0.481	0.889	1.141	0.568	1.010	0.946	1.368
	55%	0.498	0.946	1.223	0.592	1.079	1.008	1.473
	60%	0.514	1.003	1.305	0.617	1.148	1.071	1.577
	65%	0.530	1.060	1.387	0.642	1.217	1.133	1.682
	70%	0.546	1.116	1.469	0.666	1.286	1.195	1.787
	75%	0.562	1.173	1.551	0.691	1.355	1.258	1.892
	80%	0.578	1.230	1.632	0.716	1.424	1.320	1.996
	85%	0.594	1.287	1.714	0.740	1.493	1.383	2.101
	90%	0.610	1.344	1.796	0.765	1.562	1.445	2.206
	95%	0.626	1.400	1.878	0.790	1.631	1.508	2.310
	100%	0.642	1.457	1.960	0.814	1.700	1.570	2.415
1.666:	0%	1.666	1.666	1.666	1.666	1.666	1.666	1.666
	5%	1.749	1.692	1.703	1.677	1.931	1.825	3.983
	10%	1.833	1.717	1.740	1.688	2.195	1.983	6.300
	15%	1.916	1.743	1.776	1.699	2.460	2.142	8.618
	20%	1.999	1.768	1.813	1.710	2.724	2.301	10.935
	25%	2.083	1.794	1.850	1.721	2.989	2.459	13.252
	30%	2.166	1.819	1.887	1.733	3.253	2.618	15.569
	35%	2.249	1.845	1.924	1.744	3.518	2.777	17.887
	40%	2.332	1.870	1.961	1.755	3.782	2.935	20.204
	45%	2.416	1.896	1.997	1.766	4.047	3.094	22.521
	50%	2.499	1.921	2.034	1.777	4.311	3.253	24.838
	55%	2.582	1.947	2.071	1.788	4.576	3.411	27.156
	60%	2.666	1.972	2.108	1.799	4.841	3.570	29.473
	65%	2.749	1.998	2.145	1.810	5.105	3.729	31.790
	70%	2.832	2.023	2.181	1.821	5.370	3.887	34.107
	75%	2.915	2.049	2.218	1.832	5.634	4.046	36.425
	80%	2.999	2.074	2.255	1.843	5.899	4.205	38.742
	85%	3.082	2.100	2.292	1.854	6.163	4.363	41.059
	90%	3.165	2.125	2.329	1.866	6.428	4.522	43.376
	95%	3.249	2.151	2.366	1.877	6.692	4.681	45.693
	100%	3.332	2.176	2.402	1.888	6.957	4.839	48.011

Table 2.1.3:1

FUNCTIONS FOR CARICATURE EXAGGERATION. This table shows how different geometric functions (linear, logarithmic, exponential) affect facial feature delineation data under the algorithm for caricature exaggeration. `diff` refers to an arbitrary difference between a normative and target feature point. Logarithmic and exponential functions may require thresholding where delineation data differences are small. This may have the effect of improving caricaturing in certain cases; feature point differences below the threshold (which could be discriminately established) may be alternatively diminished according to a suitable scaling function which seeks to *further* minimalise typical features and may therefore require that less strong exaggerations are required in order to synthesise 'good' caricatures or anticaricatures. Where there are large differences, functions such as `exp10` require scaling. Nb. the columns simply represent the effect of applying compiler library functions for which an explicit understanding is not required; no attempt is made to *design* an ideal exaggeration rule.

- rotate the veridical face such that the pupils lie on the horizontal plane as they do on most norms (eg. Bookstein space; Goodall 1991);
- constrain one of the head dimensions (width, height) in the veridical to match that of the norm by scaling the data;
- a combination of the above [each yields the same (scaled) result].

2.1.4 Caricature Rendering

To produce continuous tone caricatures (black and white, or colour) the original image is mapped into destination image space using reference data. The reference data is derived by ordering the feature markers into a series of 340 triangular tessellations joining adjacent feature points and points around the boundary of the image to the points delineating the hair outline. Tessellating both the veridical and caricature data in the same way establishes a correlated set of triangular areas. These areas provide the rendering process with the basis from which to select the pixel intensity values in the source image and to remap them to the correct positions in the caricature image.

Figure 2.1.4:1 shows the tessellations within the face (those connecting the border have been omitted for clarity) for both data sets. Knowledge of these maps is embedded in both the caricature generation and the rendering software.

The algorithm to perform the mapping distortions is shown in Figure 2.1.4:2.

Tessellations are subdivided into 3 triangles (see Figure 2.1.4:3) each sharing a common vertex at the centre (centroid) of the tessellation. A centroid-edge scan is executed for each of these triangles. The edge opposite the central vertex is traversed at a (pixel) rate determined by the ratio between corresponding source and destination edges. A radial line is then traversed between each of these edge points and the central vertex thus mapping all pixels within a sub-triangle. Again the rate of traverse of this

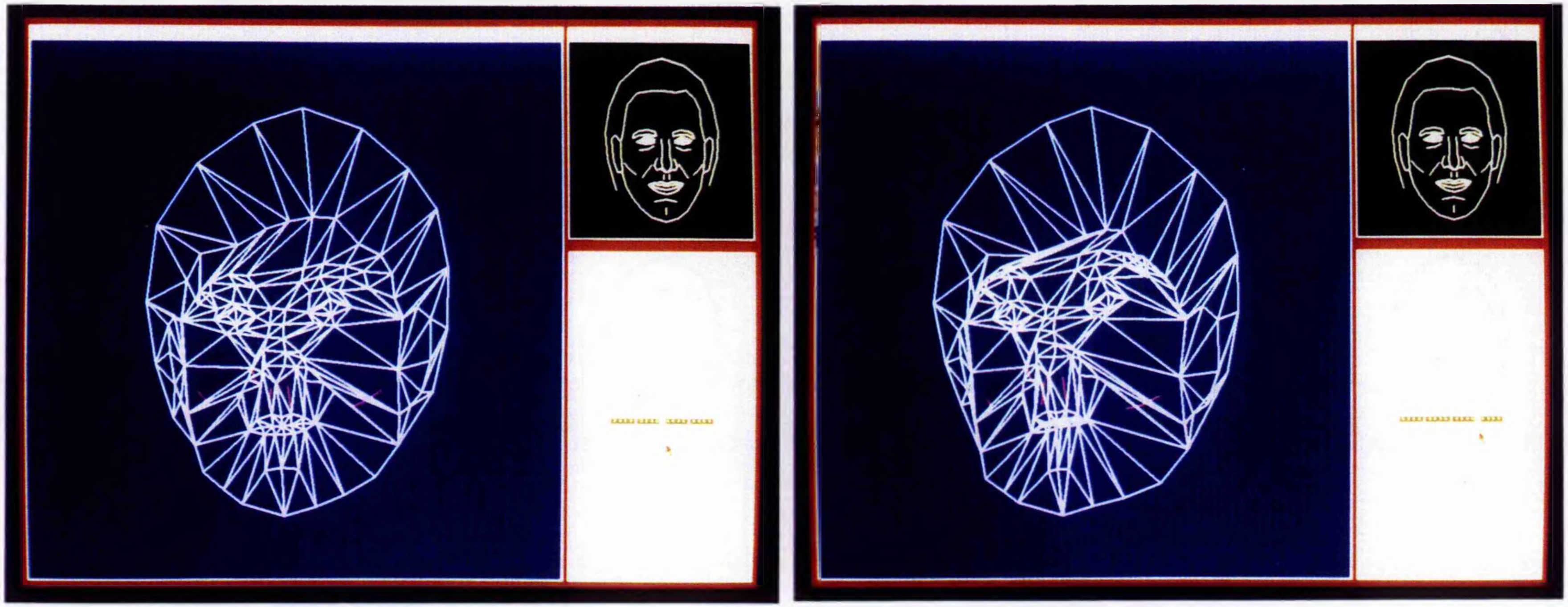


Figure 2.1.4:1

FEATURE-POINT TESSELLATIONS. A total of 340 tessellations are defined over face space including 42 to define the area between the edge of the head and the image border. Mapping is performed in an overlaid manner, ie. background, face, hair, eyes, etc. to ensure that prominent facial features are visible when overlapping tessellations are present. Left: veridical tessellations (face only). Right: destination caricature tessellations.

```
*
* Centroid-Edge Scan
*     S = source Δ; D = destination Δ
*     vertices = A, B, C
*


find centre of each Δ for S & D


for all edges A-B, B-C, C-A
{
     derive equation of line for S edge
     derive equation of line for D edge

     * set pixel stepping ratios for edges
     find length of edges, lenS & lenD

     if lenS = lenD -> stepS = 1, stepD = 1
     if lenS < lenD -> stepS = lenS / lenD, stepD = 1
     if lenS > lenD -> stepS = 1, stepD = lenD / lenS


     for each point on each edge
     {
          derive equation of line from centreS to that point
          derive equation of line from centreD to that point


          * set pixel stepping ratios for lines as before


          traverse the sub-lines for S & D
               * map the individual pixel from the image arrays
               pointD = pointS
     }
}
```

Figure 2.1.4:2

CENTROID-EDGE SCAN ALGORITHM. The image regions for the original and destination images are broken into small triangular patches. Each source tessellation is paired with the corresponding area in the destination image and so the geometric distortion between them is defined. The renderer parses each triangular patch in 3 stages sampling the original pixel intensity (image point luminance) information, stretching or shrinking it as appropriate.

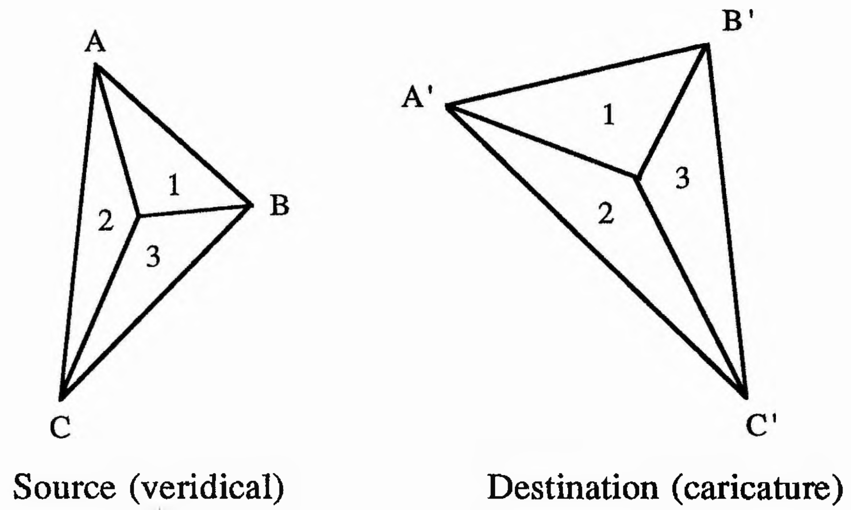


Figure 2.1.4:3

CENTROID-EDGE SCAN. The 3 sub-triangles scanned by renderer are shown. Here, stretching and rotation of the source tessellation takes place. See main text for a description of the procedure.

radial line is proportional to the ratio of the lengths of the corresponding radial scan lines in the source and destination sub-triangles. Pixel intensities at each point along the radial line in the destination triangle are mapped from the respective positions in the source triangle. *Shrinking* of the spatial distribution of pixels will occur when the destination caricature triangles are smaller than the veridical source. *Stretching* occurs when the destination space is larger.

Figure 2.1.4:4 shows the results of the 4 stages applied to an original photograph.[10] The exaggeration of features in this instance is equated by a linear distortion.

2.1.5 Rendering Methods

A number of other image warping techniques have been suggested (see Wolberg (1990) for a review). In the main these techniques involve the distortion of cubic patches on a 2-dimensional image and are most appropriate and efficient for the category of transformations being applied. Using such quadratic algorithms it *is* possible to distort facial images, and indeed to produce subjective 'caricatures' by logging a regular matrix of reference points on the original image and specifying the affine warps of the patches defined by the connectivity of the original reference matrix. Tessellation of a facial image defined in the manner described in section 2.1.4 using regular patches is only possible in *either* the original or final image spaces; there is no inverse mapping of location points which satisfies the no overlap condition (section 2.1.6 below). Triangular tessellation

---

[10] Beyond the fundamental software comprising the delineator, interactive caricature generator, and image renderer, a series of supporting tools are required, including (i) Pluto 2i 24-bit Paint (version 2.0) image file conversion to 24- or 8-bit binary image file headed by a 4-byte header specifying its dimensions, (ii) visualisation functions to display 8- and 24-bit images; although the IRIS graphics display can be configured to be doublebuffered for instantaneous presentation of images, neither the graphics library nor the geometry engines possess the concept of an 'image', and as such, image pixel information is sent line-by-line (scan-lines) into the display buffer, and (iii) image cropping in order to mask unwanted areas of an original or final image.

Figure 2.1.4:4

PHOTOGRAPHIC QUALITY CARICATURES. Centre: the original (veridical) image of Robert Redford (0% caricature). Right: a 50% linear caricature exaggerating Redford's distinctive facial features (such as the jaw and nose) by half as much again. Left: a 50% anticaricature (-50% caricature) of Redford, diminishing his face towards that of a suitable prototypical configuration.

avoids this problem. Triangular warps are more complex than those for cubics and is the only solution when fine-grain control of the deformation of the image surface is required (eg. Waters 1987; Williams 1990a, 1990b).

The success of the caricature process depends on successful remapping of image regions from veridical to caricature. Several mapping algorithms were investigated, and the centroid-edge scan described here was adopted for several reasons. The simplest alternative method is to scan each pixel from one edge to another working from the top of the triangle to the bottom. Problems with this procedure are encountered quickly when the destination polygon rotates beyond 90° because vertices will not lie in the same respective geometric quadrant relevant to the centre of mass, hence a change in scan direction to left-right or right-left is required for the destination triangle. Aliasing in the scan algorithm causes gaps to appear in the destination caricature image. Methods using systematic horizontal or vertical scanning of the triangulations give rise to inaccurate distortions within the subtended area. Two subtriangles are required for these methods which are formed by dropping a perpendicular line from the top vertex to the opposite edge in each of the triangles. In each of these alternative approaches the vertices must be sorted into a topmost-leftmost-rightmost order. Further, right-angled triangles as either source or destination tessellations cause gaps to appear in their counterparts. Scanning from each vertex to the opposite edge is wasteful as it duplicates the mapping of many pixels. Aliasing gaps appear in large triangles even with doubled scanning resolution (scan each line to half-pixel accuracy).

The centroid-edge scan although computationally intensive provides a more suitable and robust mapping method.[11] Vertices do not require sorting and rotations of the destination triangle of more than 90° are tolerated. Despite the complexity the procedure is relatively quick and is ideally suited to working with the tessellated areas in the facial image.

---

[11]The centroid-edge scan and static tessellation map are extended in section III (3.5.1) according to the nature and demands of more complicated transformations.

2.1.6 Overlapping Tessellations

In caricatures involving large distortions, triangles may overlap (at least 2 triangles occupy part of the same area on the face). This happens when veridical feature points are themselves quite distant from those of the norm; exaggerating these differences cause the greatest rates of change to take place in the caricature. By examining the tessellations during caricature exaggeration it is possible to decide at which stage the final product will begin to exhibit undesirable overlaps. The problem is of no great concern for line-drawing caricatures, but in rendered images it is undesirable. Overlapping tessellations can be determined during the remapping computation when a pixel coordinate in the destination image array is found to already have a non-zero value, ie. colouration already exists at that point, indicating that mapping of that pixel has already taken place due to another tessellation. In this case the current source and existing values may be averaged thus blending the intensities. This solution is by no means perfect, but it is satisfactory in that it does prevent harsh edges forming in the caricature image where overlaps do occur.

It is possible to avoid overlapping regions of the image in 2 ways. Firstly, one can selectively remove feature control point(s) which belong to the offending tessellations in veridical and transformed data space, and redefine the triangulation points appropriately using a simple vertex sort procedure. In extreme cases this may compromise control over feature edges (especially around the eye region). Alternatively, the tessellation map may be dynamically specified such that an optimal map is generated for each individual face. If a large transformation step produces overlaps, then rendering the final image (say 80%) in successive steps will avoid the problem, eg. 0 to 20%, 20 to 40%, 40 to 60%, and finally 60 to 80%, each intermediary step being chosen such that no overlaps occur.

2.1.7. Discussion

Starting images in which the face exhibits postural tilt or slight left-right rotation (towards profile) often produce better caricatures. For example, the nose appears more exaggerated than it would had the veridical been full-faced and upright. However, when features (such as the ears) become occluded due to head rotation it is necessary to declare the image regions missing and to redefine the appropriate part of the tessellation map.

The software can in principle be used to produce a number of image deformations (changing expression, age, even species) simply by comparing veridical data with an appropriate 'norm'. If a face with a neutral expression is compared with a norm with a smiling expression then diminishing deviations of the target from the norm (forming an anticaricature) will distort the target mouth into a smile. Similarly, comparing a target face with a younger norm will increase the apparent age of the target caricature. Ideally one would like to be able extrapolate the aging of an individual by comparing current images with images of the same individual at a younger age. By basing feature comparisons on a norm which is actually another individual's face the proportions of the target face can be distorted to incorporate the configuration of the second individual (with line-drawing caricatures one face will turn into another, but with photographic images the additional texture and brightness information prevents the complete transformation of facial identity).

III. Manipulating the Facial Image

This section begins with studies using caricature enhancement of facial identity. Applying a modified semantic to the transformation rule allows the model to produce a range of powerful visual effects which are formalised in terms of their perceptual properties. The findings and implications of the following experiments and the visual impact of each manipulation are central to this dissertation.

3.0 Continuous-tone Caricatures

Four experiments are presented which explore human perception and recognition for both caricature and veridical photographic quality images of well-known individuals. Manipulations of facial distinctiveness are considered throughout in terms of what kind of visual advantage they might confer under perceptual and recognition paradigms.

3.0.1 Experiment One
Are Photographic Quality Caricatures Perceived as Better Likenesses of Famous Faces than Veridicals?

Introduction

Caricatures are often gross distortions of the faces they represent. Moreover a cartoon caricature is usually depicted with a very few lines. Despite the impoverished and distorted nature of the information in caricatures we are remarkably good at recognising the individuals that they represent. Indeed recent findings (Rhodes, Brennan & Carey 1987; Rhodes & McLean 1990; Rhodes & Moody 1990; Carey 1992) indicate that line-drawn caricatures can be recognised more efficiently than veridical line-drawings. It is likely therefore that an understanding of how caricatures 'work' in activating representations of familiar individuals will help our understanding of how normal images of faces are stored in memory and recognised in everyday life. This Experiment compares the perception and recognition of caricatures and veridical images of highly familiar faces.

Studies of Caricatures

Perkins (1975) speculated on what parameters were necessary for caricaturing to work. He suggests humour, "ugliness" and expression of personality are irrelevant to making caricatures recognisable even though these are probably the most enjoyable aspects of cartoon art.

It is generally agreed that caricatures work by selectively accentuating particular details of a face (Perkins 1975; Brennan 1985). Presumably the details which get accentuated in caricaturing are those which are characteristic of that individual. The skill of the caricature artist begins with realising which features are characteristic and which differentiate that person from the general population in which they live. This definition of characteristic features embodies a comparison between the features of the face in question and those which are normal or average for a population of faces. The degree to which a feature departs from the population average is a measure of how characteristic that feature is. It follows that not all faces are suitable for caricaturing. If a person has facial proportions close to average then there will be nothing deviant and nothing to caricature.

Choosing the Appropriate Norm for Comparison

Careful attention must be given to the definition of an average face against which an individual's face is compared. Chance, Goldstein & McBride (1975) and Shepherd (1981) showed that people recognise faces from their own race better than faces of others, therefore cross-racial caricaturing is undesirable. Unless some humorous distortion was required, cross-sex caricaturing again would also be unsuitable because of configural differences between male and female faces.

Stereotypical influences are also critical to successful caricaturing; pop stars are often thought of and portrayed as having deviant appearances (bright clothing, long hair, excesses of jewellery, etc.), politicians tend to conform (normally clean imaged, suited, with well-groomed hair). The age parameter is important in the same context with many pop stars either depicted as very young and naive or aged hippies from the 1960's, and political leaders typically old and haggard. From these considerations, successful caricaturing of a face needs to be done with respect to an average derived from the same age range. Contrasting a face against an average face of younger age will be likely to enhance the age of the target (this may be desirable for generating amusing effects but is likely to impair recognition). Stereotypic influences of age and socioeconomic class are also important in the recognition of faces (see Cross, Cross & Daly (1971); Dion, Berscheid & Walster (1972); Klatzky, Martin & Kane (1982a, 1982b); Klatzky & Forrest (1984)). In caricaturing and recognising a face we may compare it to a norm for the appropriate age, sex, race, and perhaps perceived socioeconomic status or occupation.

Once the features of a face which are characteristic have been established, a decision must be made as to the degree to which the features are to be reduced or exaggerated in the caricature. This has been found to depend on a number of factors. Different artists use different degrees of exaggeration. For Nixon's face artists varied in the degree of exaggeration from 12% to 86% of the veridical feature dimensions (Goldman & Hagen, 1978). The extent of exaggeration also increased with time and with the decline in Nixon's popularity.

Advantages and Limitations of Automatic Caricaturing

This process of automated caricaturing described in section II has the advantage that it does not require the skills of a caricature artist. Since all deviations are amplified to the same extent, those deviations which are characteristic of a given individual should also be accentuated. Furthermore all exaggerations can be controlled quantitatively.

Another advantage of the automated process is that the holistic cues such as the spatial configuration between features are also transformed.

While it is clear that faces are recognised on the basis of information from individual features, it has also been established that the configuration of features has a profound impact on the facial appearance (Haig 1984, 1986a, 1986b; Sergent 1984; Rhodes 1988; Shepherd *et al.* 1978). The dimensions of faces which go to make up configuration cues are not well established (Yamane, Kaji & Kawano 1988), however, it is not necessary to know which features or configurational cues are perceptually important, since the process automatically amplifies all deviations, and should therefore include all relevant cues.

The process is not without problems. Perhaps the least obvious limitation is the demarcation of the feature points on the original image of the face; this can be difficult and is subjective (particularly with cheek bones). Different operators will apply different subjective criteria to determine where smile lines finish etc. As a result lines will be differentially accentuated since small differences in feature points get amplified in the caricature. Finally while the process is good for exaggerating feature shape and configuration it is not good for exaggerating hair texture or style. Indeed it is the internal features rather than the external hair style, etc. which is important in the recognition of familiar faces (Ellis, Shepherd & Davies 1979; Young, Hay & Ellis 1985). There is, however, a danger in removing the hair or other parts of the face in so far as a lack of contextual information may impair recognition.

A further limitation is that the input faces must all have roughly the same pose. This usually involves standardisation to the frontal view. Only details visible in the frontal view are therefore accentuated. Unfortunately the nose profile so often caricatured in cartoons is not visible from this view. Furthermore there are a number of psychological studies which indicate that the face turned half way to profile presents a perspective view which has advantages in certain recognition and face matching tasks (Bruce *et al.* 1987; Valentine & Baddeley 1987). This effect is not entirely consistent as the half profile view does not seem to confer an advantage on the recognition of familiar faces (see Bruce *et al.* (*ibid.*), and Harries, Perrett & Lavender (1991) for discussion). In principle, using a standard

1/2 profile pose could circumvent the limitation, but such standardisation is even more difficult with pictures of famous faces.

Caricature and Distinctiveness Advantages

The effects of facial distinctiveness can be considered in two ways. Firstly, distinctive faces are remembered better than typical ones (Going & Read 1974; Cohen & Carr 1975; Light, Kayra-Stuart & Hollander 1979; Franks & Bransford 1981; Solso & McCarthy 1981; Bartlett, Hurry & Thorley 1984; Bruce *et al.* 1991). A suitable *distinctiveness hypothesis* would therefore predict that facial distinctiveness manipulated within faces will be more useful in the identification of faces when distinctiveness is enhanced rather than diminished. It follows that caricatures, which are very efficient conveyors of facial identity through distinctiveness enhancement, should be better representations even than the true image or depiction of individuals; a *caricature hypothesis* would predict that distinctive facial information is enhanced in visual memory and caricature displays would provide more efficient access to stored representations.

Information Content and Retrieval Hypotheses

We are adept at recognising caricatures despite the relative lack of information that they contain. Many authors have questioned whether caricatures are in any way better representations than natural images. Perhaps the caricature contains not only the essential minimum of information but because the information is accentuated they may also be 'super-fidelity' or 'super-normal' stimuli. Such a concept derives from ethological studies in which accentuation of particular dimensions of natural stimuli can produce behaviour which is more marked than that produced by natural stimuli. For example if a nesting herring gull is given a choice between 2 eggs, one a natural egg and one larger than life size, it will attempt to roll the large egg back to the nest in preference to natural egg (Hinde 1982).

Hagen & Perkins (1983) and Tversky & Baratz (1985) attempted to assess the validity of the super-fidelity concept of caricatures. They found no advantage for caricatures over veridical representations of faces when comparing recognition performance. The latter study also failed to find a result for name/face matching. In these experiments, however, comparisons were made across two different media. Photographs were used for veridical representations but caricatures were line drawn. Photographs clearly contain much more information than line drawings (Davies, Ellis & Shepherd 1978). So any potential advantage which caricatures had as better representations could have been offset by the impoverished medium of display.

Perception and Recognition of Computer Caricatures

Rhodes, Brennan & Carey (1987) used Brennan's procedure to make a balanced comparison between recognition of veridical and caricature line drawings. They compared recognition of normal line drawings with caricatures which had been exaggerated 50% away from the average face and 'anticaricatures' where departures from average were attenuated by 50%. For faces of familiar individuals (departmental students and staff), student subjects were significantly quicker to name caricatures than veridical line drawings or anticaricatures. Mean reaction-times were 3.2, 6.4 and 12.3s for 50% caricatures, 0% veridical drawings and -50% anticaricatures respectively.

Although the caricatures were recognised more quickly than the veridical images, they were not identified more accurately. The proportion of correct identifications was 33, 38, and 27% (for caricature, veridical and anticaricature images) but the differences were not significant. Thus there would appear to be a caricature advantage from the reaction-time data, but not from the accuracy data. Other studies of caricature recognition for famous faces have found a speed/accuracy trade-off with faster but less accurate recognition of 50% caricatures (Carey 1992).

Rhodes, Brennan & Carey (1987) also investigated how well subjects perceived the resemblance of the caricature images of familiar faces to the depicted individual. Subjects rated the goodness of likeness of 7 randomly ordered pictures consisting of ±75%, ±50%, ±25% and 0%

caricatures. Highest ratings were found for veridical images 0% and 25% caricatures (these images were rated approximately equally). The distribution of scores was not symmetrical about the 0% veridical image; positive caricatures (25, 50 and 75%) were rated higher than their counterpart anticaricatures (-25, -50 and -75%). Indeed the distribution of scores was significantly shifted away from the veridical image towards images with positive caricaturing. Again the data suggested a caricature advantage. Interpolating from the data the peak of the rating distribution occurred at a caricature level of 16%. Since Rhodes *et al.* (*ibid.*) measured ratings for 0, ±25, ±50 and ±75% caricatures actual ratings for a 16% caricature were not yet obtained. Two possibilities exist. If the distribution of the ratings is sharply peaked then the 16% caricature level might produce significantly higher ratings than the 0% veridical image. In this case the 16% image could be considered *supernormal.* Alternatively the distribution might be fairly 'flat topped' in which case there would be no differences in ratings for 0, 16%, and 25% caricatures.

In a recent series of studies, Rhodes & McLean (1990) examined the recognition of familiar birds whose line-drawing representation had been enhanced using the caricature 'algorithm'. For expert ornithologists (but not for non-specialist subjects) some evidence was found for a caricature advantage with significantly faster reaction times to 50% caricatures than to veridical line-drawings. However, experts were significantly *less* accurate in recognising the 50% caricatures compared to the veridicals (and all other levels). This study then provides some evidence that the caricature advantage might not be restricted to faces.

The findings described above are important because they suggest that in memory we might store in memory the way in which faces deviate from a norm, rather than storing a veridical structural description of particular features or feature configuration. The caricature advantage found by Rhodes, Brennan & Carey (1987) was based on line drawings. While the recognition advantage found may have implications for the nature of mental representations, it is necessary to entertain the possibility that the results rely on processes unique to line drawings. For example cartoon conventions may apply only to simplified line drawn illustrations.

Independent of whether veridical line-drawings and natural images access the same stored representations, the caricaturing process may yield different effects on the recognition of line-drawings and natural images. It is important therefore to determine whether a caricature effect can be obtained with natural photographic stimuli. To this end the methods of Brennan (1985) and Rhodes *et al.* (*ibid.*) have been extended to compare the perception and recognition of normal images and caricatures with photographic detail.

Experiment

Rationale

The objective of Experiment One was to determine the possibility of manipulating images such that they looked more like the target faces than the original images. Evidence for facial caricatures being perceptually super-normal images was from interpolation only (Rhodes, Brennan & Carey 1987) and as noted is open to other interpretations. Furthermore the perceptual advantage of caricatures detected so far is only small. It could be argued that the use of caricature photographs might enlarge the caricature advantage at the perceptual level.

Methods

Subjects

30 voluntary members of staff, postgraduates and undergraduates from the Department of Psychology at St. Andrews took part in the experiment. All subjects were familiar with the people depicted in the photographs.

Stimuli

Photographic stimuli were produced using the techniques described in section II. For each image the x and y coordinates of 186 feature points are defined manually (see Brennan (1985), and Appendix I). The feature points of the input face were compared to those of a facial norm. Appropriate norms were prepared for adult Caucasian male and female faces (using 14 faces for the male, and 11 for the female).

Differences between feature points and the average face were then accentuated or diminished by 16 or 32%, producing 5 data sets (-32, -16, 0, 16 and 32% caricatures). These degrees of distortion were chosen because Rhodes, Brennan & Carey (1987) indicated that a 16% caricature would produce the best likeness.

Seven famous faces (television actors and personalities) were digitised and caricatured at ±32%, ±16% and 0% levels. The final versions of the veridical (0%) images used for study were constructed by back transforming a 16% caricature, in effect this used the pixels and the feature coordinates of the 16% caricature as the source and the feature coordinates of the original 0% image as the destination. This was done as a precaution to ensure that any anomalies (at pixel level) in the pixel remapping process required to produce ±16 and 32% caricatures would also be present in the 0% caricature [not repeated in other experiments as there was no change]. Otherwise the 0% caricature might be detectable as the only image without 'glitches' and hence regarded as the best (most natural) representation. In fact no obvious anomalies were visible in any of the processed images.

Continuous tone 5 by 7 inch black and white photographs were taken of each caricature displayed on the computer terminal (examples are given in Figure 3.0.1:1). The pictures were mounted horizontally on card strips such that 2 sets of stimuli were produced. An anticaricature-biased set contained -32%, -16%, 0% and 16% distortions, while a caricature-biased set contained -16%, 0%, 16%, and 32% distortions. Two partial sets were constructed rather than a complete set of five images to avoid the truest likeness or least distorted image (0%) always lying in the middle of a set.

Procedure

Subjects were presented with either 4 anticaricature-biased sets and 3 caricature-biased sets or vice versa, varying equally for each of the 7 faces amongst all 30 subjects. Thus no subject saw the entire range of 5 caricature levels for a given face. Each subject was required to give 3 verbal ratings (a) familiarity of the person depicted (7 = highly familiar, 1 = don't know

Figure 3.0.1:1

CARICATURE AND ANTICARICATURE BIASED STIMULI. Top row: anticaricature-biased set containing -32, -16, 0, +16 caricatures of Nicholas Parsons. Bottom row: caricature-biased stimuli set containing -16, 0, +16, +32 caricatures. Subjects saw either set for a given target face.

person), (b) best likeness of that person by selecting from the 4 images presented, the picture which looked most like the depicted person, and (c) goodness of likeness of photograph chosen (7 = very good, 1 = very bad).

Assessment of Image Transformations by Caricature Artists

It is possible that mistakes could occur in the computer caricaturing process itself. For example small inaccuracies in the manual placement of feature points might in the veridical image might lead to inappropriate distortions in the caricature production process. Three artists familiar with portrait and caricature production were consulted in an attempt to obtain some independent measure of the quality of the caricature manufacturing process. They were informed as to the nature of the image transformation (a comparison with a facial norm and accentuation of differences) and were then shown the 0, 16 and 32% caricature images. They were interviewed for any general comments and were asked to rate the images of the seven processed faces. Specifically they were asked to compare the features distorted in the 16 and 32% images with the features they found characteristic for the depicted individual and whether the distortions introduced were ones they would have expected for successful caricaturing. Ratings were requested on a seven point scale (7 = good caricature accentuating right details; 4 = no remarkable change to image; 1 = bad caricature with wrong details accentuated).

Results

A two-way repeated measures analysis of variance (ANOVA) was carried out on the "best likeness" ratings with the 7 target faces and 2 sets of stimuli (caricature and anticaricature biased set) as main factors. There was a significant effect of the face subjected to caricaturing, $F(6, 196) = 3.021$, $p < 0.01$, which may indicate that only some of the faces caricatured well. There was no effect of stimulus set (anticaricature versus caricature bias set), $F(1, 196) = 0.186$, $p > 0.6$, and there was no interaction between target face and stimulus set, $F(6, 196) = 1.052$, $p > 0.3$. Since there was no significant effect of the presentation set (-32 to 16% or -16 to 32%) on ratings of best likeness data was pooled for further analyses. Figure 3.0.1:2

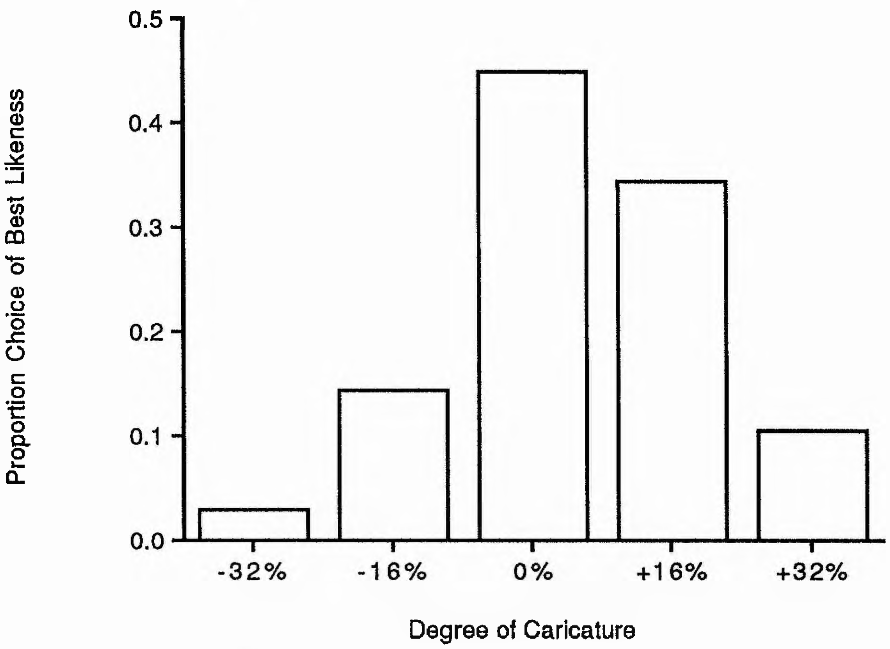


Figure 3.0.1:2

PERCEIVED LIKENESS. Overall ratings of perceived likeness for caricatures of 7 well-known faces. Ordinate: proportion of subjects choosing an image as the best likeness of the target face. Preference for images is expressed as a proportion of the number of times the image was available for choice (thus correcting for the different number of subjects seeing ±32% than other levels of caricatures). Abscissa: distortion of image from the veridical image. The data shows a preference for caricatures over anticaricatures, the mean of the distribution is shifted away from the 0% and lies at +4.4%.

gives the overall frequency with which images at different levels of caricaturing were chosen as best likeness. The mean of the distribution occurred at a caricature level of 4.4%. A *t*-test was conducted to determine whether this sample mean departed from that expected from the null hypothesis that caricature distortions had no effect on the image perceived as the best likeness of a face. Under this hypothesis subjects would be expected to rate the 0% caricature or veridical image as most like the target individual. The distribution of the level of caricatures (0%, ±16%, ±32%) chosen as best representation of the 7 faces by the 30 subjects is significantly different from the 0% mean expected by the null hypothesis, t (29) = 2.18, $p < 0.04$.

Since subjects might have seen Margaret Thatcher's face in a caricatured state before the experiment, the overall effect of caricature manipulation was therefore assessed using the data for the 6 other faces. These data still showed a significant bias to towards positive caricaturing for ratings of best likeness, t (29) = 2.09, $p < 0.05$.

Further, it is noted that subjects rated caricatures more like the target individuals than anticaricatures (matched-pairs *t*-test, pooled caricature (16% and 32%) versus anticaricature (-16% and -32%) data, t (6) = 3.021, $p < 0.05$. Thus images accentuating distinctiveness were rated higher for likeness than images decreasing distinctiveness.

