

ADJUSTING THE 'SEARCH SPACE' IN THE FACIAL COMPOSITE SYSTEM EVOFIT

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Abstract: This research paper focuses on EvoFIT, a facial composite system developed by Frowd et al. (2004) and now used in police investigations to reconstruct facial images of alleged perpetrators. The system employs Principal Components Analysis (PCA), as PCA can create a large number of faces from very few components. EvoFIT currently uses a database consisting of 72 faces and this study aimed to determine whether increasing or decreasing the variability within the system's face-space could result in a more accurate facial composite.

Participants were asked to construct faces from memory in either a small (36 faces), medium (72 faces), or large (144) database, and to either set the height and width ratio of the faces to be displayed, or not set this ratio. Composites were subsequently identified using 'spontaneous' and 'constrained' naming tasks. Results indicated that composites constructed using the small (36) database resulted in more 'spontaneous' correct naming than the medium database, but no differences were apparent with the large database, or with any of the databases using the constrained naming task. Possible explanations and implications for further research are discussed.

Keywords: Facial Composite, Principal Components Analysis, EvoFIT, Face-space.

Introduction

Humans have the incredible ability to recognise faces quickly and efficiently (Seeck et al. 1997). However, when recalling the details of a face it appears that we do not possess the skills to do this as effectively. This is problematic when an individual witnesses a crime and there is no physical evidence, for example DNA and finger prints, as they are sometimes required to make a facial composite, which often relies on their ability to recall the features of a face.

Frowd, Skelton et al. have described facial composites as 'images of alleged criminal offenders, produced from memory by witnesses' (2012, 225). They are commonly used in investigations involving serious crimes and there are a wide range of systems that can produce such images. Traditionally, facial composites were constructed using manual systems such as a sketch artist, where an artist draws the description given to them by the witness, or Photofit, which relies on the witness selecting five main features and fitting these features together in a frame, much like a jigsaw (Christie & Ellis 1981). However, there is limited evidence to support that this technique successfully brings a perpetrator to justice (Ellis, Shepherd & Davies 1975 and 1978; Laughery & Fowler 1980). As the performance of these manual methods was low, a new method was developed which involved

selecting features within a complete face, rather than looking at the features individually. A new facial composite system, EvoFIT, was thus developed, which enables witnesses to view and select complete faces with random characteristics and their choices are then ‘bred’ together to create a new set of faces.

The EvoFIT system

EvoFIT relies on a statistical method known as Principle Components Analysis (PCA) which combines the random characteristics of selected faces whilst maintaining as much relational information in the face as possible (Frowd, Skelton et al. 2012). Although it is largely assumed that external features (such as hair, neck and ears) are the most important aspects of face in the recognition of unfamiliar faces (Veres-Injac & Schwaninger 2009), this is not necessarily the case. PCA therefore calculates the important information (the principle components) within a face, to produce eigenvectors, the variation between the faces, and then produce ‘eigenfaces’ (Figure 1) (Turk and Pentland 1991). Sirovich and Kirby (1987) were among the first to apply PCA to facial recognition. They found that, by applying PCA to faces, they were able to construct new faces to within 4% error using just 40 components. This suggests that it is possible to accurately represent a large number of faces with little data.

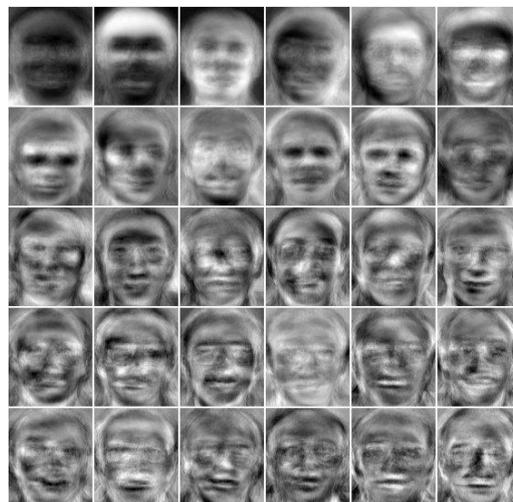


Figure 1: Examples of ‘Eigenfaces’ (AT&T Laboratories, Cambridge) available from flickr