Caricaturing of Individual Faces

Since the overall analysis indicated a significant effect of the face caricatured on ratings of likeness, the results for the different faces were analysed separately. Figure 3.0.1:3 gives the distribution of ratings for different caricature levels for each of the 7 faces. For each face the mean level of caricaturing for images chosen as the best likeness is given in Table 3.0.1:1. A positive % in column 1 indicates that more subjects chose images with 16% or 32% than images with the same degree of distortion but in the anticaricature domain (-16%, -32%). The faces of Anita Dobson, Margaret Thatcher and Nicholas Parsons all have distributions significantly different than that expected by the null hypothesis, t (29) = 4.74, $p < 0.001$; t (29) =

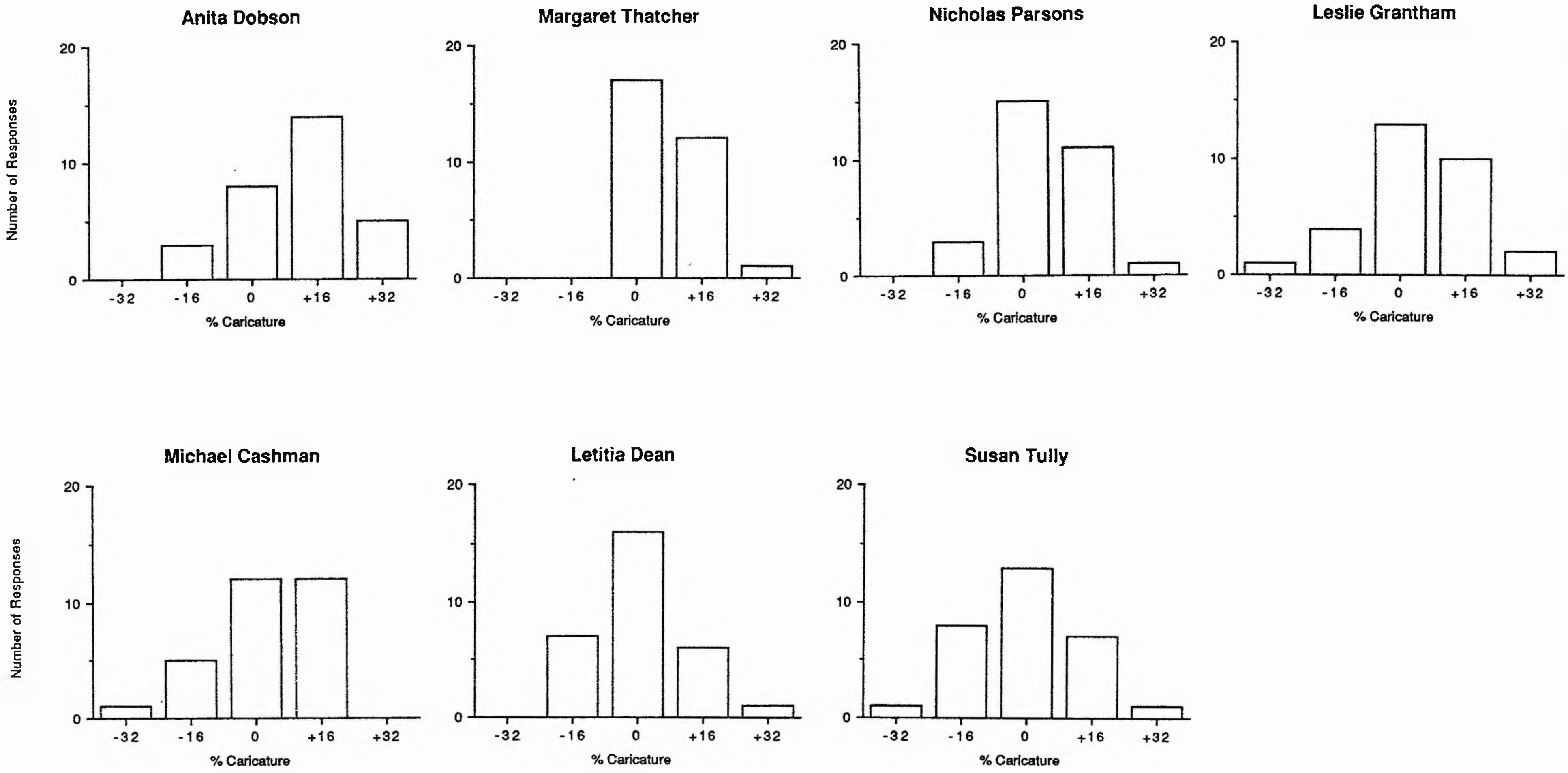


Figure 3.0.1:3

RATINGS OF INDIVIDUAL FACES. Ratings of perceived likeness of caricatures of seven familiar faces. Ordinate: number of subjects (out of 30) choosing an image as the best likeness of the target face. Abscissa: distortion of image from the veridical image.

Face	Best Likeness %-Caricature	Familiarity (7=high, 1 ="who?")	Goodness of Likeness (7=good, 1=bad)	Expert Rating (1=best, 7 = worst)
Anita Dobson	11.20 ± 2.56	6.27 ± 0.26	5.67 ± 0.24	1
Margaret Thatcher	7.47 ± 1.67	6.77 ± 0.15	5.74 ± 0.22	1
Nicholas Parsons	5.34 ± 2.08	5.97 ± 0.35	5.74 ± 0.23	4
Leslie Grantham	3.73 ± 2.62	6.20 ± 0.20	5.87 ± 0.24	5
Michael Cashman	2.67 ± 2.44	6.14 ± 0.24	5.34 ± 0.34	3
Letitia Dean	0.53 ± 2.23	6.07 ± 0.31	5.50 ± 0.28	6
Susan Tully	-0.53 ± 2.60	6.27 ± 0.23	5.50 ± 0.23	7

Table 3.0.1:1

MEAN RATINGS OF CARICATURES. Ratings for caricatures of seven famous faces. Column 1: mean (± SEM) for level of % caricaturing for image selected as best likeness (interpolated from distributions displayed in Figure 3). Column 2: mean (± SEM) for ratings for subjects' familiarity with the individual depicted. Column 3: mean (± SEM) for ratings of goodness of likeness of image selected as most similar to depicted individual. Column 4: Rank order of ratings of the success of the caricature process (comparing 0% and +32% caricatures) judged by experts (caricature/portrait artists).

4.37, $p < 0.001$; t (29) = 2.57, $p < 0.02$. For each of these faces it would seem that the image producing best likeness was one with a small degree of positive caricaturing (11.2%, 7.5% and 5.3% respectively). For the other faces the average % caricaturing for best likeness ratings were not significantly different from 0%.

Quality of Original Image

It might be expected that poor quality starting images would produce ineffective caricatures. Starting images could be poor in terms of photographic quality or because they were uncharacteristic of the target person. Accentuating differences from average would therefore accentuate inappropriate features. For such faces with poor quality starting images one might expect the image chosen as best likeness to be the 0% caricature since any computer based transformation would further degrade the initially inadequate image. This consideration leads to the prediction that ratings of image quality (whether the image is a good likeness of the target person) should correlate with the level of caricaturing chosen as the best representation. Correlation between the quality judged for the image chosen as best likeness and the level of caricaturing of that image was not significant (Spearman's Rank Correlation $r_S(208) = 0.025$, $p > 0.1$). Furthermore the quality of images was judged fairly uniform across faces and was generally high (see Table 3.0.1:1).

Correlation of likeness ratings for the veridical image and level of caricature of best likeness might be more appropriate here. Such a correlation is, however, unlikely to yield a different result since the veridical image turned out to be the best likeness for most faces and observers. Furthermore all subjects judged the images to differ in likeness very subtly. Not surprisingly ratings of quality of veridical image and image chosen as best likeness are very close.

Familiarity with Target Face

The rating of familiarity with the target person correlated with the degree of caricaturing of the image chosen to best represent that person, $r_S(208)$

0.251, $p < 0.005$. That is for more familiar faces the caricaturing process was more successful and positive caricatures enhanced the likeness of the original image. For less familiar faces the caricaturing was less successful. The effect was still significant when the results for Margaret Thatcher's face were excluded, r_S (178) = 0.228, $p < 0.02$.

Ratings by Caricature Artists

The assessments of the three caricature artists showed a high degree of concordance as to which faces they thought the caricature process had distortions in the correct direction and which faces the process had produced inappropriate results.

Of greater importance was the correspondence between their judgements of success of the computer caricaturing process and the extent of the caricature bias in the selection of images judged to be most like the target faces. The artists rated the caricatures of Margaret Thatcher and Anita Dobson as most successful. The distortions for the faces of Michael Cashman and Nicholas Parsons were also seen as in the right direction. For Leslie Grantham there was little perceptible distortion whereas the distortions for Letitia Dean and Susan Tully were seen as ineffectual or in the wrong direction. Overall the magnitude of the caricature bias for subjects making perceptual judgements of the best likeness showed a significant correlation with the rank order of expert ratings of the quality of the caricaturing process, r_S (5) = 0.883; $p < 0.01$.

Summary of Results: Experiment One

Perceptual ratings of the degree to which images resembled depicted individuals was found to vary with level of caricaturing. Interpolation indicated the best likeness would occur with a small degree of positive caricaturing (4.4% on average). The magnitude of the caricature advantage at the perceptual level correlated with the familiarity of the faces and with the quality of the caricaturing process as judged by caricature experts.

3.0.2 Experiment Two
Are Photographic Quality Caricatures of Famous Faces Recognised more Efficiently than Veridicals?

Experimental Study of Recognition of Photographic Caricatures

Rationale

Experiment One revealed a small but significant bias in subjects' perceptual ratings of manipulated images. Interpolating from the results, images judged to look most like a target figure would have a small degree of positive caricaturing.

Rhodes, Brennan & Carey (1987) found that the effects of caricaturing on recognition of familiar faces were stronger that the effects on perceptual ratings of how like an individual a line-drawing was judged. With line-drawings, Rhodes *et al.* (*ibid*) found 50% caricatures were named faster than veridical line-drawings. Despite this, 50% caricatures were perceptually judged to be less like the target individuals than veridical drawings. Thus the effects of caricaturing on speed of recognition appear more likely to benefit from caricaturing than perceptual judgements of the goodness of likeness.

Experiment Two therefore set out to determine whether a more marked caricature effect could be found with caricatured photographs using a recognition task. Unfortunately, the small number of stimulus faces used in Experiment One meant that this material was not suited to the naming recognition task used by Rhodes, Brennan & Carey (1987). A name-face matching task was employed following a similar design to Rhodes & McLean (1990) and Tversky & Baratz (1985).

Methods

Subjects

11 subjects participated in the experiment lasting approximately 1 hour for which they were paid £3. Subjects for Experiment Two had not taken part in Experiment One.

Stimuli

The images used were identical to those in Experiment One with the addition of ±48% caricatures for each of the famous faces. The grey-scale pictures were stored in on-line disk files on the IRIS 3130 workstation to be recalled individually for display on the monitor. A black cardboard mask was made to cover the monitor display leaving only an elliptical viewing aperture through which the 7 faces would appear. This was used so as to remove extraneous background details and limit subjects' use of hair outline as a recognition cue. In this way the subjects' attention was focussed on internal facial features.

Procedure

Subjects were then seated approximately 80cm from the 19 inch IRIS display. One of the 7 names appeared in the centre of the screen (through the aperture) for 1 second followed by a blank display for 1 second. This was followed by one of the 7 faces, which remained visible until a response was made. Subjects were requested to press the 'yes' key if the name matched the face, 'no' otherwise; lateralisation of response keys was alternated between subjects.[12] Stimuli were allocated to 4 experimental blocks. Each block contained each of the 7 faces caricatured at each of the 7 levels (0, ±16, ±32, ±48%) with 2 trials in which the name and subsequent face matches and 2 trials in which the name and face did not match. The order of faces, caricature level, and match/non-match trials were randomised within each block. Thus overall each subject made 16 decisions about each face at each caricature level. For each level of caricature it was arranged that on non-match trials each face was paired with all possible non-matching names. No practice session was administered in case any caricature recognition advantage persisted only for the first block of trials.

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[12]Interrupt timer resolution was limited to 16.67ms on the IRIS.

Results

Level of Caricature Producing Subjects' Most Efficient Responses

Figure 3.0.2:1 gives the distribution of caricature levels producing the fastest overall reaction time for each of the 11 subjects. For this analysis, correct match and non-match trials for all of the 7 target faces were averaged together. The averaging was performed separately for each of the 7 levels of caricaturing (±16, 32, 48, and 0%) for each subject. The caricature level producing fastest reaction time for each subject was then evident by comparing means for the 7 levels.

If all image manipulations away from the original image affect reaction times adversely, one would predict a peaked distribution with most of the subjects having fastest reaction times for the veridical image (0% level).[13] As can be seen from Figure 3.0.2:1, the majority of subjects had their fastest reaction times when the image is positively caricatured by 16 or 32%. The mean of the distribution is significantly shifted from the 0% level of image manipulation, $F(1, 10) = 5.2, p = 0.01$. In this way caricaturing can be seen to enhance recognition. Interpolating from the distribution, optimal speed of processing would occur for 19% caricatures.

The effect does not reflect any kind of speed accuracy trade off, since the distribution of caricature levels producing most accurate performance for each subject shows a similar trend for better performance with images that are positively caricatured (Figure 3.0.2:2). The mean of the distribution of highest accuracies was, however, not significantly different from the 0% caricature level, $F(1, 10) = 1.78, p = 0.1$.

Reaction Times

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[13]It is also possible that image manipulations have no effect on processing efficiency, in which case the mean level of caricaturing producing fastest reaction time would again be 0% but the distribution of reaction times across level of caricature would be flat.

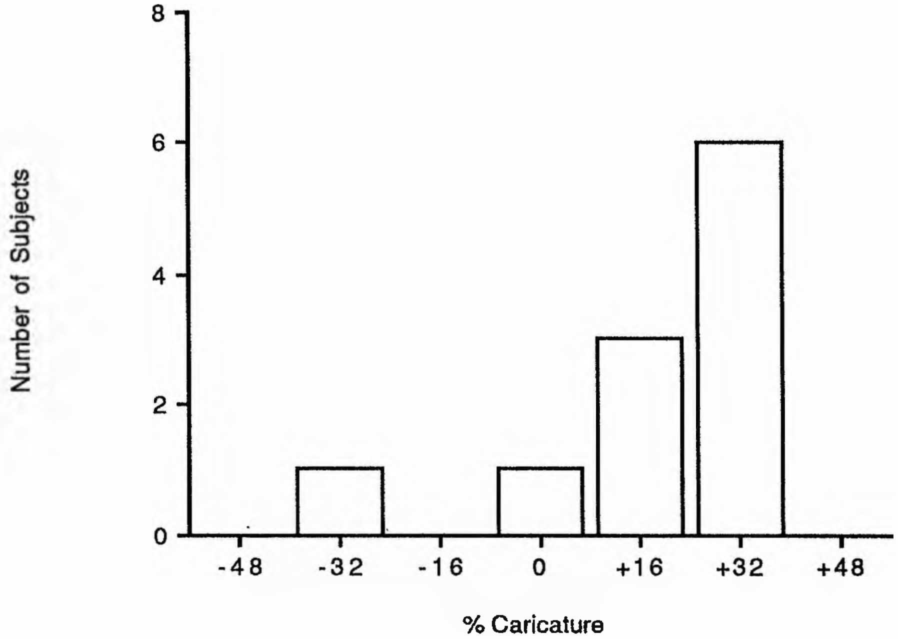

Figure 3.0.2:1

FASTEST RESPONSE. Distribution of conditions producing the fastest reaction times for 11 subjects across different levels of photographic caricatures of well-known faces.

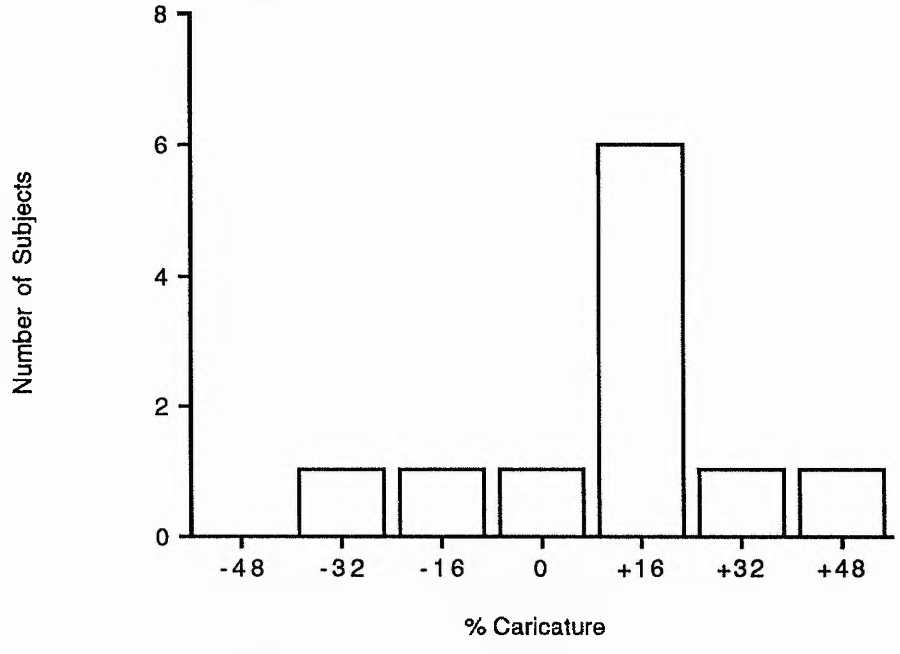

Figure 3.0.2:2

RESPONSE ACCURACY. Distribution of conditions producing the highest accuracy of response for 11 subjects across different levels of face caricaturing.

To assess evidence of the effects of distinctiveness of features on reaction time, planned comparisons were used to contrast different levels of positive caricaturing (accentuating distinctiveness) with matched levels of negative caricaturing (diminishing distinctiveness). Planned comparisons indicated a distinctiveness effect with caricatures being processed faster than anticaricatures at both the 16% and 32% levels ($F(1, 10) = 8.7, p = 0.014$; $F(1, 10) = 7.24, p = 0.023$ respectively). There was no distinctiveness effect at the ±48% levels of caricature ($p = 0.9$).

To assess evidence for a caricature advantage, mean reaction time for each level of caricaturing was compared to the mean reaction time for the veridical image. The veridical image was processed significantly faster than both the 48% and -48% caricature levels ($F(1, 10) = 5.06, p = 0.048$; $F(1, 10) = 9.55, p = 0.011$), but was not significantly different from other levels of caricature.

Match Trials

To facilitate interpretation of results two separate 1-way ANOVAs were performed on the match and non-match trials (Figure 3.0.2:3). For congruous (match) trials analysis indicated a significant overall effect of caricaturing on reaction times, $F(6, 60) = 2.66, p = 0.024$.

Planned comparisons indicated no significant advantage for caricatures over anticaricatures (distinctiveness) or over the veridical image (caricature advantage). Indeed the only emergent differences were that the veridical image lead to faster reaction times than both 48% and -48% caricatures ($F(1, 10) = 7.51, p = 0.021$; $F(1, 10) = 8.7, p = 0.014$ respectively).

Non-Match Trials

With non-match trials a different picture emerged. 1-way ANOVA revealed a significant overall effect of caricature level on reaction time to correctly reject a face not matching a preceding name, $F(6, 60) = 3.73, p = 0.003$.

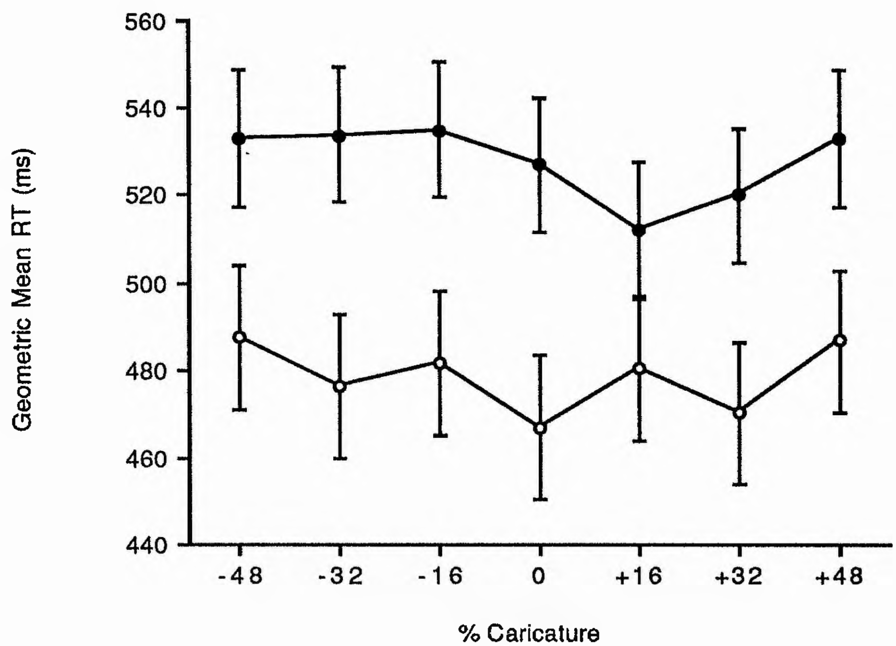

Figure 3.0.2:3

NAME-FACE MATCHING LATENCY. Distribution of reaction times for correct responses in the name/face matching task with match and non-match trials plotted separately. Positive caricatures significantly improve subjects' accuracy in rejecting non-match trials. Error bars denote the 95% confidence interval of mean reaction times.

◦ match, • non-match trials.

Distinctiveness

Planned comparisons indicated a distinctiveness effect with caricatures being processed faster than anticaricatures at both the 16% and 32% levels ($F(1, 10) = 13.4$, $p = 0.004$; $F(1, 10) = 5.57$, $p = 0.04$ respectively). There was no distinctiveness effect at the ±48% levels of caricature ($p = 0.96$).

Caricature Advantage

Planned comparisons between performance with veridical images and that with different levels of caricature revealed that reaction times were significantly faster for 16% caricatures than for veridical images, $F(6, 60) = 7.02$, $p = 0.024$. No other differences were evident.

Accuracy

Analysis of the number of errors using 2-way ANOVA revealed a significant main effect of the degree of caricature, $F(6, 60) = 3.47$, $p = 0.005$. Figure 3.0.2:4 shows the overall accuracy of subjects. Effect of trial type (match/non-match) showed a trend for more accurate performance with incongruous trials which did not reach significance, $F(1, 10) = 4.60$, $p = 0.058$. There was no significant interaction between these factors, $F(6, 60) = 1.58$, $p = 0.17$. Planned contrasts revealed an increase in accuracy with 0% and 32% over the -32% anticaricature ($F(1, 10) = 5.52$, $p = 0.041$; $F(1, 10) = 8.07$, $p = 0.018$, respectively), but no other differences.

Separate 1-way ANOVA for caricature level effects on accuracy data revealed accuracy differences for the match trials, $F(6, 60) = 2.69$, $p = 0.023$ but not non-match trials, $F(6, 60) = 2.2$, $p = 0.055$. For match trials planned contrasts showed improved accuracy in favour of caricatures at 32% and 48% over the respective anticaricature levels ($F(1, 10) = 7.45$, $p = 0.021$; $F(1, 10) = 5.2$, $p = 0.046$ respectively). There was no evidence of a caricature advantage for those levels compared to veridicality.

Effect of Novelty of Caricature on Recognition

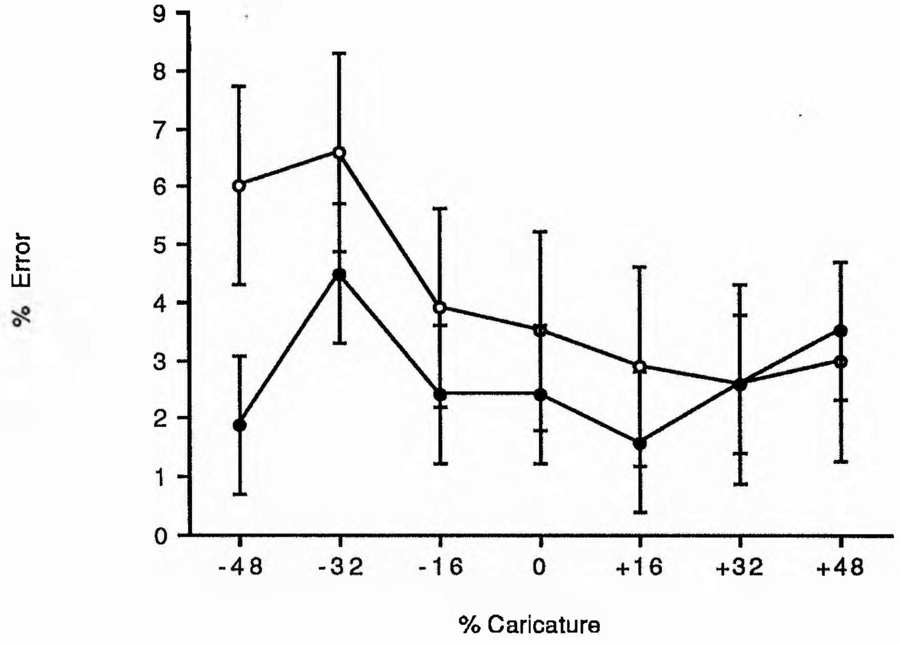

Figure 3.0.2:4

NAME-FACE MATCHING ACCURACY. Effect of level of facial caricaturing on accuracy of subjects' judgements for match or non-match between a name and subsequently presented face image. Error bars denote the 95% confidence interval.

∘ match, • non-match trials.

A 2-way ANOVA (4 blocks of trials, 7 caricature levels) was performed to assess whether caricature effects were affected by experience with stimuli within the task. There was no effect of trial block on reaction times, $F(3, 40) = 0.728$, $p = 0.539$, and block number did not interact with caricaturing effects on reaction times, $F(18, 240) = 1.004$, $p = 0.457$. As expected, the degree of image distortion affected performance, $F(6, 240) = 5.277$, $p < 0.0001$. Separate 1-way ANOVAs showed no effect of trial block on either match ($F(3, 40) = 0.795$, $p = 0.502$) or non-match ($F(3, 40) = 0.65$, $p = 0.587$) responses, and there was no interaction between the effects of block and level of caricature on response time for either trial type ($F(18, 240) = 1.136$, $p = 0.328$; $F(18, 240) = 1.466$, $p = 0.104$, respectively). Thus there was no evidence to show that the caricature effect was only prevalent within the first series of trials or that the novelty of seeing the caricatures led to improved recognition.

Summary of Results: Experiment Two

Overall analysis of the degree of image manipulation producing the fastest reaction times for individual subjects revealed a caricature advantage. This increased speed of processing for caricatured images did not reflect any speed-accuracy trade-off. Caricaturing images can therefore produce more efficient processing in a task requiring matching of a well-known person's face and name.

In the overall analysis of variance of reaction times (containing match and non-match trials) the caricature advantage did not achieve statistical significance. Three factors might have contributed to the lack of effect. First, the caricature advantage was relatively small in magnitude amounting to a 3% increase in speed. Second, the amount of caricaturing producing optimal speed of processing varied across subjects, some performing best with 16% caricatures others with 32% caricatures. Finally and of more theoretical interest, the effects of caricaturing appeared to depend on the type of trial. There was no caricature advantage on congruous trials when the name matched the subsequently presented facial image. The caricature advantage was prevalent, however, on incongruous trials where the face and name did not match. With non-match trials 16% caricatures were processed significantly faster than the veridical images. Again the increase in speed of processing was not an artefact produced by a speed-accuracy trade-off.

3.0.3 Experiment Three
Can Photographic Caricatures of Famous Faces be Named Faster than Veridicals without Loss of Accuracy?

Introduction

Experiment Two showed a slight performance advantage to be had in matching the name of an individual to a caricature of their face. This experiment sought to improve upon the previous result using a more direct verbal naming task when viewing caricature and veridical images of more famous individuals.

Here, a larger sample of target faces was used; in addition, it has been shown that the internal features of a face (eyes, nose, mouth) are most appropriate in the identification of highly familiar faces (Ellis, Shepherd, & Davies 1979; Young *et al.* 1985; de Haan & Hay 1986) whilst we additionally rely on the external features (hair) for more unfamiliar faces (see also Carey & Diamond 1977; Diamond & Carey 1977, 1986; Carey, Diamond, & Woods 1980). For this reason it was decided to exclude all background and head hair and ears from the final images. In this way subjects would be forced to consider only the most relevant facial information during the experiment.

In this experiment, only a caricature advantage was sought. It was hypothesised that a distinctiveness enhanced veridical image (caricature) should be more recognisable than the original.

Methods

Subjects

28 subjects took part in the experiment, 14 male. Each were paid £3 to participate. Testing lasted approximately 30 minutes.

Stimuli

20 full-face photographs of famous people, 5 female and 15 male as available (TV, film, sport, politics), were prepared for caricaturing on a Silicon Graphics Personal IRIS following the procedures described in Experiment One. Using the delineation data, a 50% caricature of each target face was prepared. Both veridical (0%) and caricature images were then masked as shown in Figure 3.0.3:1. Lagrangian interpolation (eg. Harrington 1985) was used to provide a continuous delineation of the jaw-line through the original feature point markers (11); this region was joined by an arc extending from the top of the ears locations centred half-way down the nose such that the forehead was partially and evenly visible. Examples of the stimuli used are shown in Figure 3.0.3:2.

Procedure

Ratings

Subjects were first required to give ratings of their familiarity with a presented list of famous names on a scale of 1 ("don't know") to 9 ("highly familiar"). The names shown were of those individuals to be named in the speeded response task. Printed guidelines were thus:

> "How familiar are you with the facial appearance of this person? How well-known are they to *you*? Your decision of degree of familiarity has nothing to do with how famous that person is now, or how famous you think they were in the past. Concentrate your responses in terms of your visual experiences only."

If a subject rated any face as being unknown (1) then the veridical representation of that person was shown briefly on the monitor. Subjects

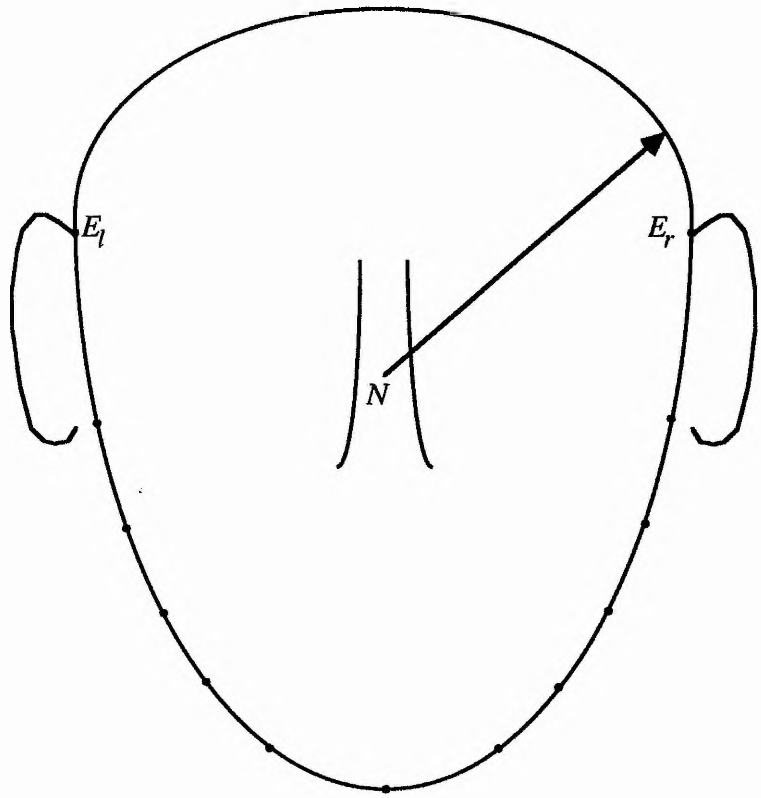

Figure 3.0.3:1

FACIAL MASK. A mask was constructed around the sides of the face and jawline through each of the delineation points. A continuing arc was drawn between the tops of the ear registration points centred at the middle of the bridge of the nose. The surrounding image area was blanked leaving only the 'internal' facial features visible. Ear and part-nose outlines are shown for clarity.

Figure 3.0.3:2

MASKED FACIAL CARICATURES. Cyril Smith is shown here as a true image (left) and a +50% caricature (right).

were then allowed to modify their rating of familiarity in accordance with whether they now knew that person.

After the response task was completed, a further set of ratings were made. Subjects were requested to give an indication of how distinctive they thought each of the people they had just seen were. Ratings were given on a scale of 1 ("average looking") to 9 ("highly distinctive"). Instructions were indicated thus:

> "How facially distinctive do you think this person is? How unusual is their face in terms of their facial features (not head hair)? Would you be able to pick them out in a crowded railway station quite quickly? Here, you should not allow your answer to be influenced by their person's personality or on-screen character, how they speak, or how attractive you find them. As before, how famous you think they are does not contribute to your response."

Stimuli Presentation

Subjects were seated 1 metre from the Personal IRIS display. 6 blocks of randomly ordered faces were presented (all 20 targets, 10 as 0%, 10 as 50%, with 0% and 50% for each face interleaved across blocks; total of 60 (0%) + 60 (50%) = 120 presentations). Each stimuli was preceded by a white fixation cross (subtending 2°) lasting 500ms, followed by the target face (approximately 7°) lasting 300ms in order to minimise eye-movements.[14] Subjects were requested to name each face as quickly and as accurately as possible. Errors and failures to recognise were immediately corrected by the experimenter who was responsible for cuing each trial. A short delay occurred between blocks.

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[14] Experiment One showed that given sufficient inspection time, subjects were able to detect slight distortions in the caricatured (and anticaricatured) images. By presenting the faces briefly it was hoped that perception of distortions would not be possible thereby ensuring responses were guided directly by the recognition of the individual.

A Sony TC161SD stereo cassette-corder recorded stimulus onset (right channel, Sharp PP-150 microphone collecting a synchronised keyboard tone) and vocal response latency (left channel, Radio Spares (RS 250-485) lapel microphone) on standard magnetic audio tape. Response latencies were analysed off-line using a Zeon (ZR9492SL) handheld stopwatch (accurate to one-hundredth of a second). Stimulus onset was signalled by the keyboard tone and latency measured by the first vocalisation. Each response time was estimated twice and the mean tabulated (in milliseconds).

Results

First block reaction-times and accuracies were also analysed separately because correction of responses by the experimenter could not yet have affected subjects' responses.

Reaction Times

Examination of the response times to faces made in the first block of trials (half seen as veridical, half as caricature) showed a marked decrement in naming latencies to caricatures (1138ms) over veridicals (1345ms), 1-way between subjects ANOVA, mean reaction time to each level of facial distortion $F(1, 27) = 11.0$, $p = 0.0026$.

A 2-way ANOVA on the overall mean veridical and caricature latencies (faces as between factor, subjects within) showed a highly significant difference between subjects responses to veridicals (1320ms) and caricatures (1020ms), $F(19, 1026) = 18.96$, $p < 0.00005$, Figure 3.0.3:3 with caricatures elicit the faster responses, $F(1, 54) = 14.88$, $p = 0.0003$. The subject/caricature level interaction achieved significance ($F(54, 1026) = 6.76$, $p < 0.00005$) indicating that subjects responded differentially to the images.

Accuracy

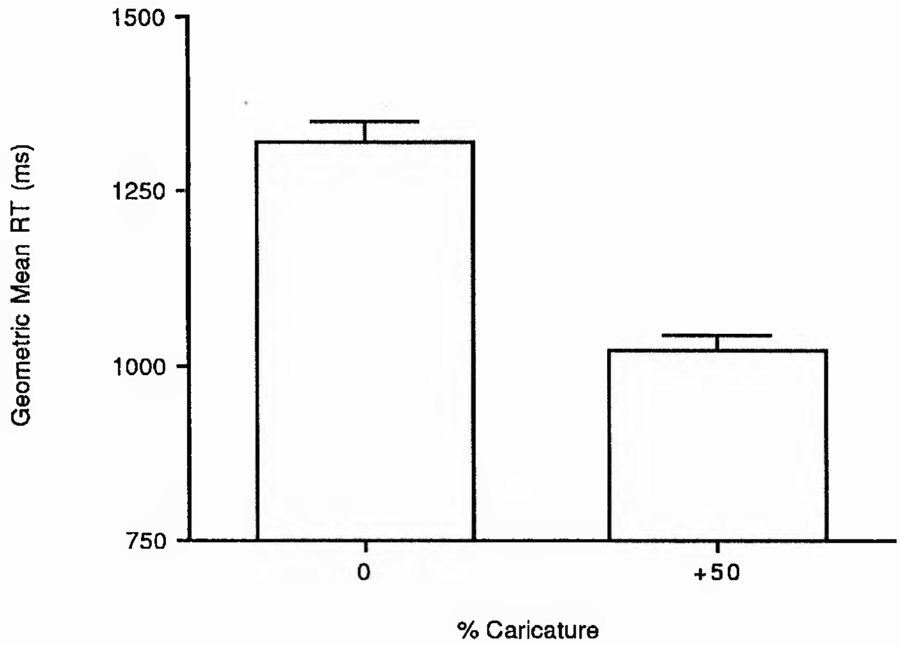

Figure 3.0.3:3

VERBAL NAMING LATENCY. Mean overall response latency for subjects to name a given famous face. Subjects responded more quickly to the sight of photographic caricatures (1020ms; veridicals 1320ms), $F(1, 19) = 18.96$, $p < 0.00005$.

A 1st block 1-way ANOVA showed there was no difference in subjects' accuracy in naming between veridical (74% correct) and caricatured (68%) images, $F(1, 27) = 1.67$, $p = 0.21$ (arc-sine transformation of raw data).

Overall, there was no difference in performance accuracy with caricatures (84.4%) being as effective as the true images (85%), $F(1, 27) = 0.69$, $p = 0.41$ (arc-sine transformation; Figure 3.0.3:4).

Familiarity and Distinctiveness

Subjects' individual ratings of familiarity with the target faces correlated with the difference in reaction times (veridical RT minus caricature RT per face), Spearman's Rank Correlation $r_S(558) = -0.119$, $p = 0.0049$, indicating that the more familiar subjects were with a face the quicker they were to recognise it.

Subjects' ratings of distinctiveness correlated with the difference in reaction times, $r_S(558) = -0.105$, $p = 0.013$, showing it took less time to recognise more distinctive faces.

How familiar a subject was with a face also correlated strongly with the degree of typicality afforded to it, $r_S(558) = 0.526$, $p < 0.00005$. The more familiar a subject was with a face the more distinctive they considered it to be.

[For individual target faces, the subjects' mean ratings also correlated with the speed-up in response times: familiarity, and RT difference, $r_S(18) = -0.574$, $p = 0.008$; distinctiveness and RT difference, $r_S(18) = -0.661$, $p = 0.0015$; familiarity and distinctiveness, $r_S(18) = 0.621$, $p = 0.0035$. All correlations were in the same direction as the analyses for individual responses.]

Summary of Results: Experiment Three

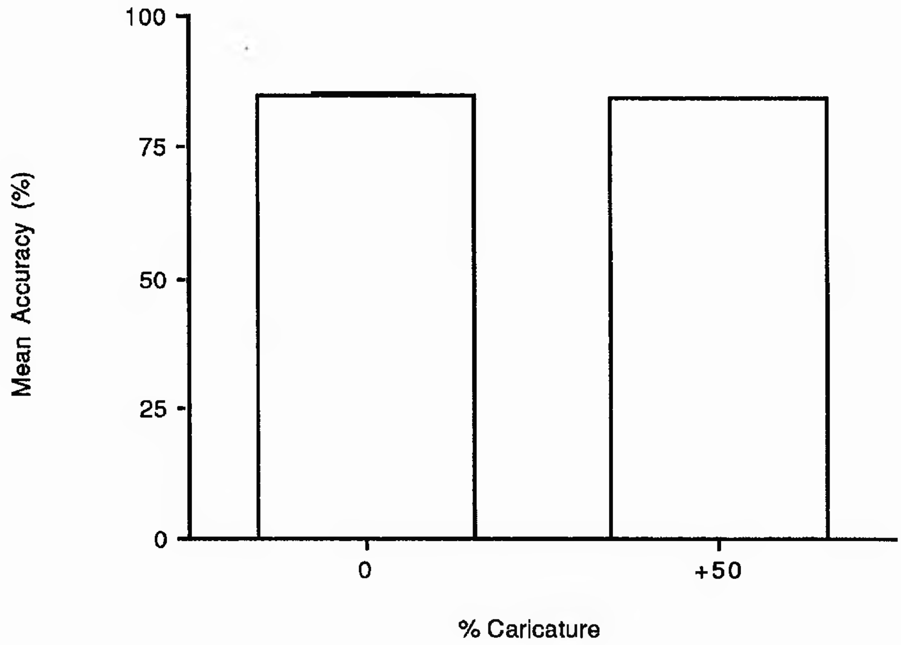

Figure 3.0.3:4

VERBAL NAMING ACCURACY. Mean overall accuracy of subjects naming responses to famous faces. Caricature and veridical photographic images are just as accurately named under the test conditions (veridicals 85%, caricatures 84.4%), $F(1, 27) = 0.69$, $p = 0.41$ n/s.

The results show a clear caricature advantage over true images under the conditions of the experiment. On average, subjects responded faster to caricatures than veridicals by 300ms.

Although corrections may have been made to a subject's failure to recognise or in misidentification of a face in the first block of trials, this could not influence their responses to any other forthcoming face: each target was presented once per block. The reaction time advantage conferred by caricatures is upheld. Accuracy was no different for veridicals or caricatures. Providing facial distinctiveness information in an enhanced way reduced the time taken to identify a famous face.

Ratings of facial distinctiveness were in accordance with this, as was familiarity; the greater the value of such judgements the more easy it was to identify the target. However, subjects appeared to confuse familiarity with distinctiveness in that the ratings of each increased and decreased commensurately. Subjects did not necessarily make judgements of the latter independently of how familiar they were with the appearance of the individuals.

3.0.4 Experiment Four
Can Photographic Caricatures of Personally Familiar Faces be Recognised as Efficiently as Veridicals and which are Better Likenesses?

Introduction

Valentine & Bruce (1986a, 1986c) examined ratings of facial distinctiveness, or typicality, of famous and unfamiliar faces. In a familiarity decision task they reported that distinctive faces were classified as familiar more quickly than typical famous ones. However, there was a non-significant trend for typical unfamiliar faces to be rejected faster than distinctive unfamiliar faces; there were also more false-positive responses to typical unfamiliar faces. From this they deduced that these faces were more easily confused than distinctive unfamiliar faces which in turn may be mistakenly confused with famous faces. Thus, the distinctiveness hypothesis (see Experiment One; Rhodes, Brennan & Carey 1987) proposes that an image exaggerating the distinctive aspects of faces should be a better representation of the face than an image which reduces them. Such exaggerated images should be better representations of the face than the veridical image as predicted by the caricature hypothesis (Hagen & Perkins 1983; Rhodes *et al. ibid.*). Together, these two hypotheses suggest that emphasising the distinctive aspects of a facial image with respect to a chosen population average or norm is likely to improve recognition of a familiar individual as opposed to either an image in which the same aspects have been reduced by an equal amount (anticaricature) or the veridical image.

Experiments One and Two showed slight perceptual and recognition advantages for caricatures of famous faces. Experiment Three showed a marked reduction in the time taken to recognise (name) a photographic caricature of a famous face as opposed to a true image. These results are a positive indication that exaggeration of distinctive facial features can improve recognition of highly familiar individuals in photographs or digital images. The experiments of Rhodes, Brennan & Carey (1987) used line-drawings of departmental faces which were reasonably familiar to their subjects. The aim of this experiment was to discover whether a similar advantage for continuous-tone caricatures of locally or personally familiar faces also existed. According to the stated hypotheses, it was also predicted that responses to relatively unfamiliar faces would show little or no facilitation by caricatures.

Part One: Familiarity Decision

Methods

Subjects

6 male and 12 female undergraduates from the final year course in Psychology were used. Subjects were aged between 20 and 24 years. All subjects were familiar, to varying degrees, with individual's faces in the

stimuli set which were taken during the previous academic session. All subjects took part voluntarily.

Stimuli

Full-colour 35mm transparency slides were taken of the faces of 27 third-year and 27 final-year undergraduates from the Psychology department using a Nikon AF-F801 camera. Both sets of slides were taken using identical lighting conditions with a uniform neutral background. All males were clean-shaven and apparel removed. Photographic subjects were requested to pose with a neutral, relaxed expression. 22 females and 5 males were present in each year of enrolment. Slides were back-projected using a Kodak S-RA1000 Carousell projector onto a translucent screen and frame-grabbed.

Caricatures were prepared at ±50% for each target face giving a stimuli set of 162 images (including veridicals). In addition, a practice set of 8 members of staffs' images (lecturer or research assistant) were prepared in the same way as practice stimuli (24 images).

Procedure

Subjects were seated approximately 80cm from the IRIS monitor. Each subject was presented with written instructions describing the task and nature of response. Subjects were required to classify each face presented on the computer monitor as that of a member of either their own class, or the previous years'; stimuli subjects who had been photographed as members of the third-year undergraduate class were used as experimental subjects. Responses were categorised as either 'us' or 'them' and labelled accordingly on the response keys which were used in place of the computer keyboard. Subjects were requested to guess even if they failed to recognise a particular face. Response keys were left/right swapped for each subject. Three blocks of trials were presented. Each face occurred once in each block at either veridical (0% caricature) or ±50% caricature. Degree of caricature and year membership was balanced equally within each block. Order of presentation of each block was balanced between subjects. The computer recorded response latencies from stimulus (display) onset in milliseconds. Inter-trial interval was fixed at 1 second. For practice trials, the responses were either 'lecturer' or 'other'. Faces were displayed through an elliptical card aperture to mask possibly distracting distortions external to the face and remained visible until a key response was made.

Part Two: Perceptual Best Likeness

The effect of caricaturing on subjects' perceptual ratings of 4 images of the faces used in Part One was made.

Methods

Subjects

All subjects were the same as those who took part in Part One of the experiment.

Stimuli

Additional caricatures were rendered at ±25% for each of the target faces used in Part One. All 5 levels of caricature (±50, ±25, and 0%) were photographed from the non-interlaced IRIS monitor using a Nikon AF-F801 camera on black-and-white film; a duplicate set of prints (100 x 120mm) was also made. Two sets of prints were constructed for each target face, *A* and *B* (as in Experiment One). Each set was mounted horizontally on a strip of card. Set A contained images of a face at -25, 0, 25, and 50% (caricature-biased set). Set B contained images of a face at -50, -25, 0, and 25% (anticaricature-biased set). Sets of photographs were randomly assigned to one of two books, such that half of the face sets in each book were either caricature- or anticaricature-biased. Within each set of 4 images the order of presentation was randomly left-to-right or vice versa to prevent the veridical image appearing in the same positions.

Procedure

Subjects were given written instructions asking them to make ratings for three judgments of the images of each face (i) goodness of likeness, (ii) familiarity with that face, and (iii) facial distinctiveness. Subjects were instructed to disregard any slight differences between photographs caused by contrast or developing differences.

Goodness of Likeness

Ratings on a scale of 1 ('very poor likeness') to 7 ('very good likeness') were made. Subjects were permitted to allocate the same score to several images of one face, but were requested to indicate which particular image they considered to be the best overall.

Familiarity

Ratings on a scale of 1 ('don't know this person') to 7 ('very familiar') were made.

Facial Distinctiveness

Distinctiveness was defined as there being "something about their face which distinguishes them from the general population: a large nose perhaps, close-set eyes, thin face, etc." Subjects were also instructed to base their judgements only on facial appearance and not to be influenced by any personality traits they were familiar with. Ratings were on a scale of 1 ('typical or average looking face') to 7 ('very distinctive face').

Results: Part One

All analyses discounted subject data wherever a target face was unknown (familiarity rating = 1).

Accuracy

Three separate 1-way ANOVAs were carried out on the mean proportion of correctly classified familiar faces with caricature level (±50, 0%) was within-subjects factor. Data were segmented according to the familiarity ratings given in Part Two of the experiment:

- all familiar faces (*familiarity* > 1);
- low familiarity faces (1 < *familiarity* < 4);
- high familiarity faces (*familiarity* > 3).

All Familiar Faces

There was a significant effect of level of caricature presented on the accuracy of classification, by-face $F(2,106) = 9.33$, $p = 0.0002$. A Newman-Keuls post hoc test[15] showed that the caricature (77%) and veridical (76%) images were more accurately classified than anticaricatures (73%), $p = 0.047$. There was no difference in accuracy between caricatures and veridicals (Figure 3.0.4:1).

ANOVA by subject showed that subjects' response accuracy across level of caricature showed significant differences, $F(2, 34) = 9.02$, $p = 0.0007$. Newman-Keuls showed veridicals (41%) were responded to more accurately than anticaricatures (39%), $p = 0.005$. Caricatures (42%) were more accurately identified than anticaricatures, $p = 0.001$. No other differences were found (Figure 3.0.4:2).

Low Familiarity Faces

There was no effect of caricature level on the accuracy of recognition of low familiarity faces, $F(2,104) = 2.8$, $p > 0.06$ (df-2, missing cells; anticaricatures 23%, veridicals 24%, caricatures 24%).

Subjects who were of low familiarity with the target faces responded differentially to levels of facial exaggeration, $F(2, 34) = 5.02$, $p = 0.012$. Newman-Keuls showed that veridical faces (18.3%) were responded to more accurately than anticaricatures (17%, $p = 0.015$), and caricatures (18.1%) were responded to more accurately than anticaricatures (p =

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[15] Significance at 5% level.

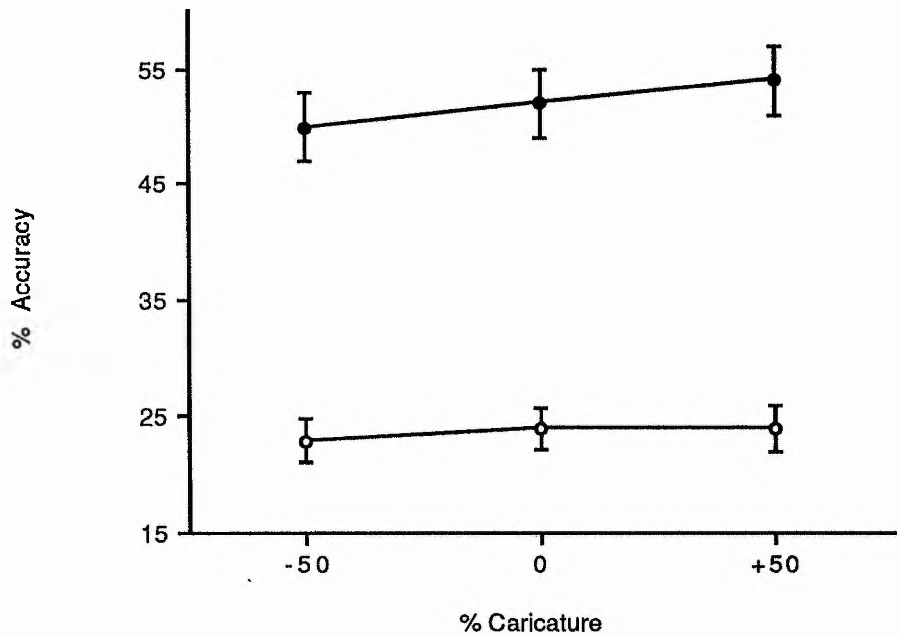

Figure 3.0.4:1

RECOGNITION ACCURACY FOR FAMILIAR FACES. Faces with which subjects were only slightly familiar were equally accurately responded to regardless of whether presented as caricature, anticaricature, or veridical, $p > 0.06$. More familiar target faces were more accurately responded to when presented caricatured ($p = 0.001$) or as veridicals ($p = 0.018$).

◦ low , • high familiarity.

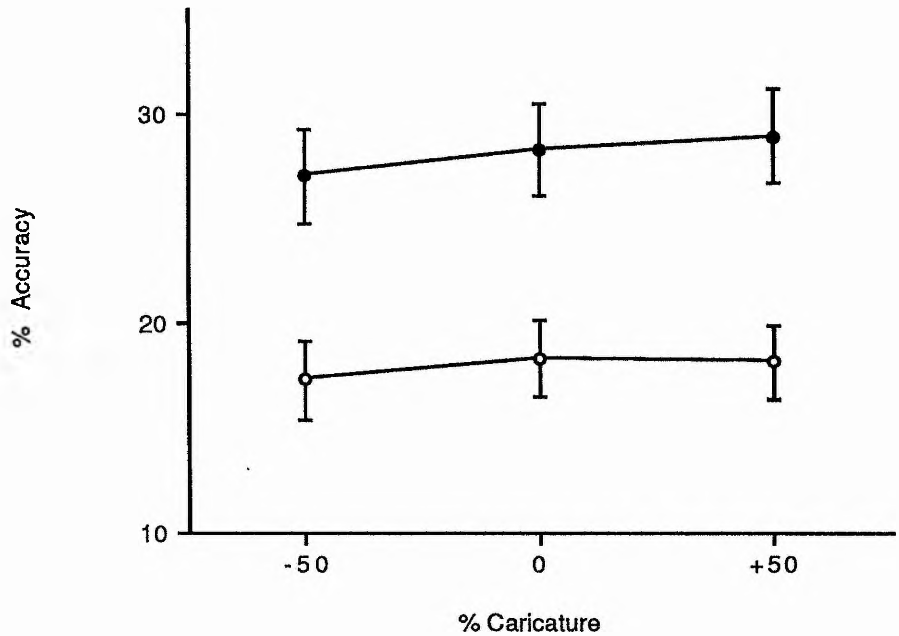

Figure 3.0.4:2

SUBJECTS' RECOGNITION ACCURACY FOR FAMILIAR FACES. Individual subjects, when presented with faces of low familiarity, responded more accurately when viewing veridical images than anticaricatures ($p = 0.006$) or caricatures ($p = 0.004$). Faces which were more familiar to subjects illicit more accurate responses when shown as veridicals ($p = 0.017$) or caricatures ($p = 0.001$).

◦ low, • high familiarity.

0.019). There were no differences between performance for caricatures over veridicals.

High Familiarity Faces

There was a significant effect of level of classification of highly familiar faces, $F(2, 106) = 7.15$, $p = 0.0012$. Newman-Keuls showed that the caricature (54%) and veridical (52%) images were both more accurately classified than the anticaricatures (50%, $p = 0.001$, and $p = 0.018$ respectively). There was no difference in accuracy between caricatures and veridicals.

Subjects who were highly familiar with particular faces also responded with differing degrees of accuracy according to the level of caricature presented, $F(2, 34) = 6.41$, $p = 0.0043$. Newman-Keuls revealed that both veridical images (28%) and caricatures (29%) were recognised more accurately than anticaricatures (27%, $p = 0.017$ and $p = 0.001$ respectively).

Reaction Times

Three 1-way repeated measures ANOVAs were carried out on categorisation responses to faces at each of the three levels of caricature according to the mean familiarity ratings given in Part Two.

All Familiar Faces

There was a significant difference between level of caricature on response latency, $F(2,106) = 4.5$, $p = 0.013$. Newman-Keuls showed that veridical images (740ms) were classified more quickly than anticaricatures (775ms, $p = 0.011$) and caricatures (764ms, $p = 0.048$). No other differences were found (Figure 3.0.4:3).

There was a significant difference between subjects' response latencies according to which level of caricature was seen, $F(2, 34) = 11.22$, $p = 0.0002$. Newman-Keuls showed that veridicals (731ms) were also

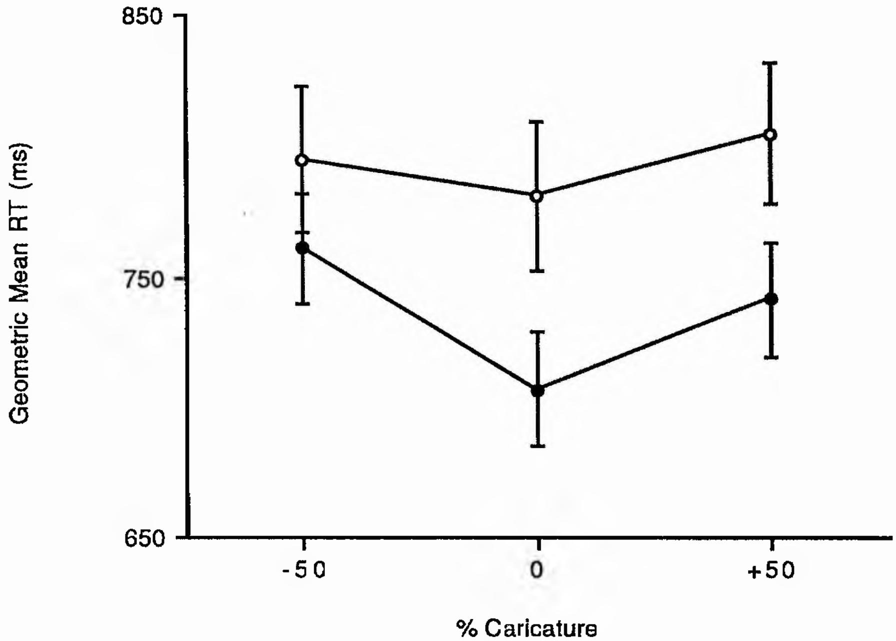

Figure 3.0.4:3

CLASSIFICATION LATENCIES FOR FAMILIAR FACES. Faces of low familiarity were equally quickly responded to, $p > 0.97$. For higher familiarity faces, veridical images showed lower response times than anticaricatures, $p = 0.003$. Caricatures and veridicals were responded to equally quickly, $p = 0.56$ n/s.

◦ low, • high familiarity.

recognised more quickly than both anticaricatures (770ms, $p < 0.0005$) and caricatures (760ms, $p = 0.002$; Figure 3.0.4:4).

Low Familiarity Faces

There was no statistical difference for reaction times to faces shown as anticaricatures (769ms), veridicals (766ms), or caricatures (764ms), $F(2, 102) = 0.03$, $p > 0.97$ (df-4, missing cells).

Subjects' responses to varying levels of caricature did not differ significantly either, $F(2, 34) = 2.12$, $p > 0.14$ (anticaricatures 795ms, veridicals 781ms, caricatures 805ms).

High Familiarity Faces

There was a significant difference between response times to faces with whom subjects were highly familiar, $F(2,106) = 6.22$, $p = 0.0028$. Newman-Keuls showed that responses to veridicals (734ms) were faster than to anticaricatures (784ms), $p = 0.002$. Caricatures (762ms) and veridicals were responded to equally quickly, $p = 0.056$, n/s. No other differences were found.

Subjects responded preferentially to particular levels of caricatured images when they were highly familiar with the target individuals, $F(2, 34) = 14.66$, $p < 0.00005$. Newman-Keuls showed that veridicals (707ms) were classified faster than both anticaricatures (761ms, $p < 0.0005$) and caricatures (741ms, $p = 0.002$). Caricatures did not elicit significantly faster responses than anticaricatures, $p = 0.059$, n/s.

Results: Part Two

'Goodness of likeness' and 'best likeness' ratings were analyses independently on the basis of familiarity ratings for each face. Ratings were only analysed for familiar faces (*familiarity* > 1) since subjects could not rate images of unknown face as 'like' the individuals if they did not recognise them.

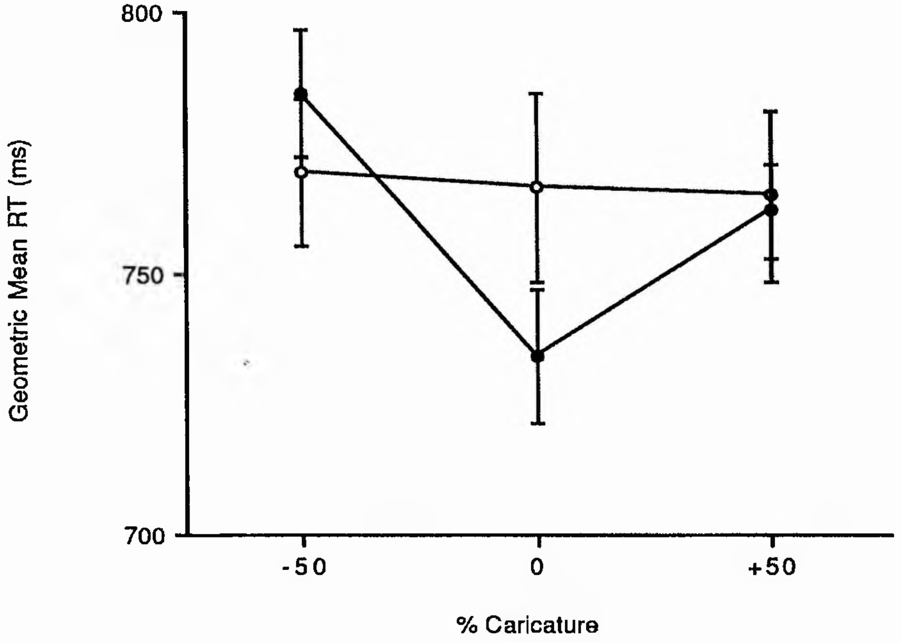

Figure 3.0.4:4

SUBJECTS' CLASSIFICATION LATENCIES FOR FAMILIAR FACES. Subjects' responses to faces of low familiarity were equally distributed across veridicals, anticaricatures, and caricatures, $p > 0.14$. More familiar faces facilitated optimal responses when shown in the veridical condition as opposed to anticaricatures ($p < 0.0005$) or caricatures ($p = 0.002$).

∘ low, • high familiarity.

Goodness of Likeness

A 1-way repeated measures ANOVA was carried out on ratings of 'goodness of likeness' with 5 levels of caricature as the within-subject factor. Average ratings were taken across all subjects for one face at a given level of caricature. There was a highly significant effect of level of caricature, $F(4, 212) = 111.87, p < 0.00001$. Newman-Keuls revealed that veridical images were considered more like the individual than all other images (all, $p < 0.0001$). -25% anticaricatures were rated as better likenesses than the 25% caricatures, $p = 0.04$. ±50% caricatures were rated equally bad, $p > 0.2$.

Best Likeness

A 2-way repeated measures ANOVA was carried out on the proportion of faces chosen at each level of caricature as 'best likeness'. Classification type ('us', 'them') and level of caricature (-50, -25, 0, 25, and 50%) were within subject factors. There was a significant effect of caricature level on the proportion chosen, $F(4, 208) = 116.9, p < 0.0005$. Newman-Keuls revealed (amongst other differences) that veridicals (mean best likeness rating 4.87) were considered more like the target individuals than -50% (3.25), -25% (4.27), 25% (4.07), and 50% (3.13; all $p < 0.0005$) levels of caricature. -25% anticaricatures were rated slightly better than 25% caricatures, $p = 0.035$. There was no significant difference between the two groups of targets, $F(1, 52) = 2.04, p > 0.16$. There was an interaction between level of caricature and the year to which the target faces belonged, $F(4, 208) = 3.42, p = 0.01$ (although a different caricature level(s) mediated a differential classification latency this result does not provide any useful insight into task performance or nature of stimuli).

Interpolation of the level of caricature representing the 'best likeness' was -1.2% overall as shown in Figure 3.0.4:5 (-1.8% for faces of low familiarity, -0.6% for high familiarity).

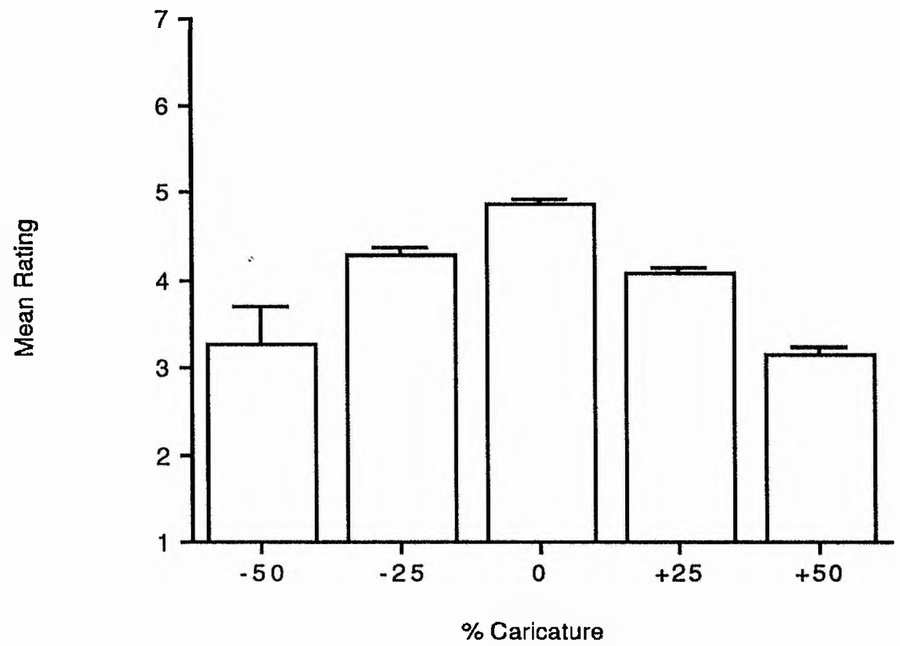

Figure 3.0.4:5

PERCEIVED BEST LIKENESS. Overall ratings of perceived likeness for caricatures of 54 personally-known faces (collapsed across low and high familiarity). Ordinate: mean rating of best likeness for each level of caricature. Abscissa: distortion of image from the veridical image. The data shows no statistical preference for either caricatures or anticaricatures over true images. The interpolated mean of the distribution is -1.2%.

There was no correlation between decisions of how good the images were in capturing likeness of individuals and estimations of best likeness from the range of caricatures seen, Spearman's Rank Correlation $r_s(52) = -0.13$, $p > 0.3$. No relationship between the degree of familiarity subjects' expressed of the target individuals and selections of the best likeness amongst caricatures presented existed, $r_s(52) = 0.08$, $p > 0.5$.

Distinctiveness

The level of caricature selected as being the best likeness of target faces did not correlate with ratings of how distinctive subjects considered those faces to be, $r_s(52) = 0.13$, $p > 0.3$. However, ratings of familiarity were significantly correlated with those of distinctiveness, $r_s(52) = 0.55$, $p < 0.0005$.

Summary of Results: Experiment Four

A caricature advantage was not found for exaggerations of personally familiar faces. Neither perceptual ratings or response latencies revealed a significant difference between caricatured and veridical images.

Although computationally enhancing the facial distinctiveness of a familiar face did not improve subjects' responses in the direction of preferring caricatures in no way did this have a detrimental effect. This indicates that at least some of the correct dimensions of target face appearance had been manipulated. Data indicate that true veridical (or near-so) images were classified more quickly than those diminished or enhanced. Anticaricatures were far less accurately classified than both veridical and caricatured. No speed-accuracy trade-off was seen and hence this lends support to the argument that distinctiveness enhancement was carried out in at least a few of the correct dimensions.

Perceptually, veridical images were considered to be the better likeness of target faces. This can be accounted for in two ways. It is possible that subjects' were able to detect the slight distortions and defaulted to the 'normalised' image in the set. Indeed subjects reported detecting distortions or slight glitches when examining some of the faces in highly caricatured states; it is also possible that subjects were capable of matching target images to their stored facial representations of those people, with distorted pictures failing to produce a best match. ±50% distortions were considered very poor likenesses of the individuals compared with the true image.

The more familiar subjects were with the target individuals the greater their ratings of facial distinctiveness. This correlation does not indicate any useful relationship between these two factors. As was suggested in Experiment One, subjects frequently erroneously describe distinctiveness (under these conditions) in terms of personality or character traits. The more familiar a person is with the appearance of a face does not necessarily indicate changes in their impressions of distinctive aspects. In absolute terms, a face either has distinguishing features or it does not.[16] These visual characteristics may not be present in a frontal pose and many in fact are not. Incorrect ascriptions of distinctiveness according to, for example, a prominent nose or receding chin in profile view is a misrepresentative measure in terms of the pose struck and measure required of the facial appearance in the target images.

Faces with whom subjects were relatively (slightly) familiar provoked no perceptual or classification (reaction-time or accuracy) advantage for caricatures. Only more familiar faces indicated classification accuracy for caricatures; response latencies to distinctiveness-enhanced faces reduced to that of veridicals.

3.0.5 General Discussion Continuous-tone Photographic Caricatures

[16]The caricature generator only measures featural and configural differences, and hence cannot currently be applied to skin texture and hue parameters.

Investigations using computer-generated caricatures have indicated that a systematic distortion of a facial line-drawing can improve recognition for highly familiar faces. Drawings with a slight degree of positive caricaturing were found to provide a better likeness of an individual than veridical images. Experiments One through Four supplement the study of Rhodes, Brennan & Carey (1987). The results indicate that the caricature advantage is not restricted to line-drawings but also occurs for images containing photographic detail. The caricature advantage may therefore tell us about the processing of natural images and can not be taken to reflect simply a series of artistic conventions used in line-drawn cartoons.

Explanations of the Caricature Advantage

These results have implications for the nature of representations stored in memory. Rhodes, Brennan & Carey (1987) offered two explanations for a caricature advantage. The first explanation suggested that caricatured representations of faces are actually stored in memory rather than veridical representations. The details of feature configuration, shape, size and colouration stored in memory would be exaggerated in the way they differ from the norm or the prototypical face. It could be predicted from this hypothesis that caricatures would be more efficiently recognised because they are closer to the stored representations.

A second explanation is that representations stored in memory are veridical but that caricaturing aids the processes of matching the input image to the veridical representations. This retrieval advantage can also be explained as follows. Rhodes, Brennan & Carey (1987) suggested that the attempt to match the caricature to stored veridical templates might lead to a greater relative activation of the target face compared to non-target (distracters) even though the absolute level of activation of the target might by reduced compared to that produced by the veridical line-drawing. Searching for a potential match against the stored representations of all familiar faces is presumably an extensive task. The caricaturing process could 'constrain' the search since exaggerating the features would make it easier to realise qualitatively what kind of features the target face possesses. Thereafter, search could be restricted to only those faces with approximately the correct feature dimensions.[17] The second explanation would be appropriate if faces are stored as distances in multi-dimensional space at the centre of which is the norm for a particular face type (McClelland & Rumelhart 1985; Valentine & Bruce 1986a; Rhodes 1988; Valentine & Ferrarra 1991; Valentine & Endo 1992). Thus, nose length might be one dimension, interocular separation another. When a caricature is presented for recognition the exaggeration of particular feature deviations from norm will increase the distances (in the multidimensional space) of the caricatured face from representations of other faces. One potential problem with this interpretation is that a caricature image will also be further away from the position of the target face in multidimensional space as compared with the veridical image. The caricature advantage must come, therefore, from the fact that a small increase in distance from the representation of the target face is more than offset by the large increase in distance from the representations of non-target faces.

In summary, the advantage for caricatures could result from (i) mimicking the stored information, or (ii) optimising the retrieval process.

The first model can be taken to make the prediction that caricatured images should be perceived as being more like the face they represent than veridical images. From the study of Rhodes, Brennan & Carey (1987) and the results from these experiments show there is a small but significant trend in the data to support this claim. Interpolation from the perceptual data indicates that the highest rating for best likeness occurs for images with a small degree of positive caricaturing (4-16%). In these experiments the strength of the caricature advantage was found to vary across faces and the overall effect might well have been stronger if the quality of the processing had been uniformly good (see below).

The interpretation of perceptual ratings of different images is not, however, clear cut. The actual distribution of ratings could be flat between 0% and some level of positive caricaturing (16% positive in Experiment One

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[17]Eg. face X has a big nose, therefore do not attempt matches with representations of faces with small noses.

and 25% in Rhodes, Brennan & Carey 1987). Thus although the distribution of ratings might statistically peak at 4.4% caricature in Experiment One and 16% caricature in the study of Rhodes *et al.* (*ibid.*), the ratings for these slightly caricatured images might not be significantly higher than the veridical image. In Experiment Four, such judgements of familiar faces produced an overall mean of -1.2%, no different from veridicality. One could say slightly positive or negative caricatures are perceptually no better but also no worse than the veridical image as representations of individuals. On the other hand, strong anticaricatures are consistently perceived as poorer representations than veridical images.

The second model (where caricatures give faster access to veridical representations held in memory) is perhaps favoured by the dissociation between recognition and perception of likeness. Rhodes, Brennan & Carey (1987: Experiment One) found 50% caricatures were recognised faster than the veridical representations but were judged to be of inferior likeness compared to the veridical. In Experiment Two a significant caricature advantage in the recognition of 16% caricatures was found, yet there were no differences in the perceptual ratings of 0% and 16% caricatures. Experiment Three showed a clear recognition advantage for 50% famous-face caricatures over veridicals, although subjects reported seeing distortions in certain images which affected their goodness of likeness in some way. In Experiment Four, perceptual ratings indicated that veridical images were considered the better likenesses; recognition responses were also optimal for veridicals. The absence of any evidence for caricature superiority in this experiment could be due to a combination of the influence of low familiarity, high caricature level, and stimulus presentation time (see below).

The Distinctiveness Hypothesis

A number of authors (Going & Read 1974; Cohen & Carr, 1975; Light, Kayra-Stuart & Hollander 1979; Winograd 1981; Bartlett, Hurry & Thorley 1984) note that when subjects concentrated upon the atypical features of a face they are less likely to confuse that face with others. It is perhaps not surprising that more distinctive faces are easier to recognise. An effect of distinctiveness was found in Experiments One, Two and Three. Positive caricaturing accentuates deviations from norm and hence should make a face more distinctive. Positive caricatures (16 and 32%) were judged better likenesses than the anticaricatures of the same degree. Furthermore in the name/face matching task, there was evidence showing 16 and 32% caricatures were processed more efficiently than anticaricatures. These distinctiveness effects, like those of Rhodes, Brennan & Carey (1987) and Rhodes & McLean (1990), occur even though the magnitude of the image deformation from the veridical image is exactly matched for positive and negative caricatures. In Experiment Four, diminishing the amount of facial distinctiveness (anticaricatures) while maintaining identity through skin colouration and texture pattern produced a marked performance decrement for familiar faces. Enhancing distinctiveness by the same relative amount did not succeed in improving performance or perceptual preference, but at the same time it did not yield impairment. In Experiment Three where distinctiveness enhancement only was applied, improvements in performance without loss of accuracy were observed; in addition, subjects' judgements of facial distinctiveness correlated strongly with the main reaction time effect.

Representing Relative and Metric Proportions of a Face

The caricature advantage is argued to reflect the existence of an abstract configural representation for familiar faces. This representation stores the configural information about how faces differ from one another and hence how individual faces deviate from average.