Before PCA is performed, a number of control points are computed on the internal features and around the head to produce an average image set. These points are triangulated, producing an image mesh (Figure 2). These areas are distorted and morphed to average the shape and produce ‘shape free’ images (Frowd et al. 2004). Hancock, Bruce and Burton (1997) suggest that the remaining information is also useful and can form the texture of the face (the colouring of the skin

and the features), whilst the triangulated information is useful for face shape. By adjusting these two models, for example by randomly changing an eigenvalue to mimic mutations in nature, new sets of faces can be produced (Frowd et al. 2004). These two models are therefore used in the current EvoFIT system and presented and selected separately by witnesses. The face shapes are initially selected and the face textures are displayed on the face which the witness believes is the best shape.

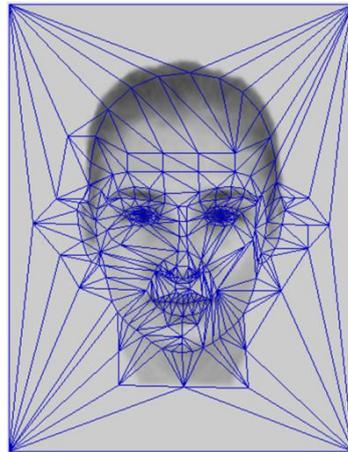


Figure 2: Example of ‘image mesh’ used to produce ‘shape free’ images

In order for a witness to produce a good likeness to a target, they are asked to select the faces which look most similar to the target from an array of 18 faces. An evolutionary algorithm is then used to recombine and mutate the selected parameters of the faces to produce a new set of faces, using our ability to recognise faces, rather than traditional systems which rely on recollection of-faces (Frowd et al. 2004).

EvoFIT uses parallel presentation, meaning that whole faces are presented in an array, it also contains ‘holistic tools’ which allow the witness to make slight adjustments to the face under 10 options: facial width, age, weight, pleasantness, outgoing/extroverted, health, honesty, masculinity, threatening and face position. These changes can have a dramatic impact on the overall appearance. Witnesses also produce the face without the external features (hair, neck and ears) as research has indicated that the internal features (such as eyes, nose and mouth) are more important for recognition (Ellis, Shepherd & Davies, 1979b).

The current EvoFIT system uses a database consisting of an initial set of 72 faces (known as the face-space). Eighteen faces are presented in a parallel arrangement from the face shape palette and a

further eighteen faces from the texture palette; as with Hancock et al. (1997), the texture palette displays the 'shape free images'. The two palettes are presented separately so that shape and texture are viewed as accurately as possible (Frowd et al. 2004). The witness first chooses the six best face shapes from the shape palette, which are the closest match to that of the target face. The facial aspect is set with the initial face shape palette; this enables the witness to fix the height and width of the faces, ensuring that all the faces seen are the same size. After selecting the six face shapes from a selection of a possible four screens, the witness then selects six textures, again from a possible four screens. For both shape and texture the witness is required to select two faces from each screen (and if they wish to make any changes on the last screen), the two faces they choose contain the important information needed for the evolutionary algorithm. This uses the parameter sets to produce new sets of faces; this should ensure that the new set of faces will be similar to those previously selected. Once six shapes and six textures have been-selected, they are combined to make a selection of thirty-six faces across two screens. The witness is then asked to select the two best faces, one from each screen and select the best face from the two chosen. A final screen is presented where the witness is asked to select the best face, which is given double the breeding opportunities in the evolutionary algorithm (Frowd et al. 2011). The second generation is then made, which requires the witness to carry out the same steps as previously stated. The composite can be evolved as many times as necessary to get a good likeness to the target, though two is usually sufficient.

Once the witness feels that the composite has been evolved enough to get a good likeness to the perpetrator, holistic tools are applied to the composite; this should give the composite a 'personality' and uses the ten characteristics mentioned above. The composite can then undergo slight adjustments, using the shape tool, to get a better match to the individual facial features, after this the hair can be applied. Once a witness feels that the composite is a good enough match to the perpetrator the composite can be made available to the media.