Caricatures present the interpretational system with a conundrum. It is possible that at an abstract configurational level of representation the caricature forms a better match than a veridical image because a caricature *draws attention* to the way the face differs from norm and therefore presents information in the same format as the abstract representation. Caricatures are, however, distortions of reality and observers are sensitive to the distortion. The fact that subjects can perceptually judge a caricature to be a distortion from reality implies that at some level representation(s) of each face must be veridical and maintain the metric proportions of the face.

It is of course possible that there are multiple representations for particular faces (for a discussion see V. Bruce 1982; Bruce & Young 1986; Marr & Nishihara 1978). One level might be concerned with representing pictorial or photographic details and would maintain an accurate metric account of the dimensions of the image. At a higher more abstract level concerned with differences between faces, representations might be more concerned with selective storage of deviations of faces from prototypes. In this two stage processing scheme the metric or pictorial code would maintain veridical dimensions and the abstract code might stress the importance of configural deviations from norm or prototype.

Caricature Advantage in Name/Face Matching

If one concedes that both the metric proportions of a face and the manner a face differs from norm are coded by the visual system then it is possible to account for the greater benefits of caricaturing found with non-match trials in Experiment Two. These two types of information could be present in the same representational code though it is easier to consider two separate codes.

On trials where the name and face stimulus are the same identity, a caricature may form a better match with the abstract representation of the target face than a veridical image. On the other hand, at the level of the metric code the match between input image and representation will be less good. Thus any advantage of the caricature at the abstract level will tend to be offset by the disadvantage at the metric level.

In the case of non-match trials this conflict is not present. For example, if the target name is Michael Cashman and the stimulus face subsequently presented is a veridical image of Nicholas Parsons, then the image will not match the abstract representation of Cashman's face nor will it match the metric representation of Cashman's face. A "no" or "doesn't match" response can be given as soon as sufficient evidence is amassed indicating the unacceptable nature of the match between input to representations of the target face. If we now consider the case where a positive caricature of Parson's face follows Cashman's name, it is evident that the evidence for mismatch can be accumulated more rapidly. The caricature of Nicholas Parsons will form a very bad match to the abstract representation of Cashman's face and a poor (possibly very poor) match to the metric representation of Cashman's face. For the non-match trials caricaturing can be seen to aid recognition because it increases the discrepancy between input image and the stored representation(s) of the target face.

This explanation predicts an increasing advantage for more exaggerated caricatures. Alternatively on non-match trials the advantage may come because a caricatured image of Nicholas Parsons may be recognised as Nicholas Parsons quicker than a veridical image in Experiment Two. Matching the abstract representation of Parsons is quick and performed in parallel without reference to the matching to the veridical representation of Parsons. Any evidence that the face is not Cashman is a signal to stop the 'recognition' search.

Caricature Advantage in Verbal Naming

Experiment Three was successful in optimising the likelihood of a caricature advantage by using highly familiar (famous) faces, directing subjects' attention towards the salient internal features of the faces using a simple feature mask, and minimising stimulus presentation time. 50% caricatures were named far quicker than the veridical counterparts without loss of accuracy. Here, the caricature advantage was specifically tested and produced very clear results.

Relatively strong caricaturing of each facial image did not appear to adversely affect subjects' performance; it is suggested that the combined related effects of familiarity and facial distinctiveness were responsible for ensuring that the reaction time advantage was observed. Controlling subjects' attention towards any distinctive internal facial features present by masking and controlling stimulus presentation so as to minimise eye-movements undoubtedly contributed to the result. Having ensured that these factors were suitably controlled it is clear that photographic caricatures of famous faces can improve recognition. Again there is evidence that both veridical *and* distinctiveness information is coded for faces with which we are highly familiar. Subjects were aware that distortions were present in an image of someone they are familiar with, yet these manipulations must be in the correct direction so as to facilitate improvements in recognition latencies.

Caricature Effects in Semantic Categorisation

Distinctiveness enhancement of personally familiar faces did not improve subjects' response performance, nor did such manipulations affect the choice of freely inspected facial distortions of an individual's face. What is clear is that at least a subset of the visual dimensions necessary to produce good caricatures were correctly manipulated. Diminishing the structural appearance of distinctive components of a face served to degrade recognition performance while enhancement by the same amount never elicited responses which were worse (accuracy); responses were, on the whole, comparable with that of the veridical condition. On average, analyses of response latencies showed that veridical images provided the most efficient access to stored representations of the target faces' coding.

Three parameters can be identified which are likely to be responsible for the failure of this experiment to produce at least a consistent distinctiveness advantage. (i) Subjects' classification accuracy for familiar, but not well-known or famous, faces was very low and hence affected the variance in response times which may be in turn responsible for the lack of a clear distinctiveness or caricature result. (ii) High levels of caricature (±50%) causing strong facial distortions did not serve to improve likenesses so as to impair or improve recognition rates correspondingly. It is entirely possible that less strong distortions could have produced an advantage for images of caricatured faces. (iii) Inspection time of individual images, both for the purpose of perceptual ratings in Part Two and the recognition task in Part One could also be criticised in so far as subjects were given ample opportunity to visually process any distortions (or glitches) in the target images. From the results of Experiment Three it seems that controlled brief presentations in a recognition task help to qualitatively improve results. In this experiment subjects were not so familiar with the appearance of members of differing classes and academic years, though it may have been sufficient to improve the classification results by employing such a strategy.

Photographic and Line-Drawn Representations

Where found, the magnitude of the caricature advantage was small. With photographic images interpolation from the data in Experiment One indicates that a caricature level of 4.4% would on average be chosen as best likeness, whereas with line-drawings Rhodes, Brennan & Carey (1987) found a value of 16%. Likewise in the recognition task of Experiment Two photographic images produced an advantage with 16% exaggeration present but there was no such improvement with much greater exaggeration (48%); Rhodes *et al.* (*ibid.*) reported a significant advantage for 50% caricatures of line-drawings. The success of Experiment Three can be attributed in part to the lack of external, and possibly erroneous, information present; when viewing a famous face's image containing only internal facial features subjects were forced to use this relevant (manipulated) information alone. In this case 50% photographic caricatures also improved the ease of recognition.

Simple line-drawn faces are impoverished stimuli containing no texture, colour, shadows, etc. At the level of the metric code for facial attributes line-drawings will match stored representations less well than real photographs. Line-drawings may, however, maintain all the configurational information necessary to access abstract codes of the relative proportions of facial features. Thus line-drawn caricatures can reap the benefits of improved matching to representations at the abstract configurational level without suffering such a disadvantage at the metric level. In this sense, greater advantages would be expected for caricaturing impoverished representations of faces. It could be argued that because anticaricatures tend towards the 'same' face the nature of the perceptual and recognition tasks using line-drawings are biased towards finding a caricature advantage; photographic caricatures do not suffer from this problem because of the compelling nature of the skin texture patterns prevalent in *all* rendered images of an individual.

Quality of Starting Image

The amount of caricaturing present in the image chosen as best likeness was affected by the identity of the face portrayed. Since faces differ in the amount that they deviate from the norm different levels of caricaturing might be required for efficient matching of the input to the stored representation. If a face has a highly deviant nose and lips then these may not need further exaggeration in caricatures. The difference found here between the level of caricaturing required for best likeness may thus reflect the feature dimensions of the target face chosen.

Alternatively this result may arise from limitations of the processing technique or from poor quality of starting images. In the Experiments, subjects rated all the images they chose as best likenesses as being reasonably good representations of the target individuals. Thus one can assume that the starting images for each of the faces was at least adequate. A photograph may be of good quality in terms of contrast, focus, pose and lighting image. In this sense it may be a good likeness of an individual, however, it is often the case that nuances such as expressions, gestures, facial asymmetry and posture that are typical of a person are absent from a given photograph. In attempting to assess the quality of our original images it is possible that subjects rated the goodness of likeness more with reference to photographic quality than with reference to the visibility of characteristic features and expressions. This explanation accounts well for the range of responses in Part Two of Experiment Four.

Caricature artists noted that when preparing a caricature they have the opportunity to experience many instances and views of a target's face before constructing a portrait, they can therefore spot the appearance of facial features, expressions, mannerisms, etc. which are characteristic of the individual. The automated process has access only to one starting image and no matter how good the photographic quality is if important idiosyncratic features or expressions are absent in that starting image they will not be accentuated in the final caricature.

Expert Assessment of Caricature Processing

For some of the faces in Experiments One and Two particular feature transformations, such as raising the forehead, were considered distortions rather than accentuations typical of a caricature of the face in question. While individual artists may pick on slightly different features to accentuate the three interviewed were in agreement as to which images had been caricatured successfully and which had not. The ratings of artists with experience in caricaturing faces thus provided an independent measure of the quality of the computerised image transformations. Of great interest was the finding that the ratings of the experts as to the quality of the caricature processing correlated with a tendency of subjects to choose caricatured images as those most like the target faces. This provides evidence for thinking that the magnitude of the potential caricature advantage was underestimated in the present study. It might have been larger if the computer processing or selection of starting images was improved.

Ratings by artists and experimental subjects were qualitatively different. Caricature experts had to determine the extent deviations introduced by the computer were those that they would have introduced. Subjects on the other hand were simply choosing which out of a set of images they thought looked most like a target face. They were aware that images had been deformed to differing extents but were attempting to choose an image most similar to how the person looked in real life.

Familiarity and Caricaturing

Rhodes, Brennan & Carey (1987) found a caricature advantage for the recognition of familiar faces but no advantage for unfamiliar faces (Rhodes & Moody 1990). Rhodes & McLean (1990) also found a caricature advantage for line-drawings of birds, but only with subjects who were highly familiar with the targets. The results reported in the photographic caricature experiments also show an effect of face familiarity. The caricature advantage at the perceptual level was greater for faces which were more familiar to subjects. That is images with a greater degree of positive caricaturing were judged to be more like the target face when the face was highly familiar. Relatively familiar target faces failed to produce a positive result as did those which are unknown.

The relation of the caricaturing success to face familiarity is expected from both explanations of the caricature advantage (in terms of mimicking stored representation or optimising retrieval) because there would be no long term representation for unfamiliar faces, and a less detailed coding for faces of low familiarity. Under the first explanation caricatures would fail because there would be no caricatured representation in memory. Under the second explanation caricatures would also fail because there would be no veridical representation in memory to match the caricatured input image.

It is true that to recognise an unfamiliar face after even a short interval some representation must be stored but evidently the type of representation and/or matching process used for unfamiliar faces is qualitatively different from that for familiar faces and is not affected by caricaturing. Familiarity is known to produce qualitative differences in the processing of faces. For familiar faces more attention is paid to the internal facial features whereas for unfamiliar faces more attention to the external detail of the hair. Future work on caricaturing faces of relatively low or complete unfamiliarity may demonstrate stronger effects if the hair of target faces was masked out during perceptual and recognition tasks; Experiment Three employed such a strategy which helped facilitate such clear response differences.

The results suggest that to achieve the biggest caricature advantage highly familiar or famous faces should be chosen as target images. There are problems, however, with using the faces of some highly famous politicians and media stars because they may have already been subjected to caricaturing. In Experiments One and Two this confound of familiarity and previous caricaturing was present only for Thatcher's face. Data from the other faces not known to have been subjected to caricaturing before the experiment still revealed a significant correlation between familiarity and degree of positive caricaturing accepted as providing the best likeness.

Response Latencies

In Experiment Two the name-face matching latencies were of the order of 500ms for the fastest responses. When subjects were presented with the name of a potential target face they were able to bring to mind a mental image of the appearance of that person. Performing a visual pattern match with a subsequent face is a means of recognition or verification which does not require explicit name generation. The framework for a model of face recognition advocated by Bruce & Young (1986) in Figure 3.0.5:1 shows that name generation is the last stage in the process. 'Recognition' of the famous faces in the task is performed at the *Face Recognition Unit* (FRU) stage where the pattern is recognised as a face and then the mental image of that person is either verified or discounted. In the latter case, subjects were able to respond quicker in the 'non-match' condition because of clear dissimilarities. Presented with caricatures, subjects were even quicker to reject non-matching trials. In accordance with the Bruce & Young (*ibid.*) model, semantic information is accessed at a later stage at the *Person Identity Nodes* (PINs). The classification decision involved in Experiment Four (Part One) on class membership happens at this point. In optimal responses, subjects latencies were approximately 700ms (veridical, high familiarity). Indeed, the 200ms difference (match/non-match mean optimal response was approximately 500ms) reflected according to the two different tasks[18] is supported by the FRU/PIN schema and is in accordance with the latency approximations made by Young, McWeeny, Ellis, & Hay (1986) and Young, McWeeny, Hay, & Ellis (1986). Finally, the naming latencies for caricatures (approximately 3800ms) and veridicals (approximately 6000ms) found in Experiment Three also support the model with activation occurring at the final *Name Generation* stage.

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[18] 9 out of the 11 subjects who participated in Experiment Two also took part in Experiment Four (n = 18).

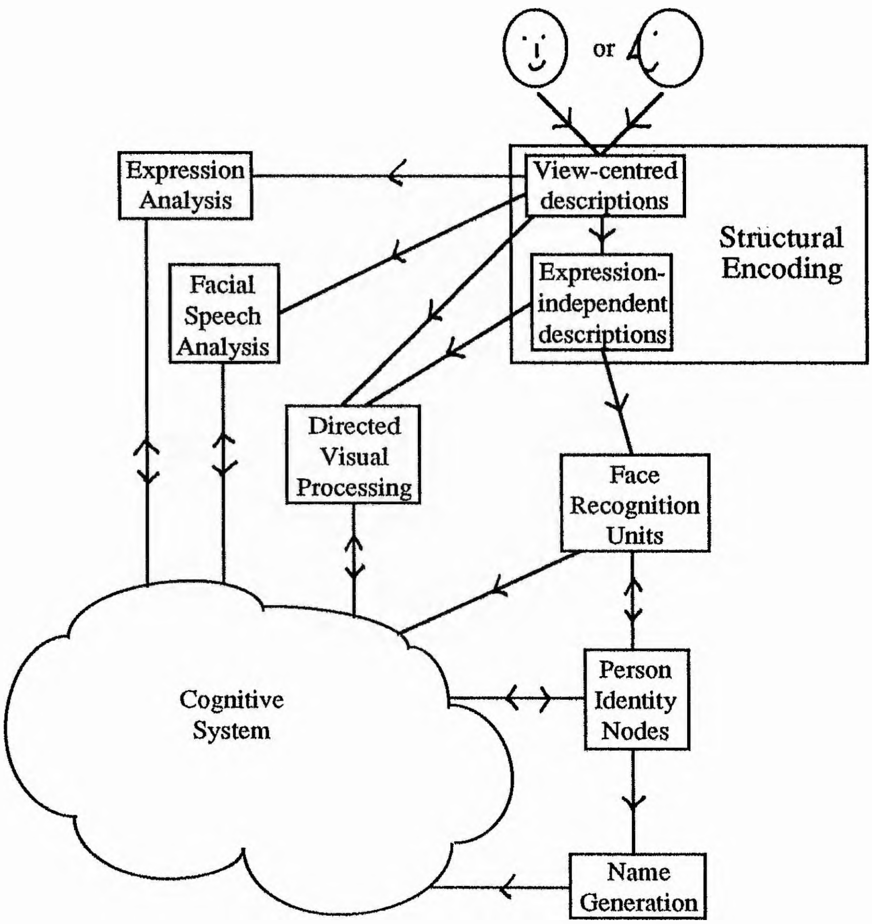

Figure 3.0.5:1

A FUNCTIONAL MODEL FOR FACE RECOGNITION (adapted from Bruce & Young 1986). The results from the photographic caricature latency studies are in accordance with this model. The short name/face matching latencies procured in Experiment Two are commensurate with information processing occurring at the *Face Recognition Unit* and *Person Identity Node* stages. Semantic information about an individual is thereafter accessed (*Person Identity Nodes*; Experiment Four), and is, in turn, processed before the retrieval of an individual's name (*Name Generation*; Experiment Three).

3.1 Line-drawing Caricatures

Three experiments are reported which examine how impoverished representation affects human perception and subsequent recognition of highly familiar faces. The studies are critical of the methodologies of previous work and offer significant improvements.

3.1.1 Experiment Five
Are Line-drawings with Caricature Exaggeration Perceived as Truer Likenesses of Famous Faces?

Introduction

Faces can be recognised under a wide range of conditions. The target individual may be disguised, have aged, or the viewing perspective may be altered; illumination conditions and contextual information may also vary. Despite this we are readily able to identify many thousands of people quite accurately. When the medium through which a person is imaged changes, recognition may become more difficult. The face may be a photograph, or on film or television. It may be represented in a painting, which may be considered a good or a bad likeness. An artist's sketch may also render an image of the individual yet the sketch may not quite capture some essential qualities about the appearance of the face. A child's drawing of the face will almost certainly not be accurate. Yet all such images are supposed to represent one thing: the facial identity of an individual. It is astonishing then to discover that impoverished cartoons and caricatures are actually quite good at capturing the likeness of well-known people we are familiar with from the Press and television.

Caricatures in the media it seems are often *better* representations of an individual than a portrait photograph, but this can be for a number of reasons. First, caricatures are often topical and relate to a particular world event with which we can readily associate, and picking out the relevant characters embroiled in the scene is quite easy. Second, the cartoonist or caricaturist is able to draw upon a wealth of experience and knowledge about the appearance of a familiar face and can use this to embody a great deal more character and personality in the drawing through expression, pose, and gesture than a single photograph ever could. Caricatures thus make statements about people. Third, caricature is economical in terms of the detail required to convey particular aspects of information. Successful caricature depends on a number of issues, as distortion away from the veridical configuration tends to obliterate likeness. Careful and subtle enhancement of facially distinctive features, without reference to personality traits or bestial resemblance, is sufficient to produce a good caricature which is eminently recognisable as a particular person (Gibson 1971; Perkins 1975; Brennan 1985).

Experiments One through Four used a software system to systematically distort computer images of famous faces based on the formal mathematical model of caricature developed by Brennan (1982, 1985). In perceptual tasks where subjects chose an image most like the target person, the subjects were able to see that some of the images were distortions and this was reflected in the small caricature advantage conferred by the best likeness paradigm. The average level of caricature exaggeration producing best likeness was only 4% for highly familiar faces and veridical (0%) for those which were personally familiar. In the naming recognition task it was observed that although subjects reported seeing caricatures as distorted images they were in fact faster and more accurate when naming caricatures than veridical images. The level of caricature producing fastest name/face matching responses was on average 19%; semantic classification of faces was most efficient (reaction-times and accuracy) for undistorted images of personally familiar faces.

The study using line-drawn caricatures of faces by Rhodes, Brennan & Carey (1987) found a naming reaction time advantage in the recognition of 50% caricatures of familiar faces (departmental staff and students) over veridical drawings (0% caricatures). This was somewhat offset, however, by a (not significantly) lower recognition accuracy for the caricatures. Again the caricature advantage was diminished in a perceptual task requiring subjects to choose one of 7 images most like a target face (mean level of caricature producing best likeness, 16%).

Davies, Ellis & Shepherd (1978) demonstrated greater recognition accuracy for photographs than for fairly detailed line-drawings than for outlines (which are referred to as line-drawings in these experiments). One would perhaps expect to find no facilitation using photographic caricatures because such images are still photographic images of those people and include texture details which might form the basis of recognition independent of caricature. Artists' caricatures seem to work because they contain an essential minimum of information which we use to recognise their targets (Hagen & Perkins 1983) whilst being distortions of facial character in some way or other. Shepard (1984) argued that the psychometry of reduced input to the visual system by means of impoverished representations of natural objects may be a better and more controlled means for determining the properties of internal representations for classes of objects. It was shown in Experiments One through Four that this is not necessarily a requirement for the study of facial caricature as photographic images also confer a perceptual and recognition advantage.

Because line-drawings are more closely related to the cartoonist's representation of caricatured individuals than photo-caricatures, it is important to discover if a stronger caricature advantage could be found with famous faces using an optimal version of Rhodes, Brennan & Carey's (1987) perceptual task but again using highly familiar faces. If found, this would have implications for both representation and recognition.

Experimental Background

Previous perceptual studies of computer-generated facial caricatures have used fixed interval stimuli gradations (25%, Rhodes, Brennan & Carey (1987); 16%, Experiment One; 25%, Experiment Four). This does not permit subjects access to at least a 'theoretical full range' of stimuli, -100% (norm) to 100% ('twice' the person). Results from these experiments indicate an optimal level of caricaturing only slightly exaggerated from veridicality (4 to 16%). In a perceptual study examining exaggeration of facial distinctiveness, each stimuli has a mean range within which caricaturing will be most effective, accounted for by the variance in analyses of individual faces. This range does not necessarily apply to other faces. Hence, fixed stimuli sets can either prevent any caricature advantage being found, or minimise it by increasing variance in the data.

Experiments using line-drawn (Rhodes, Brennan & Carey 1987) and photographic (Experiment One) caricatures have suggested that some of the variance in the analysis of the target face data could be explained by the fact that some faces caricature 'better' than others, that is different faces require different levels of exaggeration to produce a caricature advantage relative to veridical representation. The level of exaggeration may well relate to the distinctiveness of the target face and it's familiarity (Experiments One through Four).

The central aim of this experiment was to determine how accurately subjects could estimate the best or truest likeness of famous faces from memory. It was considered important to see if by permitting subjects to interact with the level of facial caricature (and hence veracity of representation) whether more consistent evidence could be obtained for caricature exaggeration than that of previous estimates of perceptual best likeness.

Previous experiments have tended to focus on familiar but not famous faces (or has employed a small set of famous, or highly familiar, faces). The success in finding a caricature advantage may depend on familiarity. Rhodes, Brennan & Carey (1987) found no advantage for unfamiliar faces, and Rhodes & McLean (1990) found no advantage for caricatures of birds conferred by non-ornithologists. Experiment One showed with a small number of faces a correlation between familiarity and exaggeration in 'best likeness', while Experiment Four demonstrated no effect of caricature enhancement for faces of low familiarity. Therefore one might expect to find a stronger caricature advantage when *famous* faces are used as targets.

As accurate line-drawings are very poor representations of individuals (Davies, Ellis & Shepherd 1978; Rhodes, Brennan & Carey 1987) it may be necessary to enhance accurate line stimuli in order to capture any inherent likeness for an individual. It may also be the case that for individuals who have more angular faces (square jaw, straight or sharp nose, pointed ears, etc.) that line-drawn faces composed of features rendered with straight line segments would produce better likenesses than an equivalent representation using smooth curves. The present experiment manipulated the style of line depictions (straight lines or curves) in a further attempt to define optimal conditions for caricature effects to be obtained.

Since the principle behind caricature generation relies upon the selective exaggeration of atypical features, the present study included assessment of facial distinctiveness. There should therefore, exist some relationship between estimations of veridicality and estimations of perceived distinctiveness.

Methods

Subjects

13 male and 19 female subjects took part in the 'best likeness' experiment. A further 7 male and 12 female subjects gave assessments of facial distinctiveness. All subjects took part voluntarily.

Stimuli

30 photographic images of famous faces (from film, TV, politics), 15 male and 15 female, were frame-grabbed. Following the procedures described in section II 165 feature points were manually logged on each facial image, each feature described by a fixed number of points. Joining the Cartesian information appropriately with line segments or spline curves produces an accurate line-drawing representation of that person's face. The number of points was reduced from that used in previous experiments (approximately 180, Brennan 1985; Rhodes, Brennan & Carey 1987; Experiments One through Four) because a number of facial features cannot be either consistently or reliably delineated from photographs. Features not included were cheekbones, under eye lines, chin cleft and protrusion line. The resulting line images were clearer representations of the face, those lines not used would perhaps be better represented in drawings by shading. All target

faces were represented with an identical number of lines or spline curves (Figure 3.1.1:1).[19]

Male faces were caricatured with respect to the average of feature points from a large set of male faces, and female faces against a female average.

Procedure

Before the experiment each subject was required to rate their familiarity (whether they knew the person or not) on a list of all 30 names which would be used in the experiment. Experimental data were subsequently analysed only for faces known to subjects.

Subjects were seated at the keyboard and mouse of the IRIS 3130 workstation. They were instructed to produce "the best, or truest likeness" of the person's face which would appear on the monitor using the mouse pointer and graphical slider bar (Figure 3.1.1:2). Moving the slider to the right increased the level of caricature of the target face, and moving the slider left decreased the level of caricature. Subjects were told that within the bounds of the slider range (the *face-space* of the slider) lay the true veridical likeness of the target individual. The concept of caricature was not mentioned and none of the subjects were aware of the nature of the research.

The main window display containing the 2-D line face appeared above a smaller one which contained the slider. Subjects were told that the name of the target face would appear on the title bar on the main window on each trial. The slider scale varied randomly between trials; 5 ranges were predefined each of which covered a range of 300% of face space ie. -50 to 250%, -75 to 225%, -100 to 200%, -125 to 175%, and -150 to 150%. Slider ranges were not visible to subjects. Faces appeared in a random order and initially at a random level of caricature (from the range -150% to

[19]For 28 of the target stimuli the ears were always visible. The remaining 2 faces had half visible features and a guess was made as to their continuing contour when delineating.

Figure 3.1.1:1

LINE-DRAWING CARICATURES. Left to right: anticaricature, veridical, and caricature line-drawings of actor Jack Nicholson. By delineating the facial features on a computer image sets of 2-dimensional coordinates can be derived. Joining these points appropriately produces an accurate line-drawing representation of an individual. The top row shows straight-line representations, and the bottom row shows spline-curve stimuli. 165 feature points were logged on each veridical face.

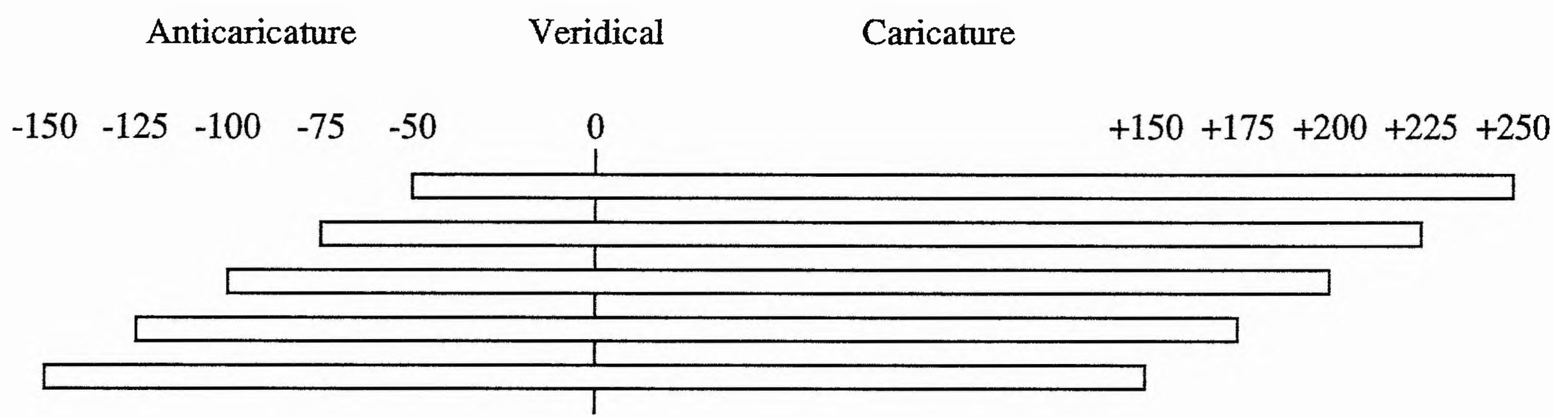

Figure 3.1.1:2

FACE ENHANCEMENT SLIDER. The slider remained a fixed size while the scale values generated varied as shown. One of the 5 scales was chosen randomly on each trial. Resolution was guaranteed to be at least 1%. Anticaricatures (< 0%) regress towards a prototype configuration and hence all faces tend to look the same at this end of the scale. Caricatures (> 0%) accentuate any distinctive featural facial characteristics. Scale gradations were not visible.

250%). Half the subjects interacted with straight line faces ('line'), half with spline curve faces ('curve'). Subjects were told not to be concerned if feature lines crossed in the display, and that this was due for example to hair falling over an eyebrow or ear. No time restrictions were imposed on the duration of the task.

Distinctiveness Ratings

The independent group of subjects were requested to give their ratings of how distinctive they considered each of the target faces to be. Each face was displayed anonymously using the experimental software with 0% exaggeration. Faces were shown without outer hairline or ears; subjects were told to concentrate solely on the internal features and their configuration, and to try to ignore any facial expressions or tilting of the head present. Hair is not necessarily a consistent feature in media pictures of the famous, and one or both ears were not always visible and therefore accurately delineated. Deleting the hair-line was also considered appropriate as this matches the increased importance of internal features for the recognition of familiar faces (Ellis, Shepherd & Davies 1979; Young *et al.* 1985; de Haan & Hay 1986). Ratings were given on a 7-point scale where 1 = an "average" and 7 = a "highly distinctive" face.

Results

On average subjects recognised 89% of the target faces (worst 53%, best 100%). Only four subjects knew less than 80% of the targets.

Analysis across 30 faces revealed that the mean level of exaggeration was highly significantly different from 0% (Planned Comparison, $F(1, 29) = 145.7$, $p < 0.00001$). Estimations chosen to represent accurately famous faces were consistently and highly caricatured. Mean exaggeration was 42% over veridicality. This bears out the hypothesis that line-drawings of even highly familiar people are poor representations of the individual and require caricaturing before they capture some quality of likeness.

Different faces were overestimated by different amounts (1-way ANOVAs, 30 faces by 16 subjects with missing elements (unknown faces), 'lines' $F(29, 425) = 3.21$, $p < 0.0005$; 'curves' $F(29, 430) = 3.63$, $p < 0.0005$. This variability may reflect the distinctiveness of the target face and the choice of original image used for delineation. Some of the original photographs would have been good likenesses of the person in the first place and others not. Figure 3.1.1:3 shows the distribution of the mean level of exaggeration for all 30 famous faces. The caricature of Jack Nicholson shown in Figure 3.1.1:1 is rated at 80% which was chosen, on average, by subjects to be the best likeness of him. The range of exaggerations ranged from 7% for Christopher Reeve to 85% for Prince Charles.

Mode of representation ('curve' or 'line') did not have a significant influence on the level of exaggeration (1-way ANOVA, $F(1, 58) = 1.1$, $p > 0.3$).

Slider scale

Slider ranges did not correlate with estimated veridical chosen for any face, $r_S(28) = 0.029$, $p > 0.1$.

Style of line-drawing

A caricature artist was asked to say for each of the 30 target faces (from memory) whether she would choose to use a 'curve' or 'line' representation. The decision was based on whether that individual would look better when represented by straight lines if they possessed spiky hair, angular features, or square jaw (eg. Christopher Reeve, Glenn Close), or by smooth curved lines for flowing or bushy hair and more rounded features (eg. Bob Hoskins, Madonna Ciccione).

There was no significant difference between veridicality estimations for those faces chosen by the artist to be better represented with 'lines' or 'curves' (planned comparisons, $F(1,27) = 0.667$, $p > 0.4$), and no difference within male, $F(1,12) = 1.44$, $p > 0.2$, or female, $F(1,13) =$

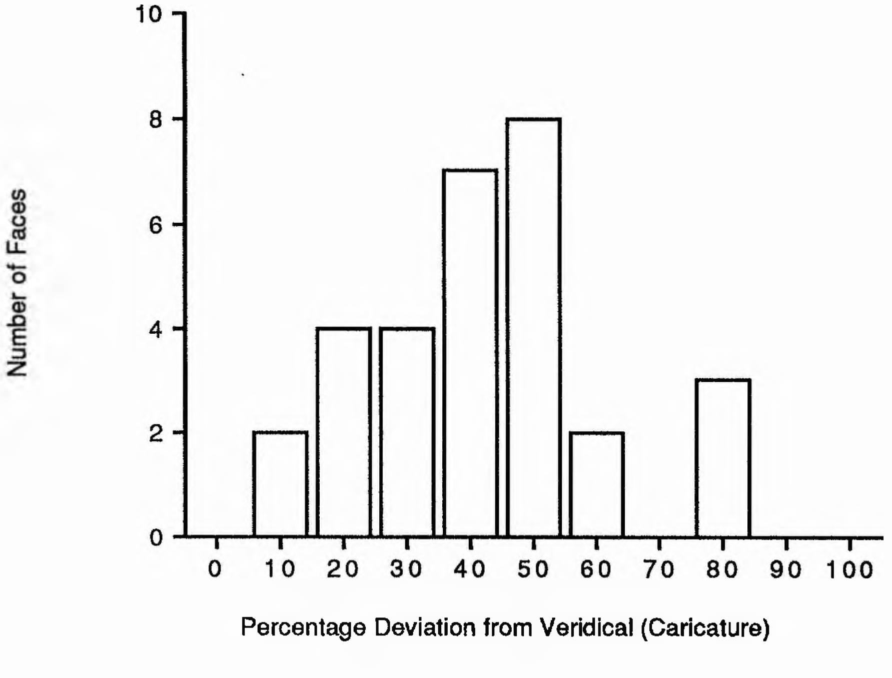

Figure 3.1.1:3

BEST LIKENESS ESTIMATES. Distribution of mean "best likeness" as estimated veridical configuration for line-drawings of 30 famous faces. Means are collapsed to 10% bins. Interpolated mean is 42%.

0.228, $p > 0.6$ target faces. Faces were equally exaggerated regardless of representation style. There was no difference between the artist's best representation and the worst, $F(1, 29) = 0.16, p > 0.6$.

Facial distinctiveness

Ratings of facial distinctiveness correlated with overestimations of veridicality, Spearman's rank correlation $r_S(28) = -0.388$, $p = 0.034$, indicating that typical faces required more exaggeration than distinctive faces to capture some degree of perceived resemblance.

A number of the subjects reported recognising one of the faces as Nicholson from a previous lecture on facial prototypes even though no hair or ears were present in the stimulus. No other faces were spontaneously recognised. As it was undesirable for familiarity factors to influence decisions of distinctiveness, removal of his data from the correlation showed an improvement in statistical significance, $r_S(27) = -0.409$, $p = 0.028$ (Figure 3.1.1:4).

Summary of Results: Experiment Five

Line-drawings describing featural dimensions and configuration do not provide sufficient information about the identity of even highly familiar faces and therefore matching to stored veridical representations is difficult. Because this mode of portrayal is not sufficient to capture a good likeness of the individual, caricature exaggeration based on the normative model is appropriate in enhancing facial appearance to the point where the 'image' assumes a recognisable visage.

Different faces require different degrees of exaggeration in order to achieve this property and such exaggeration is closely related to the perceived distinctiveness of such sketchy depictions, more typical faces receiving greater exaggeration than already distinctive ones. On average, an additional 42% of a person's facial structure had to be added back into their face before resemblance was established.

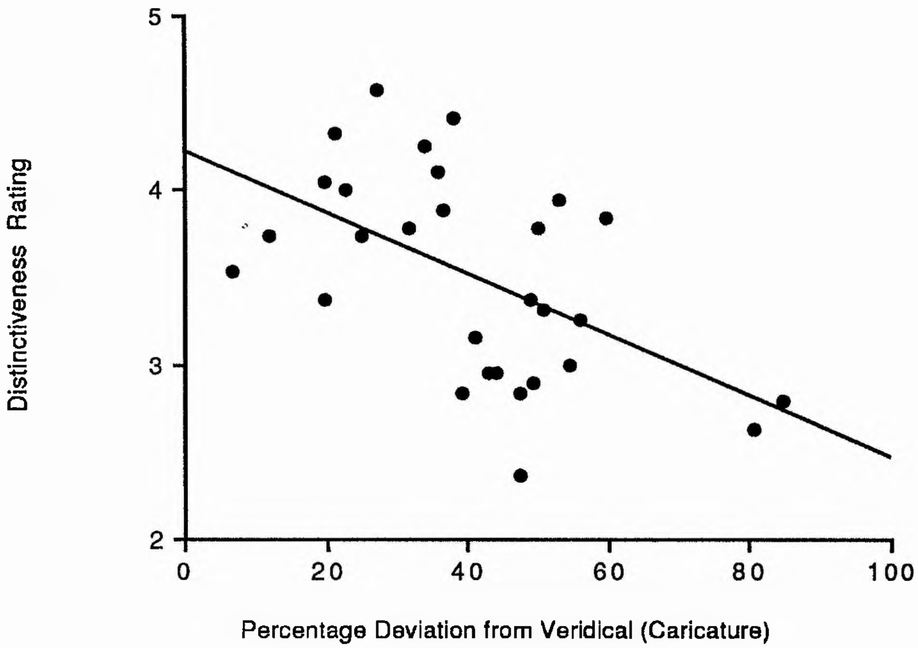

Figure 3.1.1:4

ROLE OF PERCEIVED FACIAL DISTINCTIVENESS. Correlation between mean "best likeness" for each target face and it's perceived distinctiveness ($r_S(27) = -0.409$, $p = 0.028$). Ordinate: ratings of perceived distinctiveness where 1 = "average" and 7 = "highly distinctive". The distribution shows only those faces which were not spontaneously recognised during assessment of the latter (see text). Line-drawings of typical faces are exaggerated more than distinctive ones.

3.1.2 Experiment Six
Does the Absence of External Features Improve Estimations of Veridicality?

Introduction

Experiment Five showed a marked increase in the caricature advantage for line-drawings of highly familiar (famous) faces. As Davies, Ellis & Shepherd (1978) pointed out, faces shown in this way are much harder to recognise. Because the internal features of a face are more useful for identifying familiar faces (Ellis, Shepherd & Davies 1979; Young *et al.* 1985) it was reasoned that removal of the hair and ears (which are not always visible in portrait or publicity photographs) from a famous face line-drawing would serve to increase subjects' reliance on the more consistent features of facial appearance and produce more accurate estimations of veridicality. In Experiment Five, subjects had frequently reported that female faces were particularly difficult to visualise from simple line-drawings as they were more accustomed to the presence of coiffured hair, jewellery, and cosmetics, which were absent through standardisation on the feature set and mode of representation (Experiment One).

Methods

Subjects

20 subjects participated voluntarily in the experiment, 10 male and 10 female. 2 subjects were dropped from the analyses because they failed to operate the software in accordance with the instructions, thus frequently skipped trials.

10 independent subjects, 5 male and 5 female, were given a list of 33 male and 28 female names all of which were considered to be famous in one way or another. These people belonged to film, television, and politics. Each subject rank-ordered the male and female faces separately according to how famous they considered that person to be. The mean 'famousness' of each person was calculated.

Stimuli

The top 50 most famous persons' photographic facial images (25 male and 25 female) were frame-grabbed and delineated. Line-drawing representations of the faces were made by joining feature points using spline curves. Outer hair-line and ears were not shown (Figure 3.1.2:1).

Male faces were caricatured with respect to a male norm, and females against a female norm.

Procedure

Before the experiment, subjects were required to complete a familiarity ratings form which listed all 50 faces to be used in the experiment. Familiarity was given on the scale of 1 ("don't know this person") to 7 ("highly familiar"). Data were only analysed for faces known to each subject (*familiarity* > 1).

As in Experiment Five, subjects were requested to produce "the best, or truest likeness" of each of the persons' faces which would appear on the screen. Using the computer mouse and a graphical slider, they were able to apply linear distortions to the appearance of the named individual according to the caricature algorithm. The name of the face appeared in the title bar of the window display. The slider bar appeared in a lower window with no indication of its scale or range. 1 of 5 possible ranges were applied randomly on each trial with starting level of exaggeration at a random position. Slider ranges covered -50 to 250%, -75 to 225%, -100 to 200%, -125 to 175%, and -150 to 150% levels of exaggeration. Moving the slider left decreased the facial distinctiveness towards and beyond prototypicality; moving the slider right increased distinctiveness producing caricatures. Each face was presented once only. No time restrictions were imposed on the duration of the task.

Results

Figure 3.1.2:1

LINE-DRAWING CARICATURES SHOWING INTERNAL FEATURES. Left to right: anticaricature, veridical, and caricature line-drawings of actor Jack Nicholson displayed using spline-curves.

The mean level of exaggeration over best likeness was only 5% (standard error, 10.23). Analysis showed that this was not significantly different from veridicality (0%), $F(1, 49) = 2.89$, $p > 0.1$ (Figure 3.1.2:2).

Analyses across the 50 faces showed that different faces were exaggerated by different amounts, 1-way ANOVA, $F(49, 742) = 3.77$, $p < 0.0005$.

Different subjects exaggerated faces by different amounts, 1-way ANOVA $F(17, 742) = 10.26$, $p < 0.0005$.

Familiarity

There was no correlation between the mean level of familiarity for target faces and the mean level of exaggeration afforded to each, Spearman's Rank Correlation $r_s(48) = 0.053$, $p > 0.7$.

Slider Scale

There was no correlation between the slider range used and the mean level of caricature produced for each face, $r_s(48) = -0.07$, $p > 0.6$.

Famousness

There was no correlation between how famous the faces were considered to be by the independent raters and the mean estimations of veridicality, Spearman's Rank Correlation $r_s(48) = -0.04$, $p = 0.8$.

Male and Female Faces

There was no significant difference between exaggerations for male (9.1 ± 18.2%) and female (0.9 ± 22.8%) faces, Independent Samples *t*-test $F(1, 48) = 1.99$, $p > 0.17$.

Summary of Results: Experiment Six

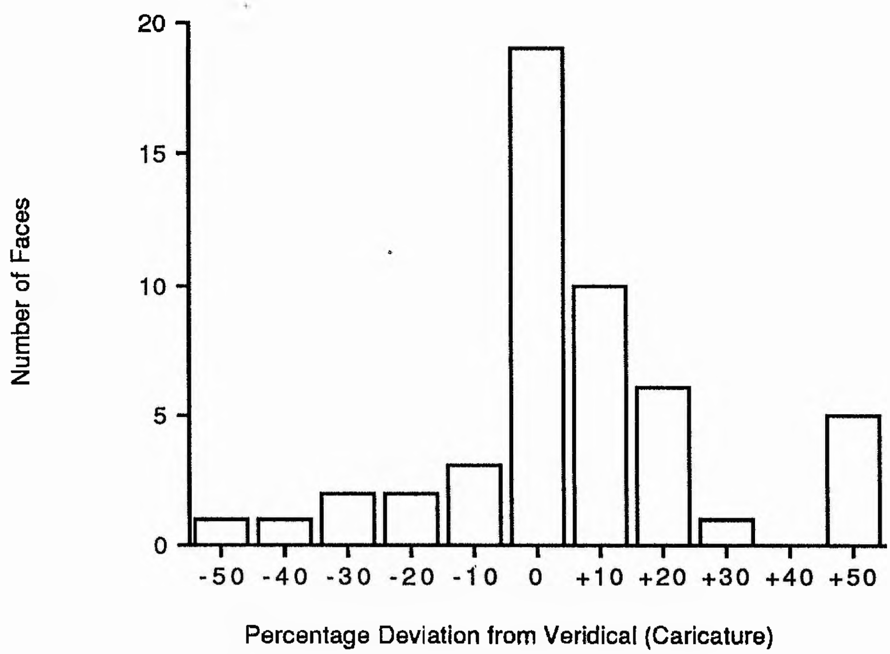

Figure 3.1.2:2

BEST LIKENESS ESTIMATES. Distribution of mean "best likeness" as estimated veridical configuration for line-drawings of 50 famous faces shown without external features (hair, ears). Means are collapsed to 10% bins. Interpolated mean is 5%.

As predicted, the absence of external facial features reduced the caricature advantage significantly to the point where, on average, highly familiar faces were accurately represented using line-drawings. There was no facial gender difference in degree of exaggeration, male faces being equally accurately estimated at veridicality as females. Neither the degree to which subjects were familiar with known faces nor the slider ranges available during the task were responsible for the predicted result. The result also indicates that interactive manipulation of line-drawings does not inevitably produce positive levels of caricature.

3.1.3 Experiment Seven
Can Optimised Likenesses of Famous Faces Improve Identification?

Introduction

As has been suggested by results in Experiments One through Four, individual faces caricature best with different levels of exaggeration. Experiment Five demonstrated the need to perceptually 'feel' when a face looked most like a named person. In this way it was possible to maximise the caricature advantage found in estimations of "best likeness" as originally described by Rhodes, Brennan & Carey (1987) and followed up in Experiment One. From these findings one would now predict that a recognition advantage should be found for caricatures which were first estimated to be the most suitable representation instead of applying discrete levels of exaggeration as before (Rhodes *et al.* (*ibid.*); Rhodes & McLean (1990); Experiments One through Four).

Part One: Estimation of Veridicality

Methods

Subjects

20 naïve subjects took part in the experiment voluntarily, 5 were female and 15 were male.

Stimuli

The 50 famous faces which had been delineated in Experiment Five were used for this study. Ears and outer hair-line were included in the line-drawings of the faces.

Procedure

Before the experiment, subjects completed a familiarity ratings form covering all 50 target faces, in which the scale ranged from 1 ("don't know this person") to 7 ("highly familiar"). Data were only analysed using responses to known faces.

The task was as in Experiments Five and Six, to make "the best likeness" of each of the named faces using the graphical slider the scale of which varied randomly from trial to trial as before.

Results

The findings of Experiment Five were replicated in that the mean level of exaggeration applied to faces in order to achieve good likenesses was significantly different from veridicality (53.7 ± 12.2%), $F(1, 49) = 131.6$, $p < 0.00005$.

A 1-way ANOVA revealed that faces were exaggerated by different amounts, $F(49, 894) = 6.82$, $p < 0.0005$.

Subjects again performed differentially in the task, some preferring stronger caricatures on average to others', 1-way ANOVA $F(19, 894) = 7.5$, $p < 0.0005$.

Familiarity

No correlation between the mean level of familiarity for target faces and the mean level of exaggeration was found, Spearman's Rank Correlation $r_s(48) = 0.061$, $p = 0.67$.

Slider Scale

There was no correlation between the slider range used and the mean level of caricature produced for each face, $r_s(48) = 0.059$, $p > 0.6$.

Famousness

There was no correlation between how famous the faces were considered to be by the independent raters in Experiment Five and the mean overestimations of veridicality, Spearman's Rank Correlation $r_s(48) = -0.13$, $p > 0.1$.

Male and Female Faces

There was a significant difference between exaggerations for male and female faces, Independent Samples *t*-test $F(1, 48) = 5.76$, $p = 0.02$. Male faces (64.5% ± 31.2%) were exaggerated far more than females' (43 ± 32.2%).

Part Two: Recognition of Optimised Line-drawn Caricatures

Methods

Subjects

12 naïve subjects took part in the experiment, 6 male and 6 female. A £10 token was awarded to one subject chosen in a lottery draw.

Stimuli

17 of the 50 faces used in Part One were used on the basis of the strongest exaggeration applied and most highly familiar rating awarded in that experiment. An additional 3 faces were selected for use as practice trials.

Equipment

Verbal responses were recorded on a Sony TC-161SD stereo cassette recorder using standard audio magnetic tape. On one channel, a Sharp PP-150 microphone was attached to the IRIS keyboard which sounded a clear tone synchronised to the appearance on each trial. A lapel microphone with clip (Radio Spares part number RS 250-485) was secured to the subjects' clothing to pick up spoken responses, and was connected to the remaining recorder channel. Microphone sensitivity was manually set on the cassette deck before the experiment began.

Procedure

Subjects were shown a list of names, each of which whose face would appear during the recognition experiment. This was done so as to familiarise subjects with the likely candidates which would follow. Each face appeared twice, once as a veridical and once as a caricature whose optimal level of exaggeration had been specified in Part One. Subjects were required to verbally name each target as quickly and as accurately as possible. A time-out period of 30 seconds was imposed, after which the following face would be displayed. Subjects indicated failure to recognise a face with a "don't know" response. The experimenter pressed the keyboard space-bar to cue the next trial. Each experiment lasted approximately 15 minutes. The session began with 6 trials of practice faces followed by the main experimental block.

Analysis

Collation of naming latencies was performed off-line using a hand-held stopwatch (Zeon ZR949252SL) in response to audio playback on a standard cassette deck. This method of latency measurement and the 100th/second accuracy was sufficient given the difficulty of the task (see Rhodes, Brennan & Carey 1987, and Experiment Three). The computer tone at the start of each trial was interpreted as stimulus onset and first meaningful vocal reaction as the latency. Each experimental session was analysed twice and the mean recorded in milliseconds for each trial.

Results

1 subject was dropped as they failed to recognise any of the target faces. A further 1 was omitted from the analysis due to tape recording problems.

Reaction-times

The mean naming latency for subjects' responses to veridicals was 6000ms, and for caricatures 3830ms. There was a significant improvement in reaction-times to caricatures over veridicals, Planned Comparisons $F(1, 9) = 5.9$, $p = 0.038$, of over 2 seconds (36% speed-up; Figure 3.1.3:1).

A by-face analysis did not show any significant difference between those shown as veridicals (4521ms) and caricatures (3935ms), $F(1, 16) = 0.77$, $p = 0.39$. Particular faces showed very poor hit-rates.

Accuracy

Subjects' responses were also more accurate when naming the caricature condition (64% correct) than the veridical (50%), Planned Comparisons $F(1, 9) = 10.76$, $p = 0.01$. In responding quicker to caricatures, subjects were not less accurate and showed a 28% improvement in recognition accuracy (Figure 3.1.3:2).

Some faces were more accurately recognised in the caricature condition (38% correct) compared with the veridical (29%), $F(1, 16) = 21.5$, $p = 0.001$.

Summary of Results: Experiment Seven

The results of Experiment Five (whole face present) were replicated and slightly enhanced where line-drawings of famous faces required high levels of caricature exaggeration in order to capture good likenesses of that person.

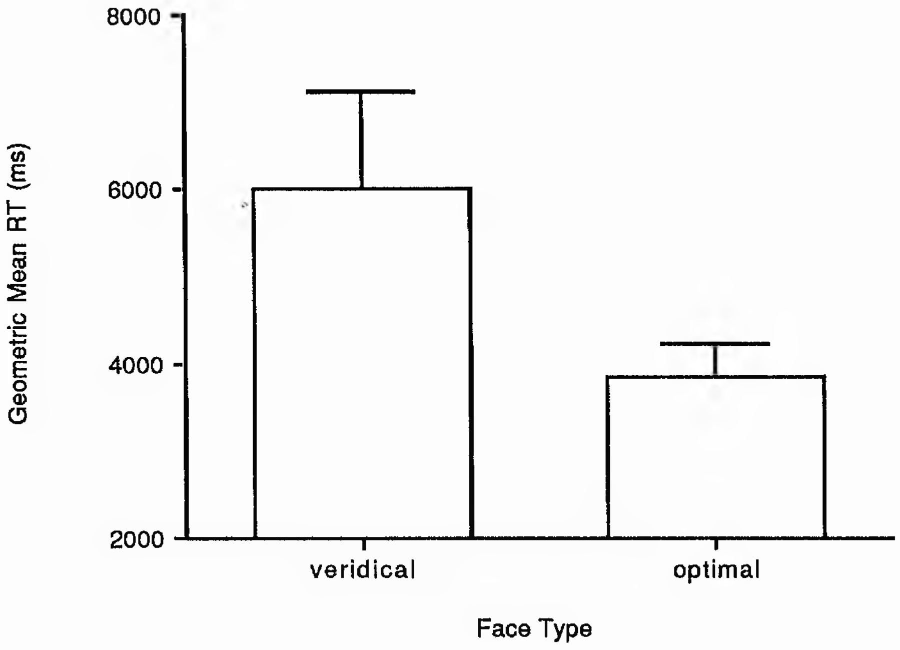

Figure 3.1.3:1

VERBAL NAMING LATENCIES. Mean naming latencies for subjects' responses to veridical and optimised caricatures of line-drawings of 17 famous faces. Reaction-times to caricatures were over a third quicker than to complementary true images ($F(1, 9) = 5.9, p = 0.038$).

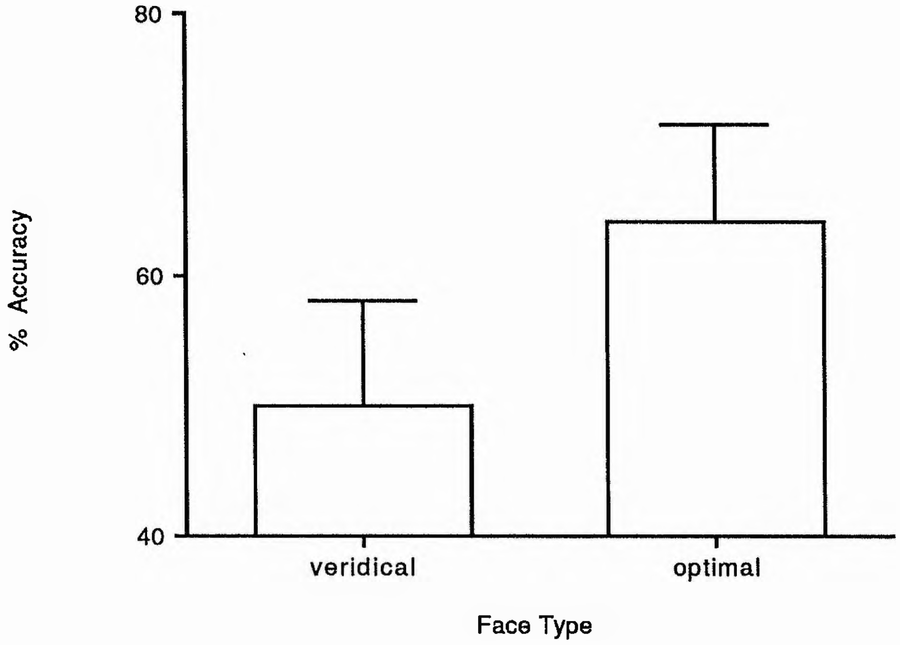

Figure 3.1.3:2

NAMING ACCURACY. Mean naming accuracy for subjects' responses to veridical and optimised caricatures of line-drawings of 17 famous faces. Caricatures facilitated a 28% improvement over the complementary veridical images ($F(1, 9) = 10.76$, $p = 0.01$).

Using these optimal levels for particular faces it was shown that caricatured 'images' were both more quickly and accurately named than their veridical counterparts. Latency results are very similar to those found by Rhodes, Brennan & Carey (1987), and accuracy appeared to be improved by using (i) optimised caricatures, and (ii) highly familiar (famous) faces.

3.1.4 General Discussion Line-drawn Caricatures

Line-drawing Caricatures

Formal studies of line-drawn facial caricatures (Rhodes, Brennan & Carey 1987; Experiments Five, Six and Seven) and birds (Rhodes & McLean 1990) have used stimuli which all lack textural information. Neither of the classes of objects used (faces or birds) exist behaviourally as line-drawn (outline) images. Recognition must therefore be based on information available from feature closure (bounding lines) and local configural information (relative inter-feature positions). In essence we would perceive the face from the complex arrangement of lines/curves. Recognising this geometric signature as belonging to a particular individual takes far longer than it does to recognise the corresponding photo-realistic image. Recognition of individuals from configural and feature information without complementary shading and textural patterns is so difficult that other cues have to be used.

Enhancing features by caricaturing them, ie. increasing the apparent distinctiveness, is one way in which likeness and recognisability can be improved. The above experiments have shown this to be a valid way of increasing the symptoms of identity.[20]

[20]The software provided performs this enhancement in a linear space. Real caricaturing does not work this way, but rather in a piecemeal manner concentrating perhaps on only a few features, accentuating them in many non-linear ways. An exponential or logarithmic caricature function may improve any advantages seen under experimental conditions. Ultimately the unquantitative combination of several kinds of interactive exaggeration would produce results most similar to those of the caricature artist.

Limitations of starting image

Ideally, one would examine the recognition of synthesised caricatures using several instances of an individual's face. One would expect to find similar exaggerations for many instances of one person. This would get round the problem of the possibility that the original choice of a single photograph did not quite capture a good likeness of the person. If the original photograph is 'atypical' then caricaturing the face is unlikely to enhance perception or recognition (cf. Experiments One through Four). Using such atypical or impoverished representations of an individual may therefore have reduced the caricature advantage found in this paper.

Selection of a good quality original image is important. It is quite likely that one image of a person may not be a good likeness especially if a portrait style pose has been struck. Pictures which capture some articulatory and perhaps characteristic expression are more likely to contain some measurable distinctive quality than a neutral pose. Another way to accomplish this is to produce a photographic composite of an individual and from this image delineate the veridical feature configuration (section 2.1). Taking several photographic instances of one person (different views and expressions) a photographic average of them can be forged by first regressing all the images to their common configuration defined by the averaged delineation data and then numerically blending these aligned images. The process produces a high quality average portrait with well-defined features which is a very good likeness of the person and contains much of the essential visual characteristics unique to them.

Conceptualising the appearance of a famous person from a line-drawing and their name may produce conflicting ideas about their appearance. At the end of the line-drawing experiments some subjects reported "that's not how I remember him/her".

Face Exaggeration Variation

Although the level of overestimation ranged from 42% (Experiment Five) to 54% (Experiment Seven, Part One), there was considerable and significant variation in the data for the individual target faces. Different faces were caricatured to best effect at different levels. The source of variation could have arisen for two reasons. The first is technical and due to limitations of the starting image. The second is more interesting and attributable to facial distinctiveness. The negative correlation (see discussion on distinctiveness) indicated that more distinctive faces were caricatured to a lesser extent, whereas in typical faces, any small deviation may require very marked exaggeration before it can be recognised.

Consistency in Line-drawn Stimuli

In the studies of Rhodes, Brennan & Carey (1987) the line-drawn faces did not have a consistent number of facial features visible. If a smile line was not visible on one side of the face then it was omitted. These disparities across faces presents an asymmetric feature set, some faces having more lines than others, although the main features were always highlighted (eyes, nose, mouth, jaw, hair). Although the resulting line faces may have been characteristic of target faces, this imbalance may have caused some distraction to subjects. Many of the lines which would be omitted under such circumstances are indicative of those areas which are perhaps better rendered by shading in a detailed drawing. Methodologically, the line-drawings used in the present experiment used what may have represented a more effective and consistent feature set. All faces were imaged using the same number of lines.

Style of Line Representation

Although the 'curve' faces were perhaps a more natural representation there was no difference between the two styles of faces in Experiment Five, and no effect of which convention an artist considered to be a better representation for a particular face. All previous experiments using Brennan's model of caricature have used the 'curve' representation.

Familiarity and Coding

The study by Rhodes, Brennan & Carey (1987) included an experiment using faces unfamiliar to subjects. Subjects rated veridical line-drawings to be the best likenesses of the person depicted either when recalling the face from memory or directly matching it to a photograph. Line-drawn caricatures (25%) and anticaricatures (-25%) were perceived as worse representations. In another study, Rhodes & Moody (1990) also found that unfamiliar faces were not susceptible to caricature enhancement. Thus the "best likeness" task *can* be done accurately for faces recalled from memory. This finding is important in the interpretation of Experiments Five and Seven (Part One). It indicates that the caricatures are most effective when depicting faces subjects are highly familiar with. Rhodes & McLean's (1990) study of bird caricatures showed a recognition improvement for caricatures by expert subjects (ornithologists), but not by subjects who were merely 'familiar' with the birds. In the line-drawings experiments above, almost all subjects knew the appearance of the named individuals. By using highly familiar and famous faces the likelihood of finding a caricature superiority in a veridicality/best likeness task was increased. Highly familiar faces (and birds) coded in long term memory appear to be better accessed by line-drawings which are enhanced by increasing their perceived distinctiveness (see Winograd 1981).

Visual Frames of Reference

Absence of a bounding frame of reference, such as the outer hair-line in Experiment Six, disrupted the overestimation effect indicating the importance of internal features on the accuracy of perceived likenesses. When dealing with facial features and dimensions which *directly* relate to visual identity subjects process the available information in a manner which is quite different from holistic face processing (see also Ellis, Shepherd & Davies 1979, and Young, Hay & Ellis 1985). It is suggested that we make considerable reference to the image or drawing boundary (hair and jawline), at least when dealing with impoverished line-drawings, even when we are dealing with highly familiar faces. Although internal features are more useful for identifying familiar faces some reference *is* made to the hairline and face outline, and when this is done these outer features interact with visual interpretation in a very powerful manner. A comparative reaction-time study is required to determine the usefulness of such frames of reference using both veridical and distinctiveness enhanced line-drawings and images.

Slider Scale

The choice of slider scale ranges could have contributed to the caricature advantage. 4 out of the 5 scales had 0% (veridicality) invisibly offset to the left of the scale, and only 1 of the scales (-150 to 150%) was symmetrical. Faces represented to the left end of the slider tended to look the same regardless of the target face because they regress towards their population prototype and therefore look less like the named individual. Faces represented to the right of the slider have any distinctive features enhanced according to the caricature algorithm and the degree of likeness increases. Setting the slider at random positions or in the middle of the scale could therefore have artificially produced a positive degree of exaggeration. The slider ranges, however, never correlated with the exaggerations yielded in the task, and this did not bias subjects' estimations of veridicality in the positive domain (Experiments Five and Seven: Part One). In Experiment Six, the lack of influence of the slider ranges is evidenced even more strongly in that removal of external facial features forced subjects to rely on the internal features in order to make their perceptual judgements.

Subject Variation

Subjects' mean responses varied considerably. This difference may have been related to the degree of familiarity subjects had with the target faces. Additionally, line-drawings may not have been particularly easy to deal with for some subjects. Both of these factors account for the high variance in the subjects' responses. It is interesting to speculate that the degree of exaggeration employed by individual subjects may reflect different memory strategies. Rhodes, Brennan & Carey (1987) report an exceptional subject who had experience drawing faces and whose accuracy was very high for recognition of caricatures, veridicals, and anticaricatures. It is quite possible that at least some of the variation these studies may reflect experience with line-drawn depictions, as was also noted by Rhodes & McLean (1990).

Distinctiveness

The more distinctive a face is the more able we are to recognise it because it differs from others in particular ways (Valentine & Bruce 1986a, 1986b; Rhodes, Brennan & Carey 1987; and Experiments reported here). At a subjective level, distinctiveness is often difficult to quantify because subjects often erroneously rate how familiar a person is or how distinctive their personality is. In Experiment Five this confounding effect was avoided by asking subjects to rate faces anonymously, making their decisions more objective. Subjects were aware they could introduce distortions into the drawings yet they were not so gross that estimations of veridicality were impaired in the sense that 'facial harmony' was upset. Exaggerations of distinctiveness for typical faces were required in order to capture some degree of best likeness.

Recognition Accuracy and Latencies for Line-drawings

Experiment Seven replicated the findings of Rhodes, Brennan & Carey (1987: Experiment One). The mean reaction-times for veridicals (6s here, and 6.4s) and caricatures (3.8s here, and 3.2s) were remarkably similar showing on average a 36% improvement in the time to name a line-drawn face. This experiment improved on the accuracy of responses by using famous faces compared with personally familiar ones, and by using individual levels of caricature estimated to be the most appropriate for each face by independent subjects. Comparing accuracies across the two studies shows that in the case of caricatures (38% here, and 33% Rhodes *et al. ibid.*) subject accuracy improved slightly. In the veridical case (29% here, and 38% Rhodes *et al. ibid.*) there was slight decrement. [Recognition accuracy for photographic and line-drawn ('outline') stimuli are also commensurate with the findings of Davis, Ellis & Shepherd (1978).] In comparing the veridical and enhanced stimuli it is clear that caricatures do support the idea that improved matching is possible according to distinctiveness encoding in the norm-based model of familiar face encoding.

3.2 Semantics of 'Caricature' Generation

The experiments reported in sections 3.0 and 3.1 used a norm-based model for the generation of realistic caricatures. Under this regime, a target face was compared with a suitably age- and sex-matched prototype. Differences in feature dimensions and configuration were calculated and interpreted in terms of the facially distinctive properties of particular individuals.

As Brennan (1985) pointed out it is possible to generate 'caricatures' by comparing one face with *any* other; the semantics of such deformations vary considerably. Comparing one person's face with another leads either to exaggerations which push each face further away from each other, or diminish differences such that one face takes on the appearance of the other. The regression effect is briefly examined in sections 3.2.1 and 3.2.2.

These manipulations form the basis of a large number of important facial transformations whose methodological application lies in studies of categorical perception (Etcoff & Magee 1992). The novel techniques described in sections 3.3 to 3.6 allows the study of a range of important phenomena for the first time.

3.2.1 The Identity Transform

Introduction

Merging digitally stored images is not a new idea. It is a trivial matter to blend one image frame into another by means of interpolating between the intensity values at corresponding pixels in the two images. Computers are ideally suited to this kind of numerical work. They are used to produce the familiar 'slow dissolves' in television and film, where one scene fades out and another scene simultaneously emerges. The dissolve can be applied to two images of faces. Transforming face A into face B simply by dissolving one image into another creates the problems described above whenever the features are not aligned. The result of poor alignment is equivalent to double exposure in photographic terms, so that the composite may end up with two mouths, etc. The aim, therefore, is to use the accuracy of the feature delineation information to produce clean, ghosting-free, transformations.

Methods

One face can be merged into a second using the methods for obtaining facial anticaricatures. Regressing face A into the shape of face B is defined as a 100% anticaricature transformation. Performing this in a number of discrete steps defines an increasing deformation of one face towards the other in terms of the configural properties of each face. Having done this it is necessary to consider how each of the individual faces affects and is affected by each step.

Figure 3.2.1:1 shows the procedure for transforming the face of Margaret Thatcher into John Major's. Thatcher's face is first rendered at each 25% stage in the sequence, 25, 50, and 75%. The 100% transform is not required, as at this stage only Major's face is required (the complete transform). Major's face is also rendered at each 25% stage towards the shape of Thatcher's. At each transformational stage (75, 50, and 25%) pairs of faces have been generated which share an identical facial shape as shown in the Figure. Blending of these pairs of images is weighted in accordance with the particular stage in the transformation.

Results

The transformation process is illustrated in Figure 3.2.1:2.

Comments

The resulting effect is quite startling and often amusing.[21] At half way through the transformation (50%) there is just as much of person A in the image as there is of person B. When examined closely one's perceptual interpretation can easily flip between the identities. At one moment it may look more like Thatcher, at the next it seems more like Major. It is

[21] A list of reference material produced in the Media is given in Appendix IV.

Thatcher's distortion	**Margaret Thatcher** →	25 →	50 →	75	% configuration change
Major's distortion	% configuration change	75 ←	50 ←	25 ←	**John Major**
image blending ratios	100:0	75:25	50:50	25:75	0:100

Figure 3.2.1:1

ALGORITHM FOR 'IDENTITY' TRANSFORMATION. In the photographic identity transformation, 2 sets of facial shape changes are prepared. First, Thatcher's face is distorted in steps towards Major's. Next, Major's face is distorted towards Thatcher's configuration. In this way, pairs of images whose facial shape is identical are generated; only the skin textures differ. The final sequence is produced by blending respectively decreasing and increasing amounts of the images intensities.

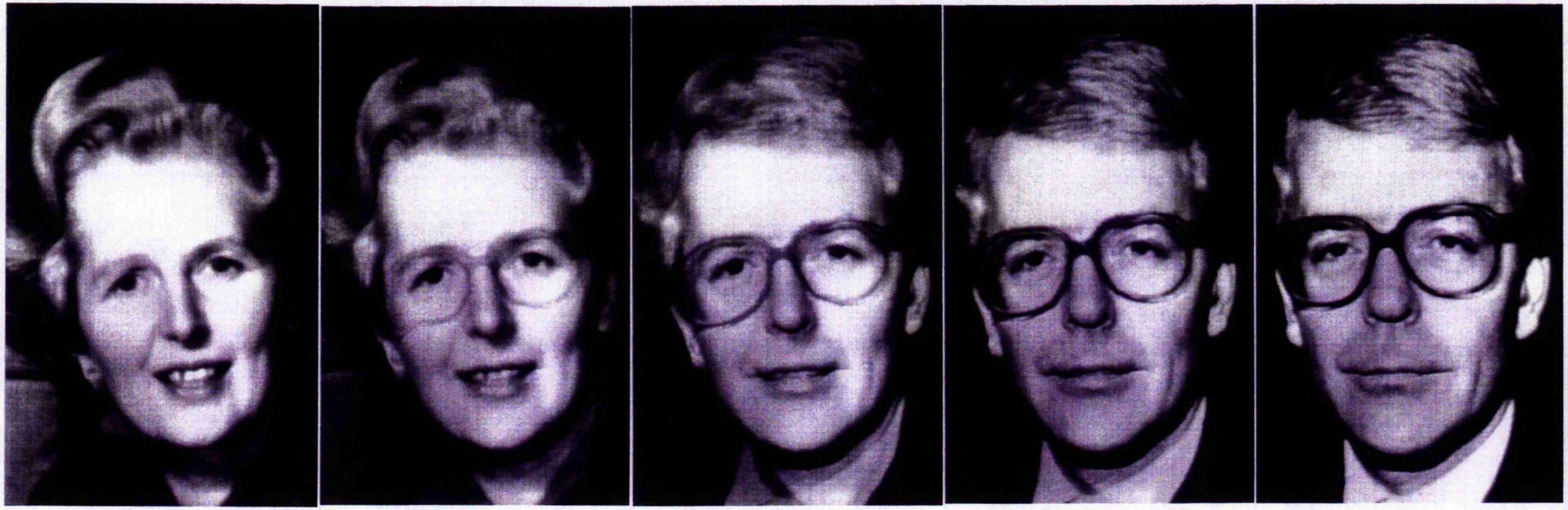

Figure 3.2.1:2

IDENTITY TRANSFORMATION. A gradual transformation of one face into another is possible by controlling each facial feature throughout the regression procedure. Two sequences, Thatcher to Major and vice versa, are blended appropriately at each stage. Each step in this figure shows a difference of 25% configuration and texture pattern.

Appendix IV lists publications details of similar effects.

interesting to note that the interpretation is not wholly categorical (we do not see the composite as Thatcher, we only see it as being like Thatcher). Galton produced a composite portrait of 2 children (A and B) and noted the reaction of one parent: "When did you do this portrait of A? How like she is to B! Or is it B? I never thought they were so like before" (Galton 1883: 9).

The process of turning one face into another is not restricted to identifiable characters. Extending the deformation rules allows very powerful and creative 'morphs' to be synthesised automatically (Wolberg 1990; Sørensen 1992). However, the most spectacular effects frequently require selective blending of different areas of the images at different epochs in the sequence. Background distortion caused by face-border warping can be avoided by using chroma-keyed foreground overlays. The process described here is entirely free from manual artistic intervention.

3.2.2 The Identity Matrix

Introduction

Extending the basic Identity Transform can be done in a number of ways. The example shown in this section is performed on 4 individual faces and demonstrates transformations in horizontal, vertical, and diagonal directions simultaneously. This effect can be applied in a slightly different manner and is described in the next section (3.2.3).

Methods

Figure 3.2.2:1 shows a 5 by 5 square matrix. Each box represents the location of a single facial image and is described by the contributing image names. Assume that one unique face lies at each corner A, B, C, and D. The Identity Transforms described in the previous section may be applied along each edge giving 4 bidirectional face changes.

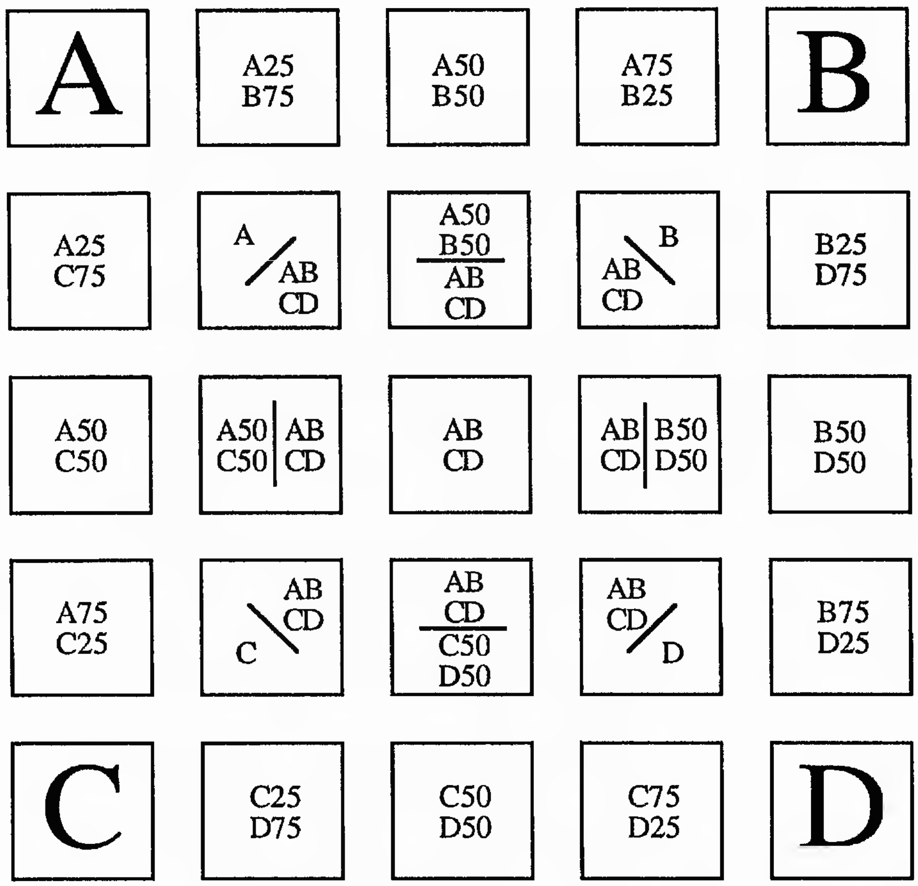

Figure 3.2.2:1

FACE MATRIX. Each original face is denoted by a major letter at the corners of the matrix. Along each edge of the grid are basic Identity Transformations (section 3.2.1). At the centre lies and accurate blend, or composite, of all four originals. Intermediary gaps are computed with the appropriate configuration and image information. For example, image ABCD/C on the BC diagonal is a 25% transformation of C, influenced by A and D, towards B. Mathematically, this is *bilinear interpolation* of the face space.

At the centre of the matrix lies the composite of all the faces produced by averaging all 4 facial delineations and warping each individual into that shape before blending. This face is the population average defined by the 4 originals. Surrounding the centre are 8 further images. These are generated by producing 'averages' along the 2 diagonals (4 images), the horizontal (2 images), and vertical (2 images) leading from the central image.

Results

An example of this technique is applied to the faces of Margaret Thatcher, John Major, Princess Diana, and Madonna Ciccione and shown in Figure 3.2.2:2.[22]

Comments

The Identity Matrix is a simple way of extending the basic linear transform previously described. More complex patterns of facial transformation are possible by increasing the number of vertices. This does, however, have more serious applications when the semantics of the effect are again slightly modified.