An initial evaluation of EvoFIT (Frowd et al. 2005) found that naming appeared to be low, yet a further evaluation (Frowd, Bruce, Ness et al. 2007) found that EvoFIT had an advantage over feature based systems with 11% correct naming rate compared to just 4% for previous systems. The success of EvoFIT is replicated with field studies, which give a clearer definition of the usefulness of this system in the 'real world'. Frowd et al. (2011) found arrest rates varying from 19% to 40% during field trials in Lancashire, Derbyshire, Devon and Cornwall and Romania. More recently, Frowd, Pitchford et al. (2012) worked with Humberside police and found that, over a twelve month

evaluation period, using EvoFIT in case investigations produced 60% arrests leading to 29% convictions. Again, this highlights the effectiveness of using this system. However, improvements can be made, particularly with regards to the interview procedure, the final composite and the EvoFIT system itself.

Improving facial composites

Ongoing studies have focused on the cognitive interview, presently used to enhance the memory for an individual's face. Frowd et al. (2008) suggest that an interview focusing on enhancing the memory for the personality of a face (a holistic-cognitive interview) would be more effective. Ways to improve a completed composite are also being researched. Bruce et al. (2002) combined facial composites of the same target made by four different participants and found that this enhanced the quality of the composite as the more accurate parts of the composite are reinforced. Frowd, Bruce, Gannon et al. (2007) also found that caricaturing completed facial composite enables the feature shapes to be deemphasized to look more like the average, producing significantly more correct naming. With regard to improvements made to the system, Frowd, Skelton et al. (2012) found that by masking the external features when constructing the face shape, textures and internal features leads to a more accurate composite, therefore the system used at present now allows the witness to construct the external features at the end of construction.

In terms of ongoing research, one factor that has not received much attention and could influence the quality of the facial composite is the starting face space. If the initial number of faces was to increase from the current 72, it is possible that a more accurate composite would be created, as there would be more faces, components and hence more variability. Alternatively, if the number of faces was reduced, perhaps the decrease in variability would cause less confusion for the witness. Additionally, if the witness gets the facial aspect (face height and width) wrong, the composite produced will be less accurate, due a wrong height and width ratio.

A study by Skelton, Frowd and Greenwood (2012) examined whether greater variability led to more accurate composites by manipulating the size of the starting model and the amount of components (eigenfaces). This study used the current database (72 faces with 72 components), a database containing 144 faces with 72 components, and a database containing 144 faces with 144 components. With the current database the set can be reproduced exactly, and the database containing 144 faces with 144 components would increase the variability. However, it was suggested that the database with 144 faces and just 72 components would increase the initial variability, yet

because only half the components were used there would be elements that would not reconstructed perfectly. They also manipulated whether the facial aspect was selected or not, meaning that the witness would either view faces with a fixed height and width (if the facial aspect was selected) or all face sizes would vary (facial aspect was not selected). Using a standard procedure of creating facial composites, Skelton et al. (2012) allowed a two-day delay in composite construction and witnesses were unfamiliar with the targets. However, whereas composite naming revealed no significant difference in database size or facial aspect selected, it did reveal that when the aspect was selected with the largest database the quality of the composite was reduced. This suggests that selecting the facial aspect reduced the variability counteracting the increase in variability from the large databases and that further research needs to be conducted regarding the size of the starting models combined with selecting the facial aspect.

Earlier research (Sirovich and Kirby 1987) has suggested that faces can be accurately represented by using a small number of components, but no comparison of a small model with a much larger face model has been conducted. The aim of this study is, therefore, to determine whether a greater variability in the starting face model will lead to a more accurate composite, or if accuracy can be increased by reducing the size of the initial face model.

Method

Stage 1: Facial Composite Construction

Design

Volunteers were recruited to construct facial images from memory. A 2 (facial aspect selection) x 3 (database size) was employed and participants were first required to view a photograph of an unfamiliar face for exactly one minute. Since the study was designed to mirror police work, there would be a 46 to 50 hour delay between viewing a target photograph and constructing the facial composite. When the participants returned two days later they underwent a cognitive interview. The cognitive interview required the participant to recall as much detail about the face as possible, without interruption or guessing. Participants then constructed a facial composite using one of three databases: small (36), medium (72) or large (144), with or without the facial aspect.