3.2.3 Expression Matrices

Introduction

The threat posture of the domestic cat changes with tendencies to attack and flee from the rival. The precise nature of the posture changes with the absolute and relative strengths of the two tendencies (Leyhausen 1956; Figure 3.2.3:1). Some investigators had thought that the richness of expressions and the variability of the facial expressions in the wolf argues against the validity of the concept of fixed action patterns in mammals, ie. those patterns of expression which are invariable. However, Lorenz (1953)

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[22]A 5th face could replace the central prototype (for example, Benson & Perrett 1992b).

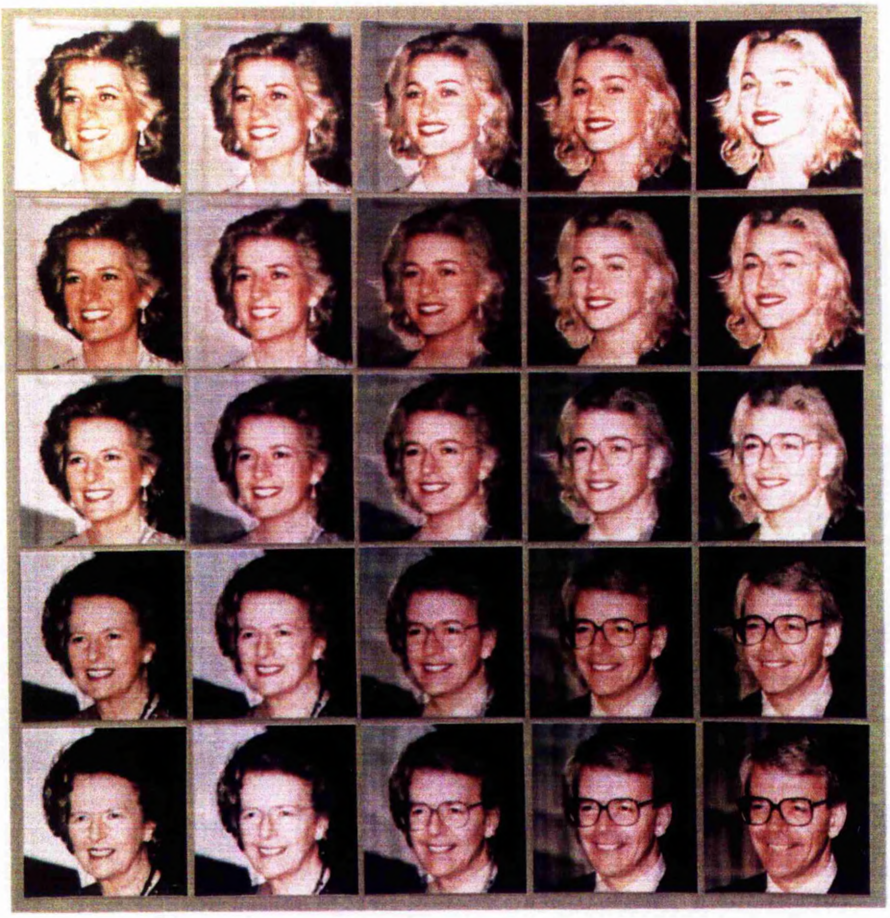

Figure 3.2.2:2

IDENTITY MATRIX. The faces of 4 famous individuals, The Princess of Wales, Madonna Ciccione, Margaret Thatcher, and John Major, are represented in this 4-face Identity Matrix according to the blending rules specified in Figure 3.2.2:1. Accordingly, the facial prototype resides at the centre of the grid.

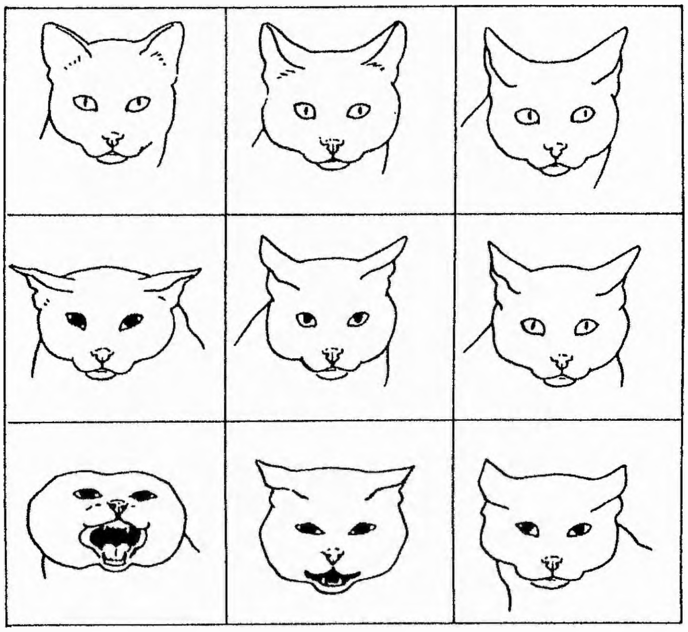

Figure 3.2.3:1

THREAT AND FEAR EXPRESSIONS IN CATS (reproduced from Leyhausen 1956). In each section, fear increases from above downwards, and aggressiveness from left to right. The precise nature of the facial posture changes with the absolute and relative strengths of the two tendencies.

demonstrated that in the dog's facial expressions the combination of the intention movements to flee and those of fighting leads to a great variety of expressions: the intention to flee is characterised by pulling back the corners of the mouth, retracting the upper lip, and wrinkling of the muzzle and forehead. Both kinds of expressions can be superimposed in varying degrees. Fighting and fleeing are often activated simultaneously and hence a combination of the two expressions usually occurs (Figure 3.2.3:2). Only rarely does a pure expression occur.

Much of Darwin's work (Darwin 1872) was concerned with animal expression in light of the wealth of the apparent similarities with our own capabilities. Fór the first time it is possible to accurately synthesise images of hybrid expressions.

Methods and Results

A matrix is defined in the same manner as in the previous section. At the 3 corners shown in Figure 3.2.3:3, images of posed facial expressions are shown. The bottom right image is a composite of all 3. The surrounding images are defined as the transformations between the blended expression and it's contributors.

Comments

Even in such a small matrix (3-sided) the effect of changing and merging of facial expression is clear and compelling. Certainly there may exist a set of fixed action patterns as suggested by the work of Ekman and his colleagues (eg. Ekman & Friesen 1971, 1974, 1975; Ekman, Friesen & Ellsworth 1972; Ekman & Oster 1979; Ekman *et al.* 1987; Ekman, Friesen & Ancoli 1980; Ekman 1992), but caricatured expressions (against a neutral prototype) used as base images may indicate a greater wealth of subtlety in the domain of our perceptions of facial emotion or deception.

Matrices and individual continua are likely to provide insight into the scale of perceptual categories which are thought to exist for facial

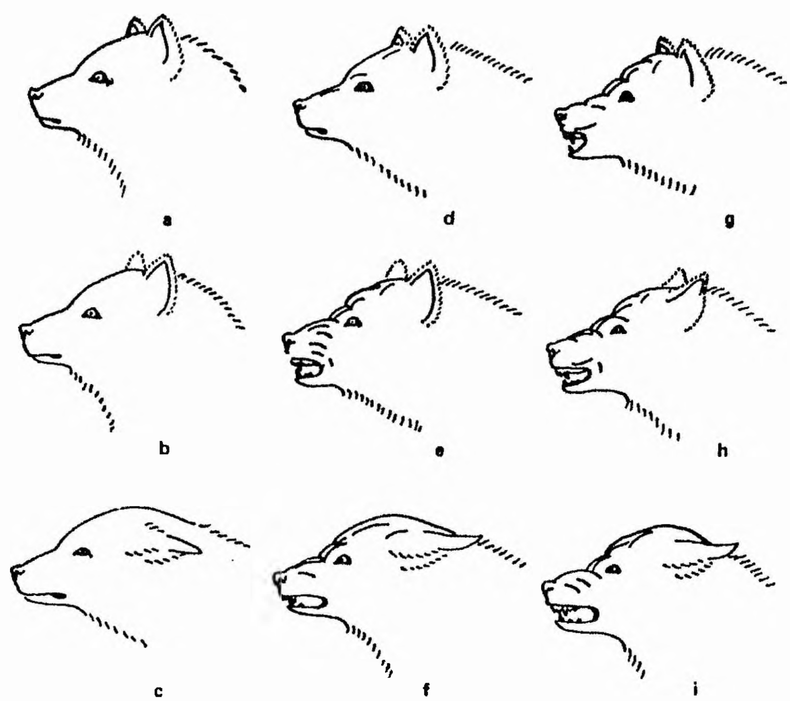

Figure 3.2.3:2

THREAT AND FEAR EXPRESSIONS IN DOGS (reproduced from Lorenz 1953). Various facial expressions of the dog which result from a superposition of various intensities of fighting and flight intentions. Fear increases from above downwards, and aggressiveness from left to right.

Figure 3.2.3:3

HUMAN FACIAL EXPRESSION MATRIX. Using the methods outlined for producing Identity Matrices (Section 3.2.2) manipulations of the facial expressions of a single individual are possible. Using the same interpolative schema as Lorenz (1953) and Musterle & Rossler (1986), a *human Lorenz matrix* can be derived. Fear increases from above downwards, and aggressiveness from left to right.

expression in order to evaluate emotional content (Musterle & Rossler 1986; Etcoff 1984; Harnad 1987; Etcoff & Magee 1992).

3.3 Facial Aging

The process of aging is one which has confounded Man for thousands of years. The search for life-prolonging substances has been relentless. Our obsession with the desire to remain youthful in both appearance, mind, and spirit has provided a wealth of inspiration in art, literature, medical, and social science. Growth-related changes in craniofacial structure can have a significant effect on human action. Ethological studies suggest that perceived age is a significant factor in regulating the type and amount of behaviour directed toward an individual. Age-variant characteristics like head shape have a vital bearing on various parental behaviours such as caregiving, warning, and protection (Alley 1986).

As the human head matures from birth to early adulthood it changes in both size and shape. The head of the infant has a typically diminutive facial mask relative to it's cranium. Within around 2 years the facial mask begins to grow more rapidly than the cranium. This results in a marked change in facial proportions. The cranium itself typically reaches it's adult size short of 10 years' development. The face on the other hand continues to grow well into early adulthood, male faces continuing to do so longer than females'.

A number of attempts have been made to define the visual effects of aging. These studies have carefully examined three factors which give visual definition of the perceived age of an individual. Firstly, the shape of the head and it's facial features. Following on from the work of Thompson (1942), E.J. Gibson (1969), and J.J. Gibson (1950, 1966, 1979), a number of researchers have used a mathematical formalism of morphogenesis using 2- and 3-dimensional geometric cardioidal strain and affine shear in terms of rectangular and polar coordinate systems (Figure 3.3:1; Pittenger & Shaw 1975a, 1975b; Shaw & Pittenger 1977, 1978; Mark *et al.* 1980; Todd *et al.* 1980). At the time, these studies were unable to relate the effectiveness of the geometric distortions to longitudinal information regarding actual craniofacial development. In addition, an examination of the natural salience of the growth transformations was not

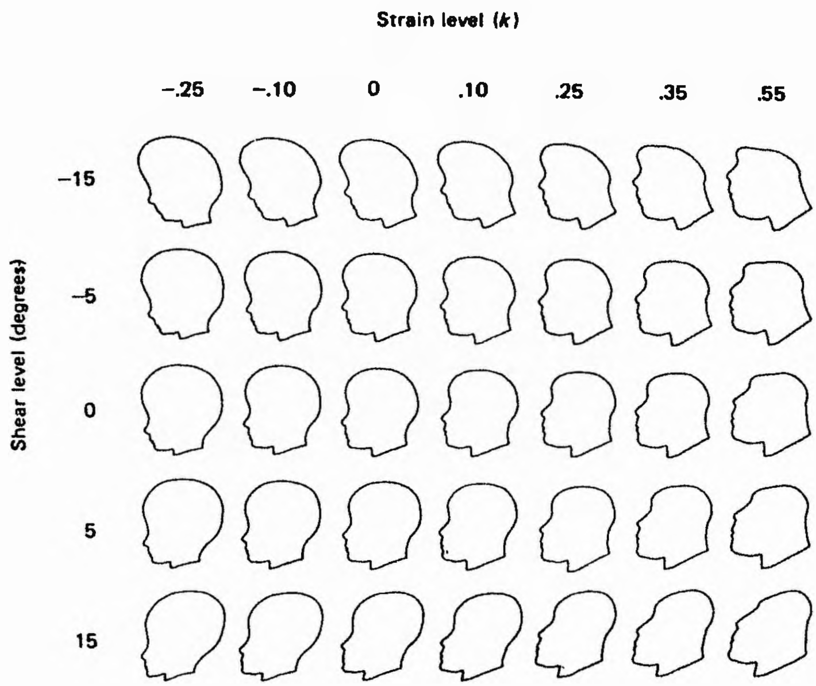

Figure 3.3:1

2-DIMENSIONAL AGE TRANSFORMATIONS (reproduced from Pittenger & Shaw 1975a). Transformations of a facial profile using shear and cardioidal strain (untransformed profile is at shear = strain = 0). Combinations of radial deformation produced by the cardioidal strain parameter, and the shear function produce visual transformations which are highly correlated with actual skull growth patterns.

made, insofar as spontaneous categorisation of craniofacial distortions was not encouraged (at least not reported in the literature). Subsequent papers addressed these criticisms and investigated slightly different procedures for altering the appearance of the schematic head (Mark, Todd & Shaw 1981; Todd & Mark 1981; Mark & Todd 1983, 1985; Shaw *et al.* 1983; Mark *et al.* 1986). Mark, Todd & Shaw (1981) demonstrated that the simplest models using cardioidal and sprial strain functions produced 'growth scores' which are, for all intents and purposes, no different from the actual growth patterns. Bruce *et al.* (1989) found that subjects interpretations of 2-dimensional images of 3-dimensional computer models of cardioidal strain age-transformed heads (*Phong*-shaded wire-frame meshes; see Phong 1975) were not spontaneously seen as younger than the originals unless they were given specific information regarding the originating age-bracket. From this study, Bruce *et al.* (*ibid.*) conclude "that cardioidal strain is but one of a number of *cues* which *constrain* the judgement of age" (Bruce & Green 1990: 373).

Secondly, the relative configuration of the face's internal features gives a great deal of reliable information as to the likely or perceived age of an individual. Facial proportions provide compelling support for both positive and negative caregiving conditions (McCabe 1988). In focussing on one particular study the power of the cue to age mediated by the congregation or separation, and relative dimensions of individual features is demonstrated. McArthur & Apatow (1983-84) simultaneously manipulated feature length, vertical placement, and eye size in schematic adult faces to produce 'babyish' or 'baby-faced' (low-placed, short features, and large eyes; Lorenz 1943), control (medium-placed, medium length features, and medium size eyes), and 'mature' (high-placed, long features, and small eyes) versions of the faces. It was found that the impact of this overall manipulation on perceived age and affordances was stronger than the impact of individual variations in any of the three facial characteristics. Simultaneous manipulation of these characteristics accounted for some 74% of the variance in attributed perceptions of physical strength, 50% of the variance in impressions of social submissiveness, and 40% of the variance in ratings of intellectual naïvety. In all cases individual feature variations accounted for less variance in these perceptions than did the overall manipulations. The considerable number of reports by Fullard & Reiling (1976), Stephan & Langlois (1984), Berry & McArthur (1985), Berry & McArthur (1986), Montepare & McArthur (1986), McArthur & Berry (1987), Berry & McArthur (1988a), Berry & McArthur (1988b), and Berry & Brownlow (1989) have all demonstrated the effectiveness of manipulating facial features in this way and the effects these have on our attribution and perception of individual and social differences.

Thirdly, the condition of the outer skin and subcutaneous musclature affects perception of age. The lustre and transparency of the skin varies widely being thinner, smoother, and more transparent in females. Females also have more underlying fatty tissue especially in youth which gives a characteristically smooth appearance. Loss of fatty tissue causes wrinkling in middle age and occurs at different rates in males and females (eg. Liggett 1974). The presence of cushions of fat on face at the root of nose between the eyes, between nose and upper lip, point of chin have a profound effect on facial appearance. In babies the cheeks are very prominent, puffed out with sucking pads between the *masseter* and *buccinator* muscles which support the cheeks during feeding. The importance of these pads can clearly be seen in the faces of emaciated children and the very elderly. The loss of elasticity gives the human face it's characteristically less expressive appearance in old age. Expression in the aged seems almost to have come full-circle, often appearing to have returned to the intensity and poverty of that of the young child. The agents of age generally include the thinning of skin (translucency), volition (outdoor versus sedentary), ill-health, diet, self-indlugence, excess alcohol, and climate. The results of the process are of course inconsistent across gender and extremities in age.[23] Tissue condition contributes most significantly to the process. There are three possible mechanisms which could account for skin aging. It is likely that these may happen in conjunction: (i) non-multiplying, non-reproducing cells, (ii) dying cells are replaced, but by new ones which never live as vigorously, and (iii) chemical changes take place, eg. in blood vessels themselves. Studies of the disease *progeria* (precocious development, premature ageing, and early death) indicate that the pituitary gland is highly

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[23]There is a Spanish proverb: "The hair deceives, the wrinkles undeceive."

involved at a high level in the process. In this way 'physiological age' as opposed to 'chronological age' may be affected.

To study the visual characteristics of aging, a process is required which addresses the complexity of the craniofacial, configural, and textural appearances of the aging face and allows these parameters to interact in a realistic and controllable manner.

3.3.1 Method One
Experiment Eight: Prediction of Linear Age Change

The simplest and most obvious application of the caricature generator to the visual study of ageing can be demonstrated by introducing a further modification to the model. Comparing an individual's face with a younger norm will give a very approximate description of the age difference in terms of the facial geometry. Accentuating the difference, ie. 'caricaturing' the age gap, may add years to the target face in various ways and levels. Diminishing the differences may have the effect of reducing the apparent age of the individual.

Methods

Subjects

15 male and 12 female undergraduate subjects participated in the experiment which was run jointly with an unrelated test. £3 payment was made.

Stimuli

A full-colour (24-bit) image of a 44-year-old male which had been previously frame-grabbed using a JVC BY-110 camera and Io Research Pluto 2i frame-store (see previous procedures) was used as the starting image. The target posed with a neutral expression and was evenly illuminated with tungsten lamps at floor and ceiling level. The image was prepared for transformation in the usual manner by delineating the facial features using a fixed set of 186 reference points.

The target data was caricatured against a 6-year-old norm (an 'average' of 14 young males). Age accentuated and diminished delineation data was produced at 20% intervals providing extrapolated ages of 51, 59, and 66, and interpolated ages of 36, 29, 22, and 14 (Figure 3.3.1:1). The original image was rendered in these 7 additional configurations. Only the shape of the face was modified; skin texture (tone) patterns remained constant throughout the target images. Colour photographs were taken directly from the computer monitor using Kodacolour ISO 100 film and a Nikon AF-F801 35mm camera, printed on 5 by 7 inch prints and manually cropped into oval images.

Procedure

In Task One, subjects were presented with the 8 mounted photographs randomly ordered in an A4 ring-binder and requested to note their estimated age of each separately viewed image as accurately as possible. They were informed that only the shape of the face had been changed in order to make the person look older or younger; the skin texture would remain constant throughout.

In Task Two, subjects were requested to order the set of faces in terms of increasing age (left-to-right spread) on the bench in front of them. When this was done, the experimenter noted the order (each photograph was coded on its reverse) and corrected any mistakes during the course of debriefing solely for the purpose of informing the subject.

Results

Task One: Estimation of Facial Age using Configural Information

The computationally transformed age correlated very strongly with the mean subject estimation of age at each level, $r_p(6) = 0.955$, $p < 0.001$ (Figure 3.3.1:2).

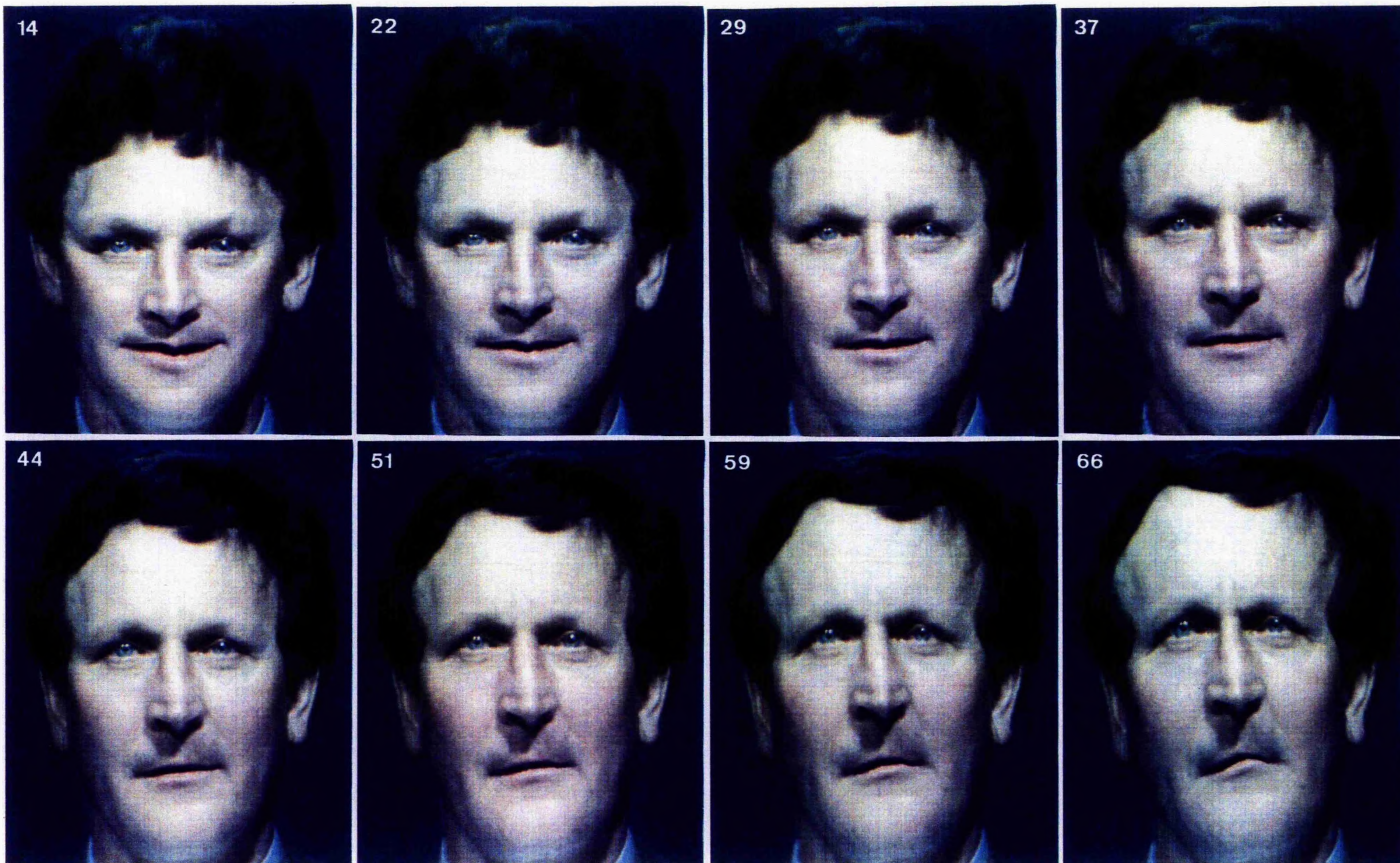

Figure 3.3.1:1 LINEAR AGE TRANSFORMATION. The original image (44 years of age) was caricatured against a 6-year-old prototype (from 18 males) to produce age-enhanced images of 51, 59, and 66 years. A configural regression (anticaricature) was made to produce 37, 29, 22, and 14 year-old images. Skin texture remained constant throughout the experiment.

Following the second task (age ordering), it was noted that the '14-year-old' image was poorly dealt with, attracting the most erroneous perceptions. This image also accrued the highest variance in age estimates. Before the experiment was conducted, although this particular image was considered to be too strong a distortion of the original and therefore perhaps unreliable it was nevertheless decided to include it in the study. Omitting this from the correlation not surprisingly improved the result, $r_s(5) = 0.964$, $p < 0.0005$.

Task Two: Rank Ordering of Facial Age

Accuracy in ordering the set of 8 facial images was very high. Table 3.3.1:1 relates the mean percentage accuracies for each face position in the series against it's actual computational position.

Discussion

When required to examine each image separately, subjects were able to use the configural information in each face to make judgements of facial age. Although their estimations were not necessarily accurate in absolute terms, they were generally in accordance with the computationally transformed age (Figure 3.3.1:2). The mean of all age estimations collapsed across all face positions was 39.5 ± 0.6. This figure is very close to the actual age of the target (44), and hence the age of his skin textures. Subjects were also clearly very much influenced by this cue.

The age ordering task forced subjects to use configural information as all skin textures were identical. In doing so, they were very accurate and only really confused the order of the 'young' images (14, 22, and 29).

It should be noted that the age transformations synthesised for this demonstration are not entirely appropriate. The age enhancements are actually caricatures of both age *and* identity, but this can be disregarded to some extent because skin texture was maintained throughout the entire experiment and the emphasis placed on facial age. Recognition of the target

Computed Age	Sort Order Accuracy (%)	Estimated Age
14	77	33
22	74	32
29	85	32
37	96	38
44	96	40
51	96	44
59	100	49
66	100	48

Table 3.3.1:1

RANK ORDERING AND ESTIMATION OF FACIAL AGE. Subjects were able to rank order the series of age-transformed images very well (middle column). Estimations of perceived age correlated highly with the computer-transformed age of each of the target images (right column; $r_s(6) = 0.905$, $p = 0.002$).

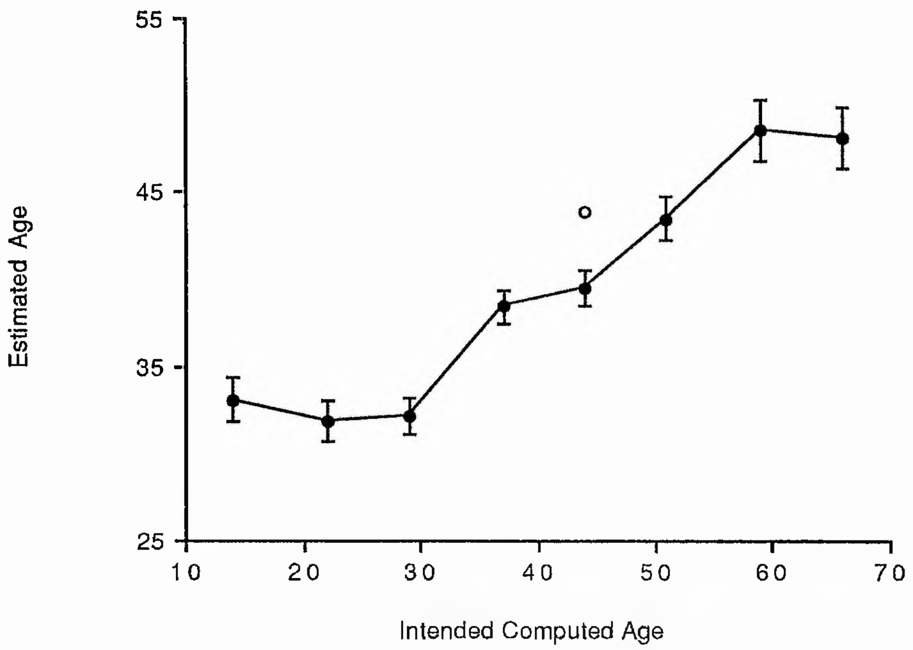

Figure 3.3.1:2

ESTIMATION OF PERCEIVED FACIAL AGE. Estimations of computer-age-transformed images correlated highly ($r_S(6) = 0.905$, $p = 0.002$). The 44-year-old skin texture constant provided some distraction, but as all images were tonally identical subjects *were* able to utilise configural information.

• estimated, ○ actual (original) age.

individual was not required (unknown to all subjects). Regression of the target face relied on the veracity of the 6-year-old prototype configuration; given a larger sample of faces it may have been possible to improve upon the results.

Subjects noted that the 'youngest' image (14) looked as if it was a middle-aged man trying to look younger. The hair was particularly relevant in this case as a number of them suggested it looked wig-like. With the age-enhanced images subjects were in agreement with the impression of age. Compared with the younger images, the older faces were definitely thinner, longer (taller), and older looking. One subject reported the oldest face as resembling a stroke victim. The hooded eyelids and increased fleshiness of the ear lobes were important factors in their decisions (for age estimations and for ordering). The artefact of the crooked mouth in the 2 oldest images, although its presence was noted, did not impress upon subjects.

The experiment clearly demonstrated that such simple (high-level) configural deformations based on prototypicality of a photographic facial image do produce reliable and effective changes to the apparent age. Todd *et al.* (1980) refer to these deformations as *topological* rather than *metrical* in that the invariant responsible for our perceptions of age differences at a fundamental level; the qualitative shape changes occurring across these age manipulations have been synthesised in an entirely quantitative (measurable) manner and therefore extends such a theory to include the metrical component. In addition, skin and hair texture patterns can clearly influence decisions against the intended direction of transformation and are probably the most important cue to an individual's age.

3.3.2 Method Two: Towards a Hybrid Aging Model Incorporating Wrinkling

Introduction

Lines and wrinkles appear at right-angles to the direction of the underlying muscles, eg. forehead lines are horizontal (*frontalis* muscle), and 'crows feet' form around the outer edges of the eyes (*orbicularis oculi*). The presence or absence of such textural information in a face is a strong indicator of how old a face (person) might be. Darkness and sagging of tissue around the lower eye area and drooping or hooded eyelids can be effective in making a face look more sedate and elderly (see also Jones & Smith 1984). Differences between young- and old-looking mouths are important; in the young, the dermis and musclature are more elastic and taught giving a definite impression of firmness and suppleness, while an aged mouth often exhibits downturned corners, a more thinned and less prominent lip region, and considerable sagging of the surrounding orbital muscle region (*orbicularis oris*, *depressor labii oris* and *inferioris*).[24]

Methods

A large enough sample of elderly faces within a suitable age bracket will possess a number of similar skin characteristics, notably wrinkles and areas of inelastic tissue. Determination of their 'average' location upon the face can be computed quite simply and the data used to construct an age 'mask' for that sample of the population.

The process of accurate facial compositing (see section 3.4) will reveal the location of common skin textures.

This information can be extracted by then considering the levels of texture information present within the internal facial area (bounded by the forehead and jawline) using a special 2-dimensional convolution matrix, or 'window' (Pearson 1986; Pearson & Robinson 1985; Pearson, Hanna, & Martinez 1990; Pearson 1992), as conventional edge-detection procedures (eg. Marr & Hildreth 1980) do not sufficiently and reliably generate realistic feature-extracted facial images. A method for yielding a feature mask (in terms of the aging model described here) which takes account of facial surfaces as well as feature edges is required; a luminance *valley* (where all image pixel intensities have a similar value, eg. side of nose) and luminance

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[24]Degeneration of these muscle groups often affects our perceptions of the strengths of the individual's emotions (eg. Liggett 1974: 9).

edge (where there is a dramatic chance in image intensity across a small step, eg. delineation of the eyelids) detection system is desirable. Figure 3.3.2:1 shows an example of a valley/edge detected image of an individual. An image region falling below the computed threshold becomes 'black' in the 1-bit mask; every other region is allocated 'white'. Varying the convolution filter size and thresholds appropriately allows the selective extraction of differing resolutions of skin wrinkles, markings, and blemishes.

Distorting an individuals face in accordance with a configural age transformation will provide the desired structural modifications, while the computation of the wrinkle mask (distorted into the same configural shape), or *eigenimage* of the prototypical case (Pearson, Hanna, & Martinez 1990), will effect the desired '3-dimensional' marking of the skin surface. The location and dimensions of wrinkle lines indicate the degree of image luminance profile damping required at that point.

Removal of wrinkles and blemishes can be performed by generating a wrinkle mask directly from the target face and computing over this with its original image. In this case, where wrinkles are located the luminance profile of each patch requires to be smoothed and blended in accordance with skin (image) surface characteristics in the immediate neighbouring regions.

Comments

Realisation of an accurate (un)wrinkling model is a matter of access to a sufficient database of elderly faces. Modification of the valley/edge detector to work with 24-bit colour images may indicate a series of extensions which need be developed; it is possible that each colour plane (red, green, blue) may contain more useful wrinkle information than others under particular circumstances. This is certainly true of similar work done using polarised light which extracts both the surface texture and the surface sheen or colour of the skin (eg. Philp, Carter, & Lenn 1988). However, as multiple individual exposures of the same living tissue are required (1 under normal illumination or flash conditions - the reference image; 1 with parallel

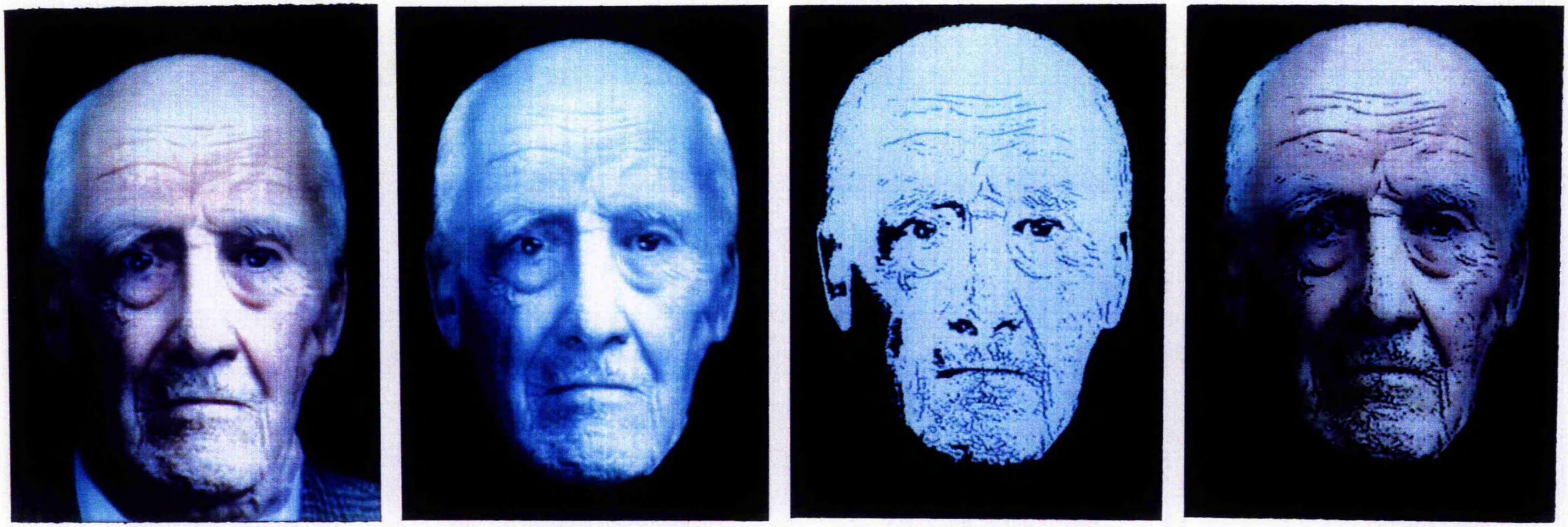

Figure 3.3.2:1

EXTRACTION OF FACIAL WRINKLES. Left to right: original image, grey-scale extraction, valley/edge detected mask, and original image with wrinkle mask superimposed for clarity. Careful selection of detector thresholds is required in order to locate wrinkles with suitable precision; it is also possible to process different parts of the face separately such as around the eyes and around the mouth, according to differing skin qualities. A blending (smoothing) or contour-enhancement operator need be applied to the original image according to the wrinkle mask to effect the removal or addition of skin texture patterns.

polarising filters - for wrinkle, or texture information; and 1 with and orthogonal filter - for surface sheen, and colouration), the method is only really suited to studies of the hands, for example, which can be securely located in the cameras field of view; a head-shot would require remarkable control of facial muscle groups and eye fixation in order to prevent the slightest movement.[25] For this reason, it is considered more suitable to compute a wrinkle mask from a single image.

Implementation of a wrinkling model would contribute in a most significant way to the continued studies of age perception and has clear implications for applications in forensic, and cosmetic and medical research. Ideally, one would like to work with 3-dimensional models of the human head[26] which have been texture-mapped with the individual's facial image (eg. Williams 1990a, 1990b).

3.3.3 General Discussion

Sections 3.0.1 to 3.0.4 described the application of the caricature generator to portraits of individual familiar and famous faces. It was shown that enhancement of facially distinctive features improved the recognisability and likeness through psychological assessment; comparing a person's face with their population average or norm revealed atypical qualities which could be enhanced.

In section 3.2.1 the role of the regressive anticaricature was demonstrated by modifying the semantics of the imaging model, allowing the transformation of one face into another; the Identity Matrix of section 3.2.2 provided a simple means by which a number of other faces could be

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[25] Absolute alignment of images is required for subsequent composition analysis. Given suitable technology it would be possible to frame-grab the 2 polarised images in rapid succession without allowing subject movement.

[26] Laser range-finding equipment for building accurate 3-dimensional head models has been used successfully for pre- and post-operative medical research (Moss *et al.* 1989; Coombes *et al.* 1991; Coombes *et al.* 1992), and more recently the surfaces of these models have been used in investigations of perception and recognition of their facial surfaces (Bruce *et al.* 1991, 1992).

transformed into one another and more importantly indicated how a central 'average' of a set of faces could be constructed.

Section 3.2.3 updated studies of animal facial expression matrices by allowing the visualisation of the differences and interaction between particular emotional expressions of human faces by controlling the superposition of relative degrees of emotion in a controlled numerical manner; identity was maintained while the expressive quality of the image was modified according to the procedures for anticaricature generation.

The basis of the model was again modified to allow enhancement of age present in the structure of a face in section 3.3.1. Comparing an individual's face with a norm much younger produces 'caricatures' not only of identity but exaggerations of age embedded within identity. Both regression towards the younger prototype and exaggeration away from the prototype resulted in perceptible age differences even though the skin tone component remained unchanged throughout. In discussion, a method for dealing with skin wrinkles and blemishes was postulated whereby age effects could be more accurately synthesised.

In the following sections, the application of the normative or 'average' face manifest as a continuous-tone image is realised and its visual impact is examined quantitatively and qualitatively.

3.4 Facial Composites

Introduction

The work of Galton (1878a, 1878b, 1879), Jastrow (1885), Pumpelly (1885), Taylor (1885), Fletcher (1886), and Stoddard (1886, 1887) producing composite photographic portraits stimulated much interest in their day. Although their techniques were relatively primitive by today's standards the results were both remarkable and intriguing. Figure 3.4:1 illustrates a composite of 49 female students, and is striking because it looks like a real person (Galton 1883: 7).

Galton's (1878b, 1883) reason for pursuing these 'trials' was to discover if it was possible to extract the typical characteristics of a number of faces from particular classes and types of people (eg. criminals, the healthy and ill, and familial resemblances). Whereas such early composites of many people were a "portrait of a type [of person] and not of an individual" (Galton 1878b: 133), blends of many instances of one person using the same techniques *are*. His later work (Galton 1879) concentrated on locating consistencies in the appearance of famous individuals. It was hoped that by combining several portraits of the same person produced by different artists a truer depiction of that person would result by reducing stylistic and erroneous idiosyncrasies. Composite portraits were fashioned of Alexander the Great, Antiochus, Poliorcetes, Cleopatra, and Nero. Taylor (1885) similarly produced composite images of George Washington in several perspective views by combining original images in the same pose. It was noticed from the outset that more often than not composites appeared younger and more attractive than constituents. For example, Galton (1878a: 137) cited Austin's letter to Darwin claiming that in the case of some ladies' portraits the composite represented "a decided improvement in beauty". Jastrow (1885: 168) noted that a composite of male faces made "a younger and handsomer man than the average of those whose faces enter into it". Perhaps with a little prejudice Galton noted of his blended Cleopatra that "the composite is as usual better looking than any of the components, none of which, however, give any indication of her reputed beauty; in fact, her features are not only plain, but to an ordinary English taste are simply hideous." (Galton 1879: 164). An increase in attractiveness has been

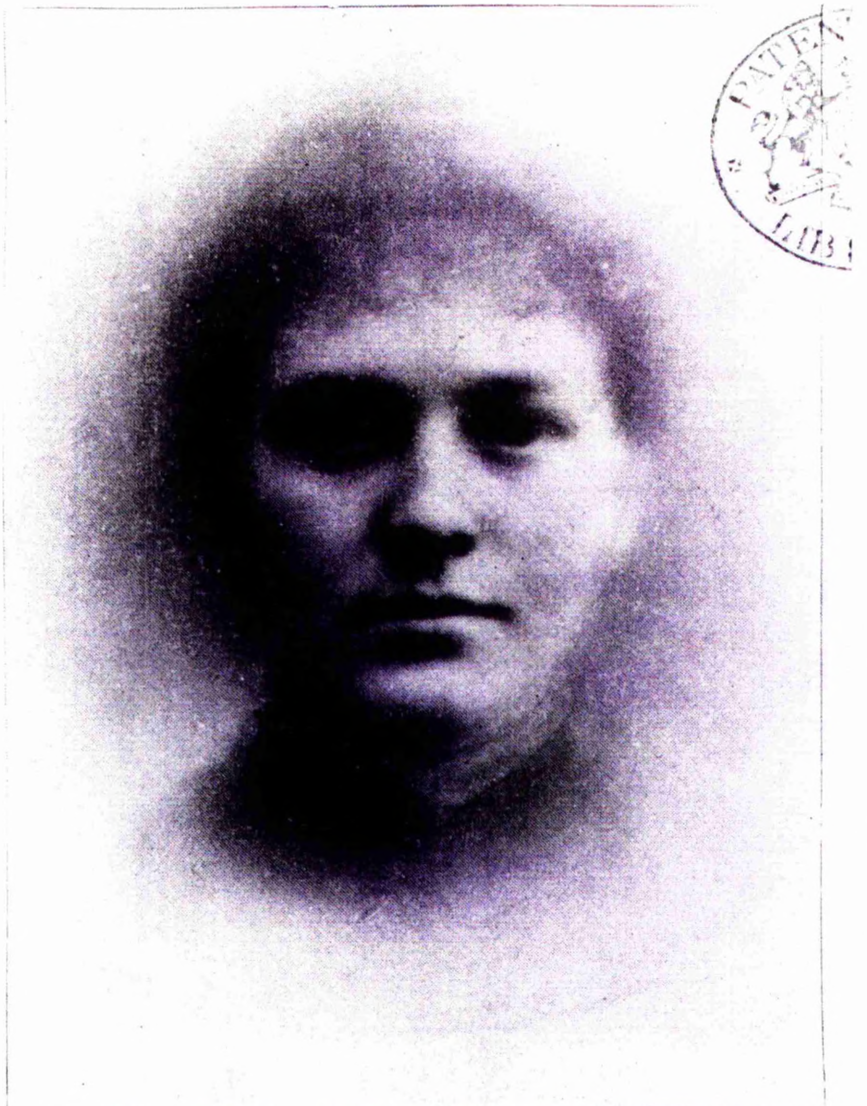

Fig. 1. — Forty-nine members of the last senior class.

Figure 3.4:1

PHOTOGRAPHIC FACIAL COMPOSITE. Galton's (1878a) photographic composites were made by multiple exposures of a number of individual pictures scaled such that features were aligned as best as possible to minimise feature blurring. This figure shows a photographic composite of 49 female undergraduates of Smith College produced by Stoddard (1886) using his principles. Careful selection "of photographs of several persons alike in most respects, but differing in minor details" (Galton 1878a: 132) ensured that such large numbers of pictures could be combined effectively.

attributed to the average shape of the composite (Langlois & Roggman 1990) and a flatness or smoothing of skin tones (Benson & Perrett 1991a, 1991e, 1992a, 1992b).

These works highlighted a number of important issues which are relevant to current psychological studies of the perception and recognition of faces: faces as a homogeneous class of objects, and memory for particular familiar faces (Young, Hellawell & Hay 1987). Faces within the same cultural groups are highly similar in appearance. Individuating differences are on the whole only slight, yet our specialised perceptual mechanisms are able to identify these minute characteristics. Certain differences may even be difficult to verbalise. One face is seen from a great many perspectives and is continually undergoing elastic transformations during expression and speech.

Our knowledge of the appearance of a familiar or famous face increases over time through experience of multiple encounters with that person and allows recognition to become more tolerant of unusual viewing circumstances. Witnessing an individuals face allows one to recognise the essential and most useful components of their visage which underly potentially distracting and unexpected changes in pose, expression, feature contortions, or apparel.

Although we are aware that abstractive mechanisms operate within the visual system, the psychological bases of this ability are unknown. Different models have been developed which simulate the effects of the generalisation process. Of these, PDP models such as that of McClelland & Rumelhart (1985) explicitly extract prototypes given multiple instances bearing common features; Hintzman's (1986) model of schema abstraction does not explicitly code the abstraction yet is able to effect generalisation if so required. This section also presents an abstraction technique which operates over multiple images of given faces to synthesise an average or prototypical appearance. Unlike the models described above the technique described here does not attempt to mimic cognitive processing but does serve to draw analogies insofar as the numerical procedure is able to *locate consistent features* and *dispense with miscellaneous details.*

Recognition also requires that a face be differentiated from others (section 3.0, Experiments Two and Three). This differentiation is not solely conducted at the level of individual features because faces are seen as a whole, processed in an holistic manner in which feature configuration is important (Carey & Diamond 1977). The failure of physiognomists such as Lavater (1780) to notice this propagated many misleading ideas about social classes, types of person, and personality traits. The composite process described here abstracts not just the average shape of a person's, or group's, features but also the average configuration of those features.

Background

Careful selection of original photographs to ensure facial similarity is not sufficient to produce sharply defined composites. For example, some faces will have wider or narrower noses than others which will cause ghosting of the feature in the final blend. Successful averaging of faces depends on the dimensions of the originals face. A second difficulty lies in the multiple exposure timing used by Galton and his followers[27]. Langlois & Roggman (1990) more recently attempted to improve upon this technique by digitally merging computed images of faces; as before, original portraits were scaled such that the pupils were as accurately aligned as possible and corresponding picture elements (*pixels*) numerically averaged to produce a high-quality composite. The results are an improvement upon the photographic technique, but still suffer from a lack of qualitative control. All facial features, even the pupils, are not aligned in any precise way since only 2 control points covering the estimated pupil centres exist. The

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[27]When producing composite faces Galton exposed each original face for the same time to the new photographic plate (Galton 1878a: 133). At very long (and very short) exposures the reciprocal relationship between settings of lens aperture and exposure time breaks down. When dealing with long multiple exposures Galton's composites would almost certainly have been limited by such *reciprocity failure*; coupled with the inferior photographic plate chemistry, this explains why many of the composites made by himself and others looked 'better' than they should have, and why some attempted replications failed; a greater exposure for a particular face means that this face will dominate the final image. Procedural problems involving changes in lighting conditions and first or last exposure bias in the photochemical process can also account for the observation by Fletcher (1886) that one individual's face appeared dominant in a composite.

computer composites produced by averaging corresponding pixel intensities in each facial image 'frame' produces blurring in the same way the original photographic portraits did (see Figure 3.4:1). Thus an improvement in processing with a decrease in blurring is desirable because an average face should after all be one which looks like a face in every way and has well-defined characteristics.

Galton's work was extended in the photographic domain by David Katz (Katz 1953) some 50 years later. His approach involved the normalisation of original images in three stages. From a set of portraits 3 composites were exposed, the first aligned on the eyes, the second aligned on the nose, and the third aligned on the mouth and jaw region; blurring occurred around all other features. Katz's composites were realised by removing the normalised sections from each of the 3 averages and pasting the components together rather like the manner in which the original *Photofit* (Penry 1971) system operated. The resulting collage was a much more precise facial composite having minimal ghosting of the internal facial features and facial outline.

Computational Procedure

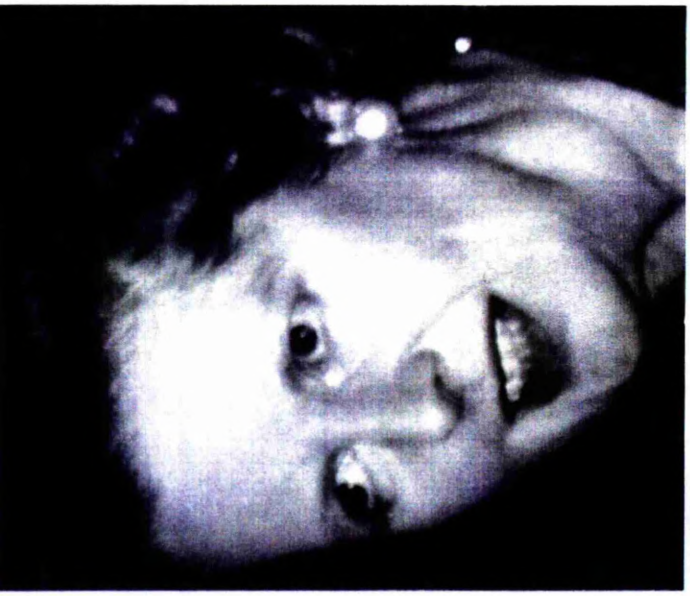
Similar procedures to those discussed in previous sections are applied to derive a highly realistic composite of one individual from a number of images. The same procedure can be applied to images of different people to produce a composite of a particular category of individual.

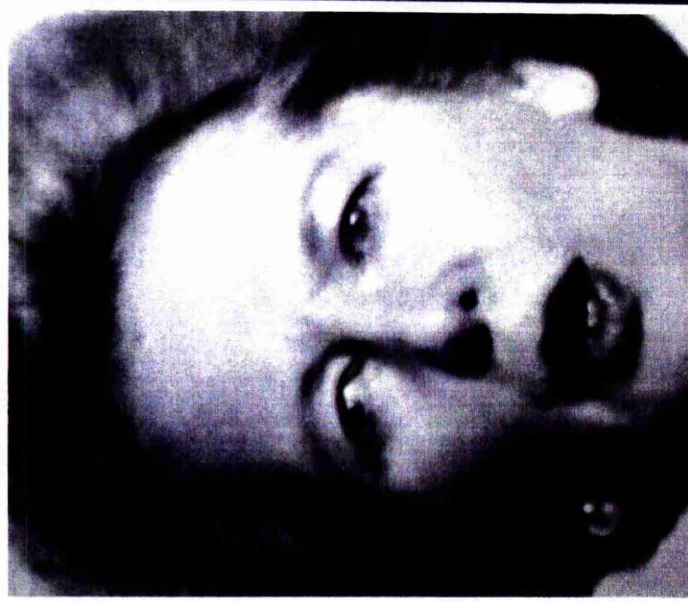
One-hundred and eight-six points were manually logged on each of 6 digitised images of Margaret Thatcher describing the positions of her facial features. Identical numbers of points described particular features and therefore a relationship between each of the original 'portraits' in different poses. By averaging the *x-y* coordinates of matched feature points across each image the mean position of each feature can be found. Comparing the difference between the original and the average feature positions (and hence configuration) defines by how much Thatcher's face would have to change in each case in order to assume her 'normal' visage. That is, the difference in positions of the original feature points compared with their average defines how each image of Thatcher deviates from a prototypical Thatcher configuration. Using the feature markers as reference points each of the 6 images were *warped* into the shape defined by the averaged coordinates such that each assumed an identical average facial shape. Figure 3.4:2 (right) was produced by averaging each corresponding pixel intensity in the 6 distorted images. The blend is well-focussed though 'soft' in contrast, and maintains various features such as drooping eyelids, hairline, and narrow nose. Blending all 6 images together without intermediary transformation produces an almost unrecognisable composite with extreme ghosting of features (eg. 6 mouths; Figure 3.4:2, left). Figure 3.4:2 (centre) shows a (digital) composite made according to Galton's method.

Discussion

The process described here does in fact produce an accurate and faithful generic face when averaging different faces. It is not intend that the graphic process be seen as an explanation of psychological processing underlying recognition. Rather the technique demonstrates that salient visually distinctive features can be extracted automatically from disparate images. Facial shape and feature configuration is maintained over large samples, only a pervasive blandness of skin textures is introduced. Although the process is restricted to images of faces in preprofile view it does provide a reliable means of normalisation.

Whatever photographic or computational process is used to create facial composites it is important to bear in mind a fundamental phenomenon being procured, that of extraction of averages or prototypes from a set of exemplars. Formation of category prototypes have been shown to be useful for recognising objects at the psychological level (Tversky 1973, 1979; Rosch 1978) by providing a level of abstraction which seeks to maximise the amount of information about a category with the least cognitive effort. In a sense the averaging process also maximises the information about the category to which the face belongs; a normalised appearance is one which may be more likely to display perceptual similarity to the target individual and consequently evoke recognition moreso than perhaps an unusual caught-unawares snap-shot would. It remains to be seem whether the



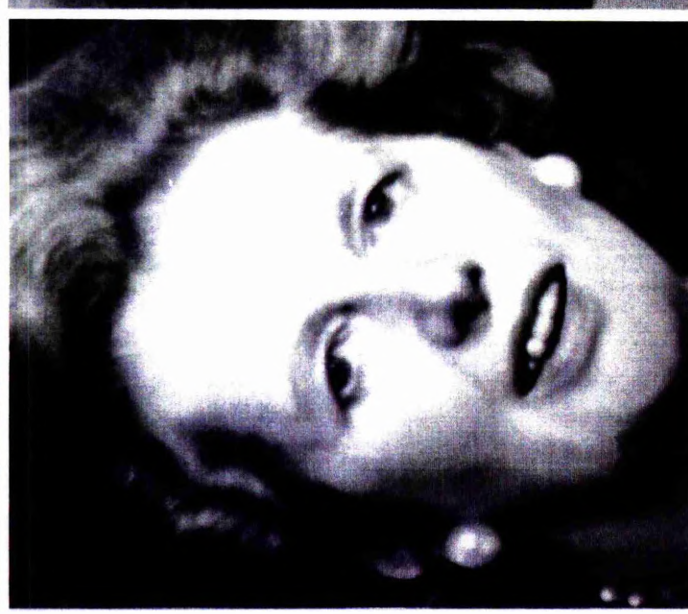


Figure 3.4:2

COMPUTATIONAL FACIAL COMPOSITE. Facing page: original photographs of Margaret Thatcher. This page; left: the composite of all 6 original unnormalised images; the image appears as an unrecognisable blur. Centre: a composite (produced digitally) according to the procedures defined by Galton; here, three of the images have been rotated and magnified to align the pupils horizontally, and 2 images were mirrored vertically to change the left-right pose. Right: the blended computer composite. The automatic process of generating the composite (see text) deals with differences in expression and pose by normalising the original images *before* blending. Here base images were deliberately chosen so as to vary a great deal in a number of ways to determine the power of the technique. The presence of *epicanthic folds* (hooded eyes) and high hairline in the composite is testament to the procedure.

average appearance of an individual is a better likeness than a caricature for example (Benson & Perrett 1992b), or even whether a caricature of the computed prototype is in turn better still.

Prototypes are not only useful for determining whether new stimuli belong to a familiar category but they enable reliable judgements of the relative distinctiveness of another exemplar to be made (Bruce *et al.* 1991; Valentine & Ferrara 1991). Of course, abstractions of this nature also allow predictions to be made about the appearance and veracity of novel items belonging to one or another phenomenal category.

It is worth noting that Galton (1879) had contemplated the biological implications of his technique. Without the evidence of experimental psychology to come a century later, he believed that like his composite photographs human memory for categories of faces must also be blurred. He argued even if people were able to reform some kind of facial prototype it would be ill-defined far in excess of his portraits due to the sheer number of acquaintances involved. He reasoned that the "human mind is therefore a most *imperfect* apparatus for the elaboration of general ideas" and "the criterion of a perfect mind would lie in its capacity of always creating images of a truly generic nature..." (Galton 1879: 169). This argument is inappropriate since it assumed that the brain worked in a way analogous to the photographic technology of the Victorian era and therefore would be limited by the blurring of successive images.

Presumably the reason for the brain 'wanting' to derive such generic descriptions is to be able to make decisions based upon perceived normality or canonicalness. Any abstraction of facial information to provide descriptions of typicality or normality must make explicit information about distinctiveness in order to discriminate between individuals, but also to capture the subtleties of age, gender, attractiveness, ethnicism, health, etc. In the interests of efficiency and breadth of knowledge we should not be restricted to one concept of average structure and dimension rather we should assume reference to a variety of norms and dimensions along which to judge faces (Valentine & Endo 1992).

The ability to deform and normalise face shapes may play an important role in the development of telecommunication procedures for transmitting many facial images at reduced bandwidth (see also Parke 1975, 1982; Aizawa, Harashima & Saito 1989). Prototypical faces could also be used in studies in the perception of facial attribute information, for example in the study of attractiveness and the characteristic dimensions of age, gender, intelligence (Anderson 1921; Argyle & McHenry 1971), identity, and expression of particular types of faces.

3.5 Gender Enhancement

Very few experimental studies have investigated the physical and perceptual (psychological) differences between male and female faces (Cross & Cross 1971; Cross, Cross, & Daly 1971; Gray 1973; Liggett 1974; McKelvie 1978; Roberts & Bruce 1988). Much of this research has been engaged in attempting to address facial gender in terms of sociopsychological issues and the stereotyping in character attribution thereof (Schour & Massler 1941; Subtelny 1959; Guthrie 1976; Adams 1977; Gould 1977; Adams & Crossman 1978; Melamed 1983; Hagg & Taranger 1985; Freedman 1986). Enlow (1982) reported a number of anatomical heterogeneities between males and females but the work is far from complete.[28] He suggested that because the male lung capacity is greater the nose region has developed more along with a stronger and more prominent brow area. This makes females appear to have more concave profiles. From the study of Roberts & Bruce (1988) it is clear that although the nose does provide and important cue to the sexual identity of an individual, it does not do so in isolation; the structural aspect of faces is important insofar as subjects are unable to make reliable gender discriminations on the basis of the nose alone.

Liggett (1974) provided an account of some of the major visual differences of male and female faces. There are of course many stereotypical traits one would expect a male face to possess (very often in terms of a contextual reference) such as the eyebrows being thin in youth, growing thicker, stronger and coarser with age; the jaw is stronger than the female's, and the mouth larger; the forehead is larger, and the nose is larger with a stronger bridge. In females the mouth is small and the top lip narrow; the eyebrows are scantier than the male's and thin with age; the eye region is perhaps the most striking, where the female's eye is slightly bigger than the male's, the lashes are longer; the tissue around the eyes is much thinner than in males and sometimes gives rise to distinctive shading giving rise to a very strong feminine signal (accentuated using cosmetics). Highly mobile faces

[28]Enlow's (1982: 6) notes make reference to "prototypical" faces. By this he means "on average", rather than providing an account of quantitative measurements of typicality through the specification of some formal model.

are more likely to be perceived as male; the female face has more fatty tissue thus concealing a degree of muscle reflexes. This lack of movement is considered a desirable feminine trait and is frequently enhanced by loosely moving hair, ear pendants, and immobilising paste and tone-flattening cosmetics.

While such observations are adequate for describing facial gender differences according to interactions with facial attractiveness, an individual's *image*, and perhaps role model requirements, the issue of fundamental differences has still not been addressed. One needs to begin to understand something about the typicality of characteristic images of gender.

Enlow (1982) also suggested that the difference between male and female faces could be related to the apparent degree of maturity of the head. It was suggested that the female face tends to possess more 'babyish' proportions. This notion had been reflected in several previous studies which have revealed an interaction between gender and age; the actual morphological differences between male and female faces reflect a greater retention of infantile characteristics in the adult female than in the adult male (Gray 1973; Liggett 1974). The suggestion is that a 'baby face' may be more appealing on a female than on a male, and may reflect an aesthetic preference for faces that are prototypical for their gender.

3.5.1 Experiment Nine
Can Caricaturing of Gender Increase and Decrease Perception of Masculinity and Femininity?

Introduction

A composite of a sample of similarly aged female faces should look quite feminine by maintaining feminine features and diminishing (averaging out) any 'erroneous' characteristics; a 'male' composite should correspondingly look masculine. If this is so, then caricaturing these faces against one another should have the effect of pushing the female face further away from the male, and vice versa. Manipulating the skin textures within the context of enhanced facial shape (degree of gender) should reveal how much each parameter contributes to our perceptions of each category of face.

Methods

Modifications to the Renderer and Tessellation Map

The centroid-edge scanning renderer described in section 2.1 was modified to ensure as perfect warps as possible when dealing with particularly strong and perceptually sensitive facial transformations. It was noticed that in cases where strong caricatures (eg. ±100%) were synthesised aliasing sample gaps appeared along the edges of each triangular and internal tessellations. This issue was addressed by developing a modified image distortion algorithm based on the cubic[29] patches described by Wolberg (1990) and in section 2.1.5.

The previous renderer operated 'blind' on both the source and destination tessellations. The distortion algorithm was preceded by processing of each triangular vertex in order to determine in which Cartesian quadrant they lay. The arithmetical sign (- or +) of the direction vectors determining the orientation of pixel scanning was thus achieved in terms of the rotation of each pair of vertices in 2-dimensions. Scanning of source pixel intensity values into destination locations then proceeded in a transparent manner. Abandoning the benefit of orientation generalisation means that ordering of pairs of vertices must follow (section 2.5.1) in order to cater for extreme cases where a destination and source tessellation differ in orientation by 90° or more (one vertex moves into an orthogonal quadrant in 2-space). Having established this, interpolation of the stretched or shrunken components of each image area can be done using an economised version of the cubic patch renderer. The algorithm for this is shown in Figure 3.5.1:1. This method also ensures that remapping of a distorted image back into the source specification is 1:1 in that no data (pixels) are lost. In the case of the centroid-edge scan, large deformations demonstrated anomalous behaviour; small distortions were ideally suited to such an approach.

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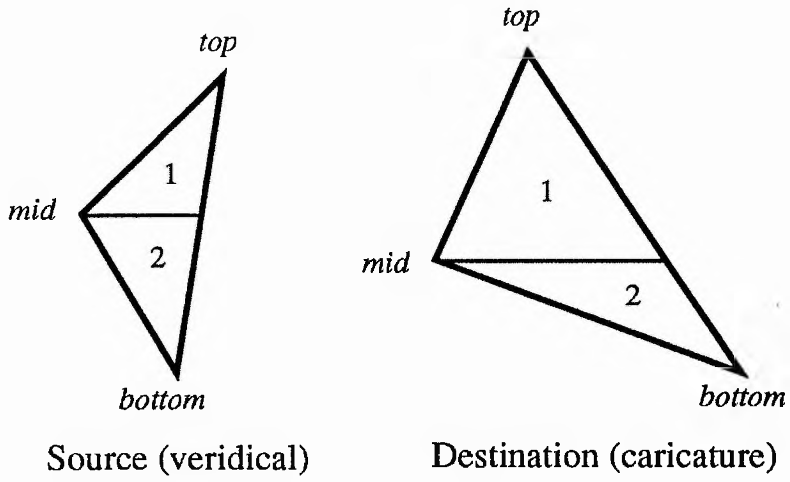
[29]'Cubic' here refers to the shape of the patch rather than its mathematical formalism.




```
*
* Oriented-Patch Scan
*

for source and destinations triangles
    orient triangles (sort vertices) to locate top, mid,
      and bottom vertices

split triangles into top and bottom halves
{
    * orient for triangle 1
    set left-right scan-line increment for destination

    scan each line top-mid, left-right of destination
        map relative original pixel into destination space

    * reorient for lower triangle 2
    set left-right scan-line increment for destination

    scan each line mid-bottom, left-right of destination
        map pixels
}
```

Figure 3.5.1:1

MODIFIED SCAN ALGORITHM. Tessellation patches are vertex-ordered and split into 2 subsections which are parsed according to the orientation of the destination patch. The loss of generalisation provided by the centroid-edge scan method is offset by a significant improvement in rendering efficiency.

The static manually specified tessellation map previously declared also requires modification if larger distortions are to be performed where predetermined ordering of patch vertices could cause unnecessary overlapping portions of the image and hence loss of information. There are many methods of tessellating a 2- or 3-dimensional surface specified by an array of surface coordinates. Most of these produce patches (Ferguson 1964; Coons 1967) and are found in instances where only flat-shaded, or Gouraud (Gouraud 1971) or Phong (Phong 1975) shading is to be applied according to associated pixel intensities at each tessellation vertex. In many cases a combination of both cubic, triangular, and occasionally polyhedral patches have been used (Parke 1975, 1982; Loop & de Rose 1989; Platt & Badler 1981; Woo & Shin 1985; Nasri 1987; Waters 1987; Lee & Majid 1991). Triangular patches (section 2.1) provide the most flexible and overlap-chance free method of providing large distortions in one step. A procedure for generating triangulated surface maps in 2-dimensions (a *Delaunay triangulation*) from a set of points is elegantly provided by Sloan (1987; see also Correc & Chapuis 1987) and more recently by Karasick, Lieber & Nackman (1991). As before, only one of the source or destination delineation data sets need be tessellated as a 1:1 relational mapping between feature points exists. As such, the destination set is used ensuring that the pixel transformations are requested by the needs of this image domain. The manual and Delaunay maps bear close resemblance in that both employ 'short, fat' (or 'locally equiangular') tessellation patches which are desirable in that overlapping portions of the destination image map are less likely.

Combined improvements to renderer techniques and the use of an automatic tessellation stage in transformations allows much greater degrees of deformation to be applied in single or multiple stages. Because this experiment (and those which follow) rely on judgments of facial attributes as opposed to the more holistic nature of identity, a modification was also made to the image delineation stage. An increase in the number of control points marked around the eyes was implemented (Appendix II) thereby inducing a smoother triangulation of the feature data map.

Subjects

12 male and 18 female 3rd year undergraduates from the Psychology department participated in the experiment voluntarily. Subjects were split into 2 approximately equal groups. Data were pooled as no procedural differences were employed.

Stimuli

16 male and 16 female Caucasian students from Aberdeen University had their faces frame-grabbed using an Hitachi HV-720K CCTV monochrome video camera and an Imaging Technology FG-100-V Image Processor connected to a SUN Microsystems 3/160 workstation. Target faces were aged between 20 and 22 years of age. Each grey-scale image was captured under identical even lighting conditions showing a neutral expression. No facial hair, jewellery, or hair bands was permitted. Each face was delineated appropriately using a set of 224 feature points (Appendix II). Data from the male faces were averaged to provide an 'average' male configuration set, and similarly a female average was produced using the female data. Each individuals' face was then rendered in the respective average shape/configuration (a full 100% anticaricature comparing a target with it's prototype). Photographic quality gender composites were then synthesised by blending each of the 16 faces of the same sex together giving an average male and female face. Using the caricature algorithm each composite was either exaggerated from it's opposite gender prototype giving a 100% male caricature (*hypermale*) and 100% female caricature (*hyperfemale*). The male and female faces were also rendered in the opposite gender's configurations (0% male or female) or the hyper-conditions. Finally, 3 androgynous conditions were constructed; 1 from all male and female faces (32), 1 whose skin textures were derived from the female faces, and 1 from the male faces. In all, 11 faces were created (5 with female skin textures, 5 with male, and 1 androgynous). Each face was masked computationally around the jaw-line and side of face and according to an arc rising through the centre of the forehead (Figure 3.0.3:1). Figure 3.5.1:2 shows samples of the stimuli used.

Figure 3.5.1:2

GENDER PROTOTYPES. Left: prototypical female face (n = 16). Centre: androgynous (sexless) face (n = 32). Right: male prototype (n = 16). The male and female prototypes were rendered in 5 facial configurations (skin texture unaltered) of hyper-female, female, androgynous, male, and hyper-male; an androgynous composite was also created (5 + 5 + 1 = 11 stimuli).

Procedure

Within each group, subjects took part in the experiment simultaneously. Faces were randomised and presented to the subjects on a 19-inch colour monitor for as long as was required to make their responses (about 5s). Subjects were required to rate how masculine or feminine they thought each face was on a 9-point scale where 1 = "very masculine", 3 = "masculine", 5 = "neither male nor female", 7 = "feminine", and 9 = "very feminine" looking. Subjects recorded responses on a score sheet without conferring with each other. The experimenter cued the display of subsequent images.

Results

Figure 3.5.1:3 graphs the results of the subjects' ratings.

Gender of Rater and Target Face

There were no differences between male and female subjects' ratings of either male-textured faces (Wilcoxon, $w = 5.0, p = 0.59, n = 30$) or female-textured faces ($w = 7.0, p = 0.58, n = 30$). Their ratings were also highly correlated for both male-textured ($r_S(4) = 0.9, p = 0.037$) and female-textured faces ($r_S(4) = 1.0, p = 0.0$). Given this, ratings were collapsed across gender of subject.

Skin Texture and Facial Shape

A 2-way ANOVA revealed that the male-textured faces were rated differently from the female-textured faces, $F(1, 522) = 1068.7, p < 0.0005$.

Faces rendered in different configurations were seen to be of differing gender, $F(8, 522) = 46.65, p < 0.0005$.

The interaction between gender texture and facial shape reached significance ($F(8, 522) = 11.56, p < 0.0005$) indicating that caricature manipulation of facial configuration had different effects for male and female skin textures (specifically, female textures at in hypermale shape, and male textures in the female shape; see Figure 3.5.1:3).

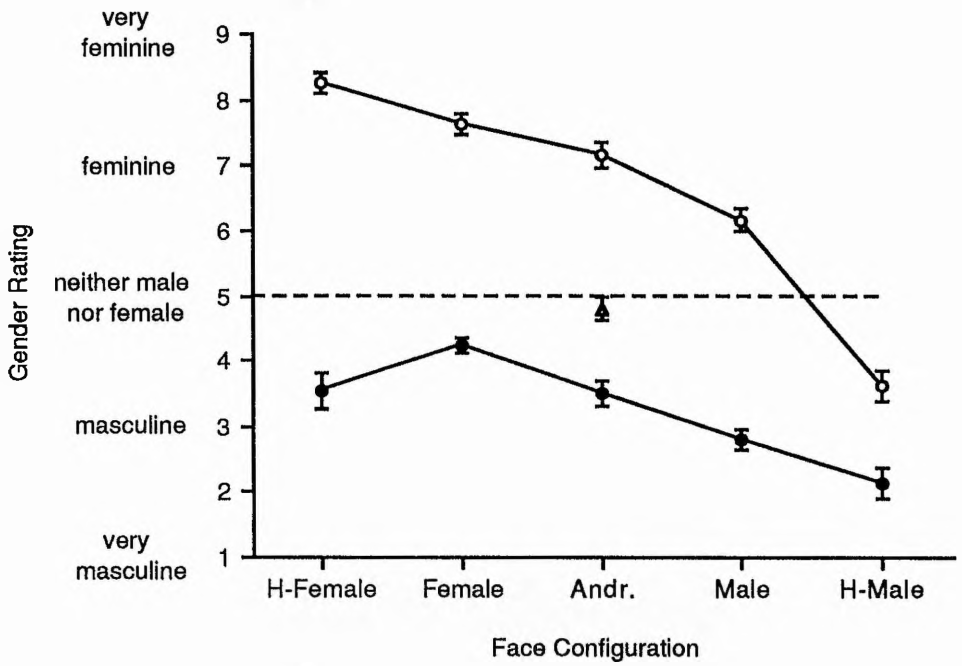


Figure 3.5.1:3

PERCEPTION OF ENHANCED GENDER. Caricaturing the gender (configuration) of a prototypical female face against a prototypical male face enhanced the degree of perceived femininity markedly. Regressing the female shape towards and beyond that of the typical male was sufficient to make the face look more masculine regardless of the presence of blended female skin textures. Similar caricature enhancement of the male prototype succeeded in emphasising masculinity; anticaricaturing masculinity to the prototypical female configuration decreased the degree of masculinity, although this effect could not be extended into the domain of the hyper-female configuration. The androgynous face (blend of the male and female prototypes) was correctly perceived as neither male nor female.

• male , ∘ female , ∆ androgynous prototype; 'H-' are hyper-conditions.

Gender Enhancement

Caricaturing appropriately skin textured male and female prototypes with respect to each other did produce gender-enhanced faces; the hyper-male face was rated more masculine than the male prototype, Planned Comparisons, Wilcoxon $w = 23.0$, $p = 0.004$, $n = 30$, and the hyper-female face was more feminine looking than the female prototype, $w = 28.5$, $p = 0.008$, $n = 30$.

The female prototype was rated significantly more feminine looking than its true rating sheet score (of 7; 7.6 ± 0.15 standard errors of the mean), $w = 174.0$, $p = 0.002$, $n = 30$. The male prototype was not rated any different from its true rating sheet score (of 3; 2.8 ± 0.16), $w = 4$, $p = 0.27$, $n = 30$.

The Androgynous Face

When a face was rendered in the androgynous configuration it was never perceived as sexless unless it comprised androgynous skin textures, 1-way ANOVA, $F(2, 58) = 87.6$, $p < 0.0005$. Post-hoc tests indicated that the female-textured androgynous-shaped face was different from androgyny, Wilcoxon $w = 351.0$, $p < 0.0005$, $n = 30$, and the male-textured face was different from the truly androgynous case, $w = 282.0$, $p < 0.0005$. There was no difference in the true androgynous face's gender rating from it's actual score (of 5; 4.8 ± 1.9), $w = 71.5$, $p = 0.36$, $n = 30$.

Degree of Exaggeration and Perceived Gender

The degree to which a female face was exaggerated and it's perceived gender rating was highly correlated, Spearman's Rank Correlation $r_S(3) = -1.0$, $p = 0.0$. The same was also true for male faces, $r_S(3) = -0.9$, $p = 0.037$.

Wilcoxon tests showed that in all cases bar one, distorting the male face's skin texture into the shape of the female configurations altered it's perceived gender in the correct direction. Although significantly different, the gender enhancement transformation from the female (0%) to hyperfemale (100%) shapes using male textures is in the wrong direction, ie. less feminine than intended. It is possible that the extreme distortion of the male skin textures into the hyper-female configuration produced a conflicting percept with which shape was not commensurate.

Discussion

It has been shown that the application of the caricature algorithm under a different semantics can markedly change the perception of gender using prototypical facial cues. The composite male looked masculine, the female looked feminine, and the androgynous face looked androgynous. Caricature enhanced male and female faces look more masculine and feminine respectively. Using composite images of male and female faces it is possible to enhance or diminish the prototypical appearance of a face in such a way as to increase its masculinity or femininity.

The 'truly' androgynous face comprised of both male and female skin textures was perceived as neither male nor female as predicted. Warping the skin textures of the female prototype into the configuration of the hyper-male was sufficient to drastically change subjects' perceptions of gender. At this degree of face-shape change it was possible to override the use of skin textures in judgments of gender. The study failed to provide a similar result in the case where the male skin textures were rendered in the configuration of the hyperfemale face defined by the caricatured enhancement of gender. It is possible that less than a 100% enhancement of the female face shape (eg. 50%) would have produced the desired change in perception. It is clear, however, that 2 high-level cues, skin texture, and facial shape/configuration, can be used to determine facial gender.

A number of subjects reported during debriefing that the hyperfemale condition looked younger than the prototypical female; there was a perceptible increase in the grouping of the facial features common in very young children. This would seem to uphold such results of the various studies cited in the introduction to this section. Examination of the images of the male and female prototypes also showed a stronger nasal region in the male while there was a definite button-like tip to the female's. The male brow and jaw regions in the male were markedly stronger than the female; the eye region differed in accordance with the observations made by Liggett (1974) with a definite increase in roundedness and tapering of the eyebrows.

This short study has been able to demonstrate that (within the sample of faces) there are clear and absolute differences between male and female faces. This has *only* been possible through the use of the computational compositing process to extract common featural bases. Studies employing a larger database of facial structure information and high quality images will be able to provide more details of which features are important in the discrimination of gender from the 2-dimensional image. Corroboration of studies such as that of Roberts & Bruce (1988) which found that the nose region[30] was important for such decisions are entirely feasible, and can elucidate many more parameters; modification of individual features across a discrete continuum should indicate whether judgements of gender can be categorically effected (Harnad 1987; Etcoff & Magee 1992) and at which point (it may be that faces are more feminine than masculine and for a face to be classified as male it may require to contain more powerful masculine cues before judgements are made consistently and reliably; it may transpire that faces are more androgynous than we think).

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[30]Cunningham, Barbee & Pike (1990) found that this region was also important for judgements bearing on the attractiveness of the male nose; a proportionally average masculine nose was more attractive than one which was slightly asymmetric or distinctive in some way.

3.6 Facial Attractiveness

A person's physical appearance, along with their sexual identity, is the personal characteristic that is most obvious and accessible to others in social interaction (Dion, Bersheid, & Walster 1972). Thus, intrinsic and extrinsic factors influence our judgements of how attractive we find someone; context, gender of target, gender of subject, age, ethnic (cultural) group, expression, and familiarity can all affect our decisions. As a consequence, much stereotyping can occur when we are confronted with situations in which categorisation of an individual is required and, as such, beauty can be seen to be very much 'in the eye of the beholder'[31] (Kerr & Kurtz 1978; Langlois & Downs 1979; Adams 1982; Morse *et al.* 1984).

Many cultural groups practice elaboration of the facial area in order to make themselves identifiable to their own people, to make themselves look attractive, and as marks of individuality and social standing. In the developed societies of today we can readily find such expression in application of colour in cosmetics, hair decoration, tattooing and piercing of the skin. By comparison, there are many examples of decoration and elaboration which are positively extreme and often involve physically modifying the structure and appearance of the face:

- flattening of noses (Aborigines)
- skull deformation in babies (Ancient Egypt; Africa, North America, Congo)
- ear perforation (Borneo, Phillipines, Solomon Islands)
- labrets (lip saucers; Botocudo Indians from Eastern Brazil, Sara tribe of Tchad region of Central Africa)
- nose and lip piercing (bone inserts; Upper Volta)
- sclera painting (South Pacific)
- teeth removal (Aborigines, New Guineans)

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[31]David Hume (Scottish philosopher, 1711 - 1776) considered that "beauty is not a quality in things themselves; it exists merely in the mind which contemplates them; and each mind perceives a different beauty." Beauty depends absolutely and completely on the eye of the beholder; it is postulated, however, that there are underlying characteristics which can be manipulated so as to affect subjects' perceptual judgements of facial attractiveness.

- teeth drilling, plugging, and filing (Ibans in Borneo; 2000BC in Japan saw teeth removal as part of marriage ceremonies)
- scarification, and hypertrophic (raised) scarring (Upper Volta), and cicatrisation (Abipone of South America)
- tattooing (Polynesia, Micronesia, Maori, and worldwide; marks of insurance, fellowship, clan, identification, dominance, virility, protection, and records of warface/childbirth/hunting success, etc.)

In many cases, the forms of decoration noted above occur in combination. Tooth decoration involving drilling for insertion of jewels (*plugging*), and *capping* with precious metal skins is becoming 'fashionable' in Western societies which have not previously considered this desirable.

The application of cosmetic substances to the face (of either sex) has a long and well-documented history. In compiling the *Karma Sutra*, 44BC Vatsyayana suggested that Indian women should be skilled in 64 'extra arts', two of which included (*#9*) colouring the teeth, hair, garments, nails, and bodies, and (*#6*) tattooing. The Roman poet Ovid (Publius Ovidius Naso, 43BC - c.17AD) told of how no woman need look ugly: careful use of 'cosmetics' could improve their looks. Even in such times, it is clear that the use of cosmetics was playing an increasingly important role in the moulding of some notion of an acceptable and classical image of the Woman. The C2 Greek writer Lucian recorded "If one could see these painted women getting out of bed one would find them less attractive than monkeys." Today, cosmetics is a billion-dollar industry and will continue to expand to incorporate a greater range of products which society will find itself unable to do without. However, beyond these issues must exist a more fundamental concept or notion of what is attractive or pleasing to the eye in terms of the human face.

Facial beauty and physical beauty are two very different concepts, and are often found integrated in judgements about a person. Within how *physically* attractive (eg. Berscheid & Walster 1974) we find a person lies their *facial* attractiveness. The basis of facial attractiveness has proved one of the most elusive of human attributes to formalise and very few studies have offered much insight into its properties. Plato believed that the essence of facial beauty lay in the "golden" proportions wherein the ratio of the whole (x) to the larger part (y) equals the ratio of y to the smaller part (z): $x/y = y/z$. In the perfect face, the brow would be 1/3 way down from the hairline and the mouth 1/3 way up from the point of the chin; the width of the face would be 2/3 the height. Such golden proportions have more recently been found in facial profiles of beautiful women (Ricketts 1982), and in the dentition of dentally 'ideal' subjects. Hence, it appears that golden facial proportions are compatible with high facial attractiveness, yet this *cannot be sufficient* (eg. when accompanied by facial anomalies) and may not even be necessary. Moreover, unattractive (but 'normal') faces may also have golden proportions. Ugliness is just as hard to define as attractiveness (Liggett 1974; Downs & Harrison 1985). There are many cases in which demonstrations of facial disfigurement can override our perceptions of facial normality and what this even might imply about the character of an individual (Bull 1979, 1982; Bull & David 1986; Bull & Green 1980; Bull & Stevens 1981; Rumsey, Bull, & Gahagam 1982, 1986). Slight aberrations of the skin (eg. birthmarks) are sufficient to cause even distress to some witnesses; a perfectly structurally and proportionally normal and 'good-looking' face can be labelled disfigured as a result, bringing with it stigmatising effects (Bull & David 1986) and physical avoidance (Benson, Karabenick & Lerner 1976; Bull & Stevens 1981; Bull 1990). Much psychological harm can be caused to a child by withholding corrective surgical operations or prescription, causing worry, extreme shyness, and introversion. A wide variety of corrective and vanity operations are commonly executed, including *blepharoplasty* (eyelids), *rhinoplasty* (nose), *rhytidectomy* (face lift), and *otoplasty* (ears); in cases where serious facial injuries have been sustained (burns, severance, chronic disease, etc.) prosthetic surgery may be necessary. Vocational demands may *suggest* that surgery is imperative. It should be recognised that the patient may be deluding themselves with a thinly-veiled rationalisation of an unrealistic impulse to return to one of their earlier 'seven ages'. In many cases the issue is not of 'self-improvement' but 'self-acceptance' without which it is believed there can be little happiness; facial blemishes are sometimes used as hooks on which to hang the individuals' feelings of inadequacy and/or abnormality.

Here, the subsumption is that it should be possible to account for at least some aspects of the appeal for some faces over others. Facial attractiveness is a highly complex issue and because of its implications merits careful consideration; this introduction is deliberately limited to a narrow discussion of the more major issues which can be related to particular qualities of the face manipulable using the computer model. The psychological literature of late has been preoccupied with attempts to establish the nature of facial types and stereotypes in and out of social contexts.[32] What is lacking are well-controlled objective studies which address the underlying visual nature of attractive or unattractive faces.

3.6.1 Experiment Ten: An Examination of the Roles of Facial Shape and Skin Texture in Facial Attractiveness

Introduction

While judgements of facial attractiveness seem to be consistent for observers from different ethnic backgrounds (eg. Martin 1964; Udry 1965; Bernstein, Lin & McClellan 1982) it is not clear *which* visual cues are used by subjects when rating the attractiveness of facial images. It has been reported that the average of several faces blended together is more attractive than the individuals' faces used in the averaging process (Galton 1878a; Galton 1879; Jastrow 1885; Langlois & Roggman 1990). This suggests that attractive faces are average in shape and that attractiveness is determined by how far a face deviates from average proportions. Previous methods for blended faces cause blurring of the features and this blurring or soft focus may itself be responsible for the change in attractiveness.

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[32]See: Secord, Bevan & Dukes (1953); Dion, Berscheid & Walster (1972); Dion (1973, 1974); Efran (1974); Landy & Sigall (1974); Feldman & Hilterman (1975); Sigall & Ostrove (1975); Hansson & Duffield (1976); Adams (1977); Cash, Gillen & Bruns (1977); Elman (1977); Gross & Crofton (1977); Leventhal & Krate (1977); Cantor & Mischel (1979); Hamilton (1979); Bellezza & Bower (1981); Berman, O'Nan & Floyd (1981); Jackson (1983); Goldstein, Chance & Gilbert (1984); Kerr *et al.* (1985); Alike, Smith & Klotz (1986); McGee & Skinner (1987); Berry & McArthur (1988); Benson & Perrett (1992a, 1992b)

While much has been done to promote the appearance of smooth, blemish-free skin as being desirable because of its attractiveness, there is a lack of understanding of matters dealing with the shape of the human face in those terms. Gross distortions of the facial features, as described above, are almost always responsible for impressions of *some* degree of abnormality and unattractiveness. It is very rare to find a truly symmetric face, indeed such faces may even look rather peculiar as there are no distinguishing lateralities. It is possible that the less distinct the object of our attention, the greater the contribution from the perceiver's own mind. Therefore the more indistinct a face, the greater the chance it will provide a means of supporting personal projections of beauty (see Liggett 1974). Many faces seem to be able to portray man's different concepts of beauty. Facial convertibility, seen in actresses such as Ingrid Bergman and Greta Garbo, may be responsible in part for their success, as such an enigmatic visage is able to support a diverse range of 'roles'.

The philosopher and essayist Francis Bacon (1561 - 1626) thought that, unlike the Greeks, an ideal face was not one which possessed true symmetry; he considered that symmetry in a face was exceedingly boring, there being "no excellent beauty which hath not some strangeness in the proportion" (cited in Liggett 1974). Assessment of subjects' judgements of faces has shown that a degree of 'cuteness' or 'baby-facedness' in an adult does affect perceptions of facial attractiveness for the better (Alley 1988; Berry & McArthur 1988a, 1988b). Slightly distinctive asymmetries in faces of children (McKelvie 1986; Cunningham 1986; Cunningham & Odom 1986; Rothbart, Taylor & Tucker 1989) and adults (Metzig, Rosenberg & Ast 1974; Schwartz & Smith 1980; Campbell 1978, 1982; Cunningham 1986; Rhodes 1986; Bennett, Delmonico & Bond 1987; McGee & Skinner 1987; Cunningham, Barbee & Pike 1990; Rhodes & Lynskey 1990; Skinner & Mullen 1991) at rest or during speech are also responsible for impressions of attractiveness. It remains to be demonstrated computationally whether highly symmetric faces are seen as more or less attractive than more commonly occurring asymmetric ones.

The majority of studies on facial attractiveness have used a consensual method to determine an individual's attractiveness. An individual is deemed attractive if a significant number of raters or judges designate that individual as attractive. Agreement of the beauty of an individual merely reflects the common experience of those who agree. Such agreement does not establish that any objective standard exists; social standards are frequently highly variable and localised. A face's attractiveness is taken to be the mean of the ratings obtained from a group of raters using a Likert-like scale (Likert 1932; Edwards & Kenney 1946; Guttman & Suchman 1947; Foa 1950; Kuang 1952). This method obtains its acceptance from the fact that there is usually a high degree of agreement among judges (Kerr & Kurtz 1978; Hansell, Sparacino & Ronchi 1982) and of judges from differing professions (Dongieux & Sassouni 1980). A similar approach was employed in this experiment.

The aims of this experiment were to assess the separate roles of facial shape and skin texture in the control of perceived attractiveness. The experiment extends the work of Langlois & Roggman (1990) but attempts to improve the quality of graphic processing. If attractive faces are only average, then one can make predictions about modifying the shape of individual faces towards an average configuration (without modifying the clarity of skin and hair textures). This should increase the perceived attractiveness.

Methods

Subjects

12 male and 17 female undergraduate students took part in the experiment voluntarily. Subjects were aged between 20 and 22 years.

Stimuli

The facial images of 16 male and 16 female Caucasian students used in the previous experiment (section 3.5.1) were used. For 4 sets of 8 faces of the same sex chosen randomly (*originals*), the average coordinates of their facial feature positions were calculated from the delineation data, and 4 composites (2 male) rendered appropriately (*blends*; see section 3.4) from the faces distorted into the average shapes (*prototypes*). The blended composite face was distorted back into the shape of each of the 8 faces from which it was constructed (*reconstructs*). All images were masked to exclude ears, neck, and hair (see Figure 3.0.3:1). Examples of the stimuli are shown in Figure 3.6.1:1.

Procedure

Faces were presented on the 19-inch monitor of a Silicon Graphics Personal IRIS in a random order. Attractiveness ratings were obtained for all 50 male faces (16 original, 16 prototypes, 16 reconstructs, and 2 blends) and separately for all 50 female faces on a 7-point scale where 1 = "very unattractive", and 7 = "very attractive".

Results

Gender of Rater and Gender of Face

Inspection of the rating data showed that male subjects gave higher overall ratings of facial attractiveness to target faces of either sex than did female subjects, Wilcoxon *t*-test $w = 3141.0$, $p = 0.034$, $n = 100$. The difference in judgements was more marked when target faces were male ($w = 312.0$, $p = 0.0017$, $n = 50$) than female ($w = 601.0$, $p = 0.91$, $n = 50$). The mean ratings afforded to each gender of face by male and female subjects are shown in Table 3.6.1:1.

Although there were measurable differences between the ratings given by male and female subjects their judgements were in fact highly correlated with the target faces. Overall, male and female ratings of all the faces were statistically related, Spearman's Rank Correlation $r_S(98) = 0.332$, $p < 0.0008$. Ratings of both male and female faces were agreed upon by each subjects regardless of their gender, $r_S(48) = 0.811$, $p < 0.00005$, and $r_S(48) = 0.948$, $p < 0.00005$ respectively. Because of the clear relationship between gender of rater and gender of target face it was only necessary to consider the data from male and female subjects as a whole.

Figure 3.6.1:2 graphs the ratings for each facial type.

Figure 3.6.1:1

MANIPULATIONS OF FACIAL ATTRACTIVENESS. (1) *original* female face; (2) *prototype* face made by distorting the original skin textures to the average shape of 8 original faces (of the same sex); (3) *blended* face made by averaging 8 prototype faces; (4) *reconstruction* of the original face made by distorting the skin textures of (3) to the shape of (1).

Gender of Stimulus	Gender of Rater: Female	Gender of Rater: Male	Gender of Rater: All
Female	3.22	3.24	3.23
Male	2.87	3.12	2.97
All	3.05	3.18	3.10

Table 3.6.1:1

PERCEPTION OF FACIAL ATTRACTIVENESS. Male subjects gave higher overall ratings of facial attractiveness to target faces of either sex than did female subjects, Wilcoxon *t*-test $w = 3141.0$, $p = 0.034$, $n = 100$.

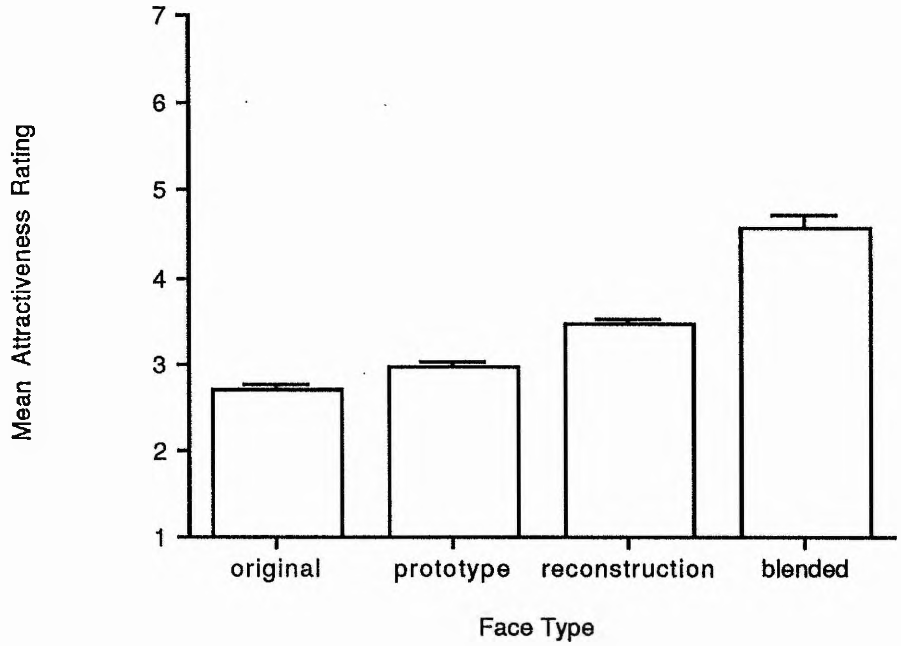

Figure 3.6.1:2

ENHANCEMENT OF FACIAL ATTRACTIVENESS. On average, changing the shape of an individual's face towards a more symmetric, average configuration increased it's perceived attractiveness (*original* to *prototype*, $p = 0.016$). Changing the shape of a blended face comprised of smooth skin textures into the configuration of some other individual lessened it's attractiveness (*blended* to *reconstruct*, $p = 0.0001$). Modifying the skin texture of a face also affected it's perceived attractiveness; an individual's face which contains smoothed skin textures was more attractive than when it contained it's original tones (*reconstructs* better than *originals*, $p = 0.0001$), and when faces shared identical configurations those which were displayed with smoothed skin tones were considered more attractive than others (*blends* better than *prototypes*, $p = 0.0001$). Blended faces (average skin tone and average shape) are considered most attractive of all.

Facial Shape

Overall, the *original* faces were judged less attractive than they were when their shape was modified to that of either gender's *prototypical* configuration, Wilcoxon *t*-test $w = 1061.5$, $p = 0.0001$, $n = 56$. In addition, each of the 4 *blended* average faces were considered more attractive than the *reconstructed* faces which shared the same skin texture pattern, $w = 0.0$, $p = 0.0001$, $n = 56$.

For male faces, the *originals* were judged as attractive as the *prototypes*, $w = 190.5$, $p = 0.114$, $n = 28$. The *blended* images were considered more attractive than the *reconstructs*, $w = 0.0$, $p = 0.0001$, $n = 28$.

For female faces, the *originals* were judged less attractive as the *prototypes*, $w = 25.0$, $p = 0.0001$, $n = 28$. The *blended* female images were considered more attractive than the *reconstructs*, $w = 0.0$, $p = 0.0001$, $n = 28$.

Skin Texture

On average, an individual's face which was represented with the smooth blended skin textures (*reconstructs*) was considered more attractive than when shown with their *original* tones, $w = 1584.0$, $p = 0.0001$, $n = 56$. When a face was shown in one of it's *prototypical* configurations with it's own skin textures, it was considered less attractive than a face sharing the same shape but with *blended* skin textures, $w = 1596.0$, $p = 0.0001$, $n = 56$.

For male faces, the *reconstructs* were judged more attractive than the *originals*, $w = 5.0$, $p = 0.0001$, $n = 28$. The *blended* images were considered more attractive than the *prototypes*, $w = 406.0$, $p = 0.0001$, $n = 28$.

For female faces, the *reconstructs* were judged more attractive as the *originals*, $w = 404.0$, $p = 0.0001$, $n = 28$. The *blended* female images were considered more attractive than the *prototypes*, $w = 406.0$, $p = 0.0001$, $n = 28$.

Discussion

Facial Shape and Skin Texture

The results indicate that facial shape and skin pigmentation are both important in determining perceived attractiveness. In confirmation of the work of Langlois & Roggman (1990) it was shown that the average shaped face was more attractive than any of the original faces of which it was comprised. Changing the shape of an individual face towards an average was found to increase attractiveness ratings by a small but significant amount (about 6%). Changing the skin texture of a face to a more smooth and bland average increased attractiveness by about 19%. Changing the texture and shape increased the perception of facial attractiveness by about 60%.

Langlois & Roggman (1990)

A number of methodological criticisms can be levelled against the study of Langlois & Roggman (1990). Although their study was without the superiority of the compositing technique described here and in section 3.4 there remain shortcomings. Alley & Cunningham (1991) are critical of 3 areas of their study, (i) theoretical reasons why the most average facial appearance will not be ideally attractive, (ii) comments on data which suggests that the most average facial appearance is not the *most* attractive, and (iii) limitations and weaknesses of their methodology. It is suggested here that certain of their criticisms lack definition; many of them were addressed in this experiment and the results do not always support their conjecture.

In arguing the issue of 'ideals', for which they give no suitable working definition, Alley & Cunningham (1991) clearly confuse physical with facial attractiveness. They assume that physical health and prowess is indicated by the facial structure and complexion, and thereby facial attractiveness is equatable with physical attractiveness, basing the premis on evidence from biological and evolutionary heterosexuality. The suggestion is that both males and females should exhibit behavioural preference for atypical (stronger) rather than common or average (weaker) facial qualities. Without bearing reference to the physical characteristics of an individual (in the sense of Alley & Cunningham's (*ibid.*) argument) subjects in this experiment and that of Langlois & Roggman (1990) could not make the necessary comparison. This point relies then on the fact that subjects would be suitably familiar or experienced with the appearance of the human face to directly relate the percept to other human characteristics or traits. Experience here would thus relate to types of faces rather than familiarity with individuals (qv).

The experiment reported in this section yielded data which suggest that the averaged face (either masculine or feminine) is by far the most attractive. Tied with methodological improvements it was demonstrated that careful preparation of the original and subsequent images yielded a maximised advantage for the prototype. In this experiment, highly accurate facial composites were synthesised from originals which were frame-grabbed under conditions of identical illumination. Inter-pupilary distance was controlled manually as accurately as possible; coupled with the power of each image manipulation (224 feature control points (Appendix II) as opposed to 3 (pupil centres and centre of the lip area)) much greater control was exerted upon any distortions carried out (ie. shape transformation to prototypical configuration, reconstruction of original facial shape using optimised skin tones, blending of the composites). No contrast manipulation was required to be applied to the digital images during the experiment, as was done by Langlois & Roggman (1990). Smoothness of the averaged skin textures reflected only the texture patterns of the constituents.[33]

Alley & Cunningham (1991) are also careful to point out that the results of Langlois & Roggman (1990) could have benefited from the

[33]It remains to be determined how many images require to be composited before the difference between blends is imperceptible. The effects of typicality and ethnicity will affect any results.

effects of subject familiarity with the individuals portrayed in the target images, a factor which has been shown to increase the judgement of attractiveness (Berscheid & Gangstad 1982; Moreland & Zajonc 1982; Bartlett, Hurry & Thorley 1984; Bruce 1986a). As prototypical or 'average' faces look highly familiar even if they have never been seen before (Solso & McCarthy 1981; Bruce *et al.* 1991) there might be concern for both the prototype ratings of Langlois & Roggman (*ibid.*) and in this experiment. In this instance, all subjects were made aware at the outset that they would be unfamiliar with any of the target faces, and manipulations of original faces were carried out according to 2 differing contributory factors to attractiveness (shape and texture).

The study revealed two parameters which could be manipulated independently to influence judgements of attractiveness: feature shape and configuration, and skin texture. As predicted, changing the shape of an individual face towards average was found to increase attractiveness. A suitable extension to this experiment would be to draw upon a set of target faces which were both highly distinctive and independently considered either attractive or unattractive. It should also be possible to go some way towards replicating the objective 'facialmetric' measurements of male attractiveness and female beauty made by Cunningham and his colleagues (Cunningham 1986; Cunningham, Barbee & Pike 1990; cf. neurophysiological studies of facial measurements by Yamane, Kaji & Kawano 1988, and Young & Yamane 1992), as the delineation data provides as accurate and in cases more accurate measurements of the facial image.

3.7 Summary of Regression Effects

A number of other facial effects have been synthesised and analysed in section 3.2 onwards. The basis of all these transformations has been the *regression* of the facial configuration onto that of some prototype or other individuals', while the effects discussed in previous sections dealt with the caricature model which *accentuated* the differences between faces and a prototype. Modifying the underlying semantics of the caricature model allowed many powerful and significant effects to be investigated. Nevertheless, all image sequences and transformations are produced using the same paradigm of comparing one 'face' with 'another face'.

The Identity Transformation (morphing) of the facial appearance of one individual into another (section 3.2.1) was easily extended into a regular matrix of more than two target faces (section 3.2.2). Maintaining the notion of manipulation of the *individual*, the Identity Matrix model can be used to generate matrices which display the gradual change of facial expressions. It is now possible to relate such image sets closely to studies of animal behaviour which attempted to indicate the flow of intentional and emotional display responses and the interactions thereof.

The perception of facial age according to structure and configuration components was examined briefly using both regression (making the face look younger) and exaggeration (older) of a target against a norm which allowed both transformations to be made while again maintaining some notion of identity through skin textures. As skin textures clearly give strong indications of the likely age of someone, a second more powerful aging model was proposed taking account of the surface of the face; removal or addition of wrinkle patterns is necessary to make the transformations more compelling.

A significant extension to the procedure for generating accurate facial composites was developed in section 3.4 whereby the caricature generator was again applied using the method of regression onto a single prototypical facial shape. Composite 'average' faces produced in this way were used to investigate the differences between male and female faces according to gender (section 3.5) and attractiveness (section 3.6). In the case of perceptions of gender it was possible to both enhance and diminish the degree of masculinity or femininity present in a young male or female face by manipulating the two dimensions of facial shape and skin texture separately. Caricatures of masculine faces (against a typical female face) looked more masculine; similarly, hyper-female faces look more feminine. Here the calculated difference between the prototypical male and female facial configurations formed the acceptable basis of gender enhancement or diminishment; the difference was 'gender'. A simple test of perceived facial attractiveness showed that there are at least in fact 2 parameters underlying our judgements of how attractive or unattractive raters consider faces of either sex to be; both the shape of the face and the quality of the skin tone or texture mattered a great deal. This study also addressed and expanded upon a number of criticisms made about the methodologies employed by other researchers. Synthesis of accurate composite facial images is an extremely powerful method of investigating the fundamental properties which underlie our perceptions of particular categories of facial attributes.[34] Using results from such investigations may allow a compelling encyclopedic algebra of the human face to be implemented.

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[34]It has also been possible to make progress towards extracting the *visual nature* of such diverse attributes such as 'intelligence', 'extroversion', and 'likeability'. Caricaturing allows the extraction of 'identity'; studying the differences between faces which have been scored for their impressions of low or high 'intelligence'. Although such judgements are almost never directly related to the actual abilities or personalities of the individuals, they do have a considerable bearing on the kind of 'first impressions' stereotyping which occurs on a regular basis.

IV. Summary

The appearance of the human face has been shown to be a source of great interest. Historically and socially it has been documented as being thought of as a means of offering insight into a wide range of human characteristics including character, intelligence, social standing, ethnicity, and above all personal identity. So much emphasis has been placed on our facial appearance and our interpretation of it that a diverse range of scientific approaches have been employed in an attempt to advance our understanding of it. In this thesis, a simple computer model for manipulation of the photographic facial image was developed. Each of the visual effects examined both experimentally and procedurally were based upon the comparison of the configural aspects of a target face with some other face, beit some notion of prototypicality or another individual.

A series of experiments examined the role of featural/configural atypicality in the cognitive processing of the individuals' identity. Caricature (distinctiveness) enhanced images were found to improve subjects recognition of highly familiar and famous faces; methodological improvements to a previous study using line-drawings also demonstrated recognition superiority for caricatures of well-known faces. These results indicated that processing of facial distinctiveness accounts for approximately one third of the time taken to recognise familiar individuals, and are in accordance with the established model of face recognition. The results from perceptual studies of facial caricature are in accordance with previous work on modes of representation governing the appearance of the facial image; undisorted photographs of familiar faces are the best likenesses of those people, while (impoverished) line-drawings of the same faces better capture the notion of facial identity when strongly caricatured. The caricature advantage was not manifest in a study using faces with which subjects were only personally familiar. In summary, the results upheld the proposal that different coding strategies are employed by the visual system when dealing with faces of differing levels of familiarity.

One requirement for accurate perception of age from facial information was examined. The computation of regressive and progressive age of individuals was demonstrated using powerful holistic feature configuration cues, rather than a combination of purely mathematical transformations. The experiment indicated that (relative) accurate estimations of age can be made from configural information in the absence of commensurate skin tones. A hybrid model incorporating skin (un)wrinkling was proposed which incorporated a parameterised description of facial surface characteristics.

A number of other facial manipulations were realised using the software tools. Transformation between one individual and another, in the form of a 1- or 2-dimensional matrix, provided the basis for synthesis of photorealistic expression matrices. Using these techniques it is now possible to determine whether a range of facial characteristics are perceived in a categorical manner and thus limit the number of cognitive types which need be considered.

Facial composites, or 'averages', were created using the same model. By using accurate information about the location and bounds of facial features all constituent faces were accurately aligned before blending together. Composite prototypical faces were used to extract the typical appearance of an individual by maintaining common attributes whilst dispensing with anomalous postures, features, blemishes, and expressions. The process was extended to examine gender types which, when caricatured, showed that masculinity and femininity could be reliably extracted from a set of exemplar images; both skin texture (tone) patterns and feature configuration play an important role in the perception of gender. Facial composites also provided a means of addressing the intricate and emotive issue of facial attractiveness. Separately, modifications to an individual's facial shape towards a typical ('average') configuration, and a smoothing of skin tone can increase subjects' ratings of attractiveness; together, these components were observed to provide a maximised impression of typical attractiveness. The gender and attractiveness studies provide an objective experimental methodology; the results indicate the nature of the underlying cues which have only previously been speculated about.

The computational model is a simple but extremely powerful one whose visual effects have been upheld by psychological experimentation. The manipulations have been shown to be valid and effective in assisting the understanding the physical complexity and subtelty of the facial image.

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Appendix I

Linearity of Caricature Space versus Perceptual Space

The computational model of caricature generation advocated by Brennan (1982, 1985) produces deformations of a target face according to a linear exaggeration rule. A 50% caricature has exactly the same amount of structural deformation as a 50% anticaricature, but in the opposite direction.

From the caricature experiments, it was seen that positive caricatures were seen as better likenesses than the corresponding anticaricatures. It does not hold, however, that the perception of matched caricatures and anticaricatures is related in the same linear manner, and that the range of responses to such stimuli is normally distributed and centred about veridicality. In the line-drawing experiments, subjects always constructed their estimates of perceptual best-likeness to the right of veridicality, ie. caricatures were preferred, and hence the distribution was skewed. Subjects did not prefer anticaricatures. In an hypothetical experiment, a psychometric response function could be constructed which perhaps showed that for faces to be recognised as belonging to a particular individual, a good deal of distinctiveness information would have to be added into a prototypical face before any resemblance was observed; the same relatively anticaricatured face would not be considered a good likeness at all, and would not be responded to correspondingly slower in a speeded response task for example. It is likely that a threshold region would exist to the left of veridicality (anticaricature space) beyond which all faces looked alike, eg. an 80% caricature would look very much like person X (and indeed an improvement over 0%), while a 80% anticaricature might well look like any anticaricature in the range 60 to 100%.

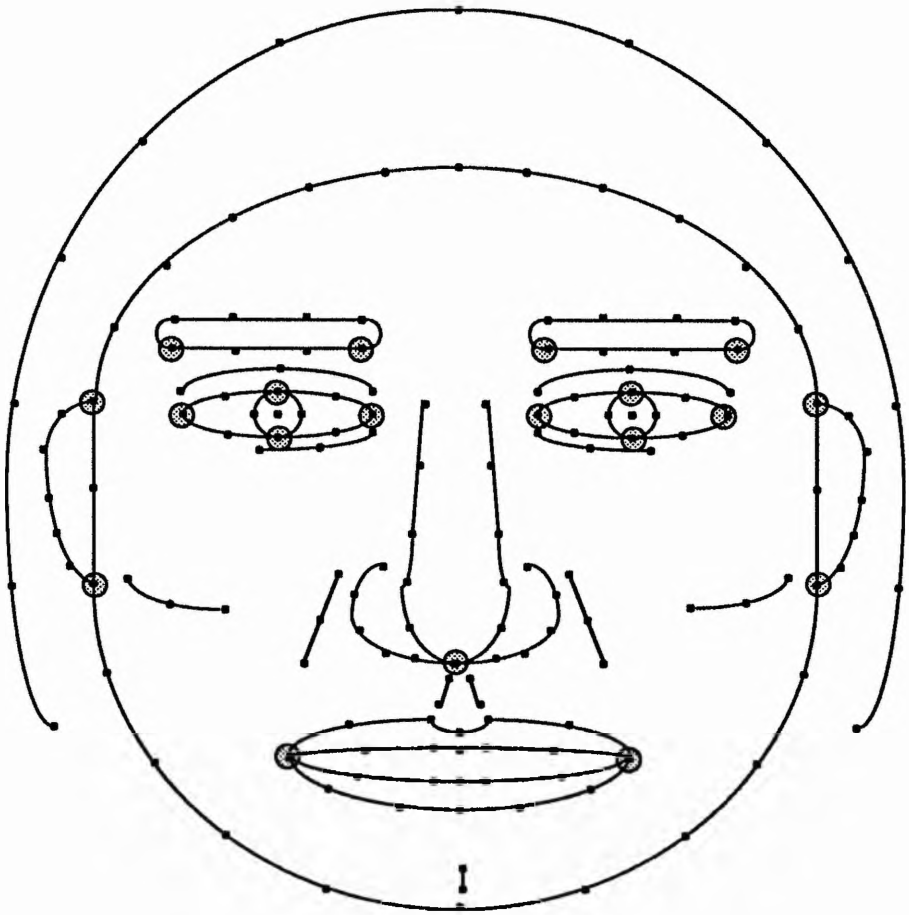
In conclusion, the response profiles for a 50% anticaricature are unlikely to be correlated with the (improved) responses to a 50% caricature, as the two scales are not colinear.

Appendix II

List of the 186 feature points logged on the digitised facial image. Each feature has a fixed number of points describing it (#), from left to right and top to bottom in order:

#	*feature*	#	*feature*
1	left pupil	7	top of upper lip
1	right pupil	7	bottom of upper lip
5	left iris	7	top of lower lip
5	right iris	7	bottom of lower lip
3	bottom of left eyelid	3	left side of face (ear area)
3	bottom of right eyelid	3	right side of face (ear area)
3	bottom of left eye	7	left ear
3	bottom of right eye	7	right ear
3	top of left eye	11	jaw line
3	top of right eye	13	hair line (forehead)
3	left eye line	13	top of head (hair)
3	right eye line	3	left smile line
6	left side of nose	3	right smile line
6	right side of nose	3	left cheekbone
6	left nostril	3	right cheekbone
6	right nostril	2	left upper lip line
6	top of left eyebrow	2	right upper lip line
6	top of right eyebrow	2	chin cleft
4	bottom of left eyebrow	3	chin line
4	bottom of left eyebrow		

Idealised location of feature points are described on the schematic face. Regions where feature markers should be coincident are highlighted (◉).



Appendix III

Extended list of the feature points (224) logged on the digitised facial image (see Appendix I). Additional points are daggered (†) and are located *in-between* existing points (Appendix II):

#	*feature*
1	left pupil
1	right pupil
†9	left iris
†9	right iris
†5	bottom of left eyelid
†5	bottom of right eyelid
†5	bottom of left eye
†5	bottom of right eye
†5	top of left eye
†5	top of right eye
3	left eye line
3	right eye line
6	left side of nose
6	right side of nose
6	left nostril
6	right nostril
6	top of left eyebrow
6	top of right eyebrow
4	bottom of left eyebrow
4	bottom of left eyebrow
7	top of upper lip
7	bottom of upper lip
7	top of lower lip
7	bottom of lower lip
3	left side of face (ear area)
3	right side of face (ear area)
7	left ear
7	right ear
11	jaw line
13	hair line (forehead)
13	top of head (hair)
3	left smile line
3	right smile line
3	left cheekbone
3	right cheekbone
2	left upper lip line
2	right upper lip line
2	chin cleft
3	chin line

Appendix IV

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