Participants

From opportunity sampling and respondents to an advertisement, 48 volunteers were recruited: 6 males and 42 females, age between 18 and 54 ($M = 25.1$, $SD=9.5$). Since the target photographs were of footballers, participants were non-football fans for the targets to be unfamiliar, thus

mirroring 'real life' when witnesses are unfamiliar with alleged perpetrators. Targets were allocated randomly with equal numbers of participants for each condition.

Materials

Target photographs were of eight, international, male footballers. Each target had minimal facial hair and no glasses. Targets were presented in colour approximately 8cm x 7cm on plain A4 paper. A HP G62-b11SA Windows laptop was used for composite construction with EvoFIT 1.5.46.

Procedure

Participants were tested individually and made aware that their involvement in this study would comprise of two visits: one for viewing and one for composite construction. Condition assigning was randomised; participants were assigned to either the small (36), medium (72) or large (144) database, and also assigned to selecting facial aspect or not. Participants were briefed given an envelope containing targets and then asked to choose one at random, ensuring they were unfamiliar with the target; they were to study this target for exactly one minute. If the participant was familiar with the target they were asked put it back in the envelope and choose another until they found a target they were unfamiliar with. If they were familiar with all the targets they were politely told they were unable to participate. Due to this one participant was excluded from the study. The experimenter remained blind to the identity of all targets by turning away from the participant during target viewing, and the participant was assured of this.

Participants returned 46 to 50 hours later, and rapport was built by informal dialogue to make the participant feel at ease. Following a discussion of what was required, a cognitive interview was initiated in order for the participant to recall the details of the target face. Participants were asked to visualise the face in the mind's eye, and freely recall as much detail as possible, even if they felt it was irrelevant. The session moved on to composite construction, which took no more than one hour for each individual. Once the composite was completed participants were given the debrief

Stage 2: Facial Composite Naming

Design

Participants were randomly assigned to view composites constructed from one of six conditions:

1. Current database (72) with the facial aspect selected
2. Current database without the facial aspect
3. Small database (36) with the facial aspect selected

4. Small database without the facial aspect
5. Large database (144) with the facial aspect selected
6. Large database without the facial aspect

Each participant was asked to spontaneously name each composite and then name each target face from the photograph. As composites can only be named by those familiar with the face, an *a priori* rule was applied. If the participant was unable to name six or more of the targets, they were to continue with the study but their data was dismissed. Participants were then asked to name the facial composites again, using a constrained method of naming, where a list of the target was available whilst naming the composites.

Participants

Participants were recruited at The National Football Museum in Manchester and UCLan Preston campus, by approaching individuals and asking if they were football fans. A total of 24 males and 12 females took part, aged 19 to 55 ($M=24.05$, $SD= 7.27$). Participants were randomly and equally distributed to one of the six conditions.

Materials

Images of the eight target footballers (Gareth Barry, Andy Carroll, Michael Carrick, Steven Gerrard, Frank Lampard, James Milner, Scott Parker, Robin van Persie) were presented individually in colour on white A4 paper; the composite images were presented in greyscale and were approximately 15cm in length and 11cm in width.

Procedure

Participants were tested individually and randomly assigned, with equal sampling, to one of the six conditions. Participants were given the brief and told they had the right to withdraw at any point during the exercise. They were instructed that they would view eight facial composites, constructed from memory, of footballers playing at an international level. Spontaneous naming was initiated with composites presented in a random order and participants were asked to name each composite, guessing was encouraged, but a simple 'don't know' answer was accepted. Once the participant had viewed each of the composites, the targets were randomly presented and participants were asked to name each target, with the *a priori* rule being applied; however, no participants were excluded on this basis. The composites were presented again but in a constrained format, with the use of a list of the target names available. Once all composites were named, participants were debriefed.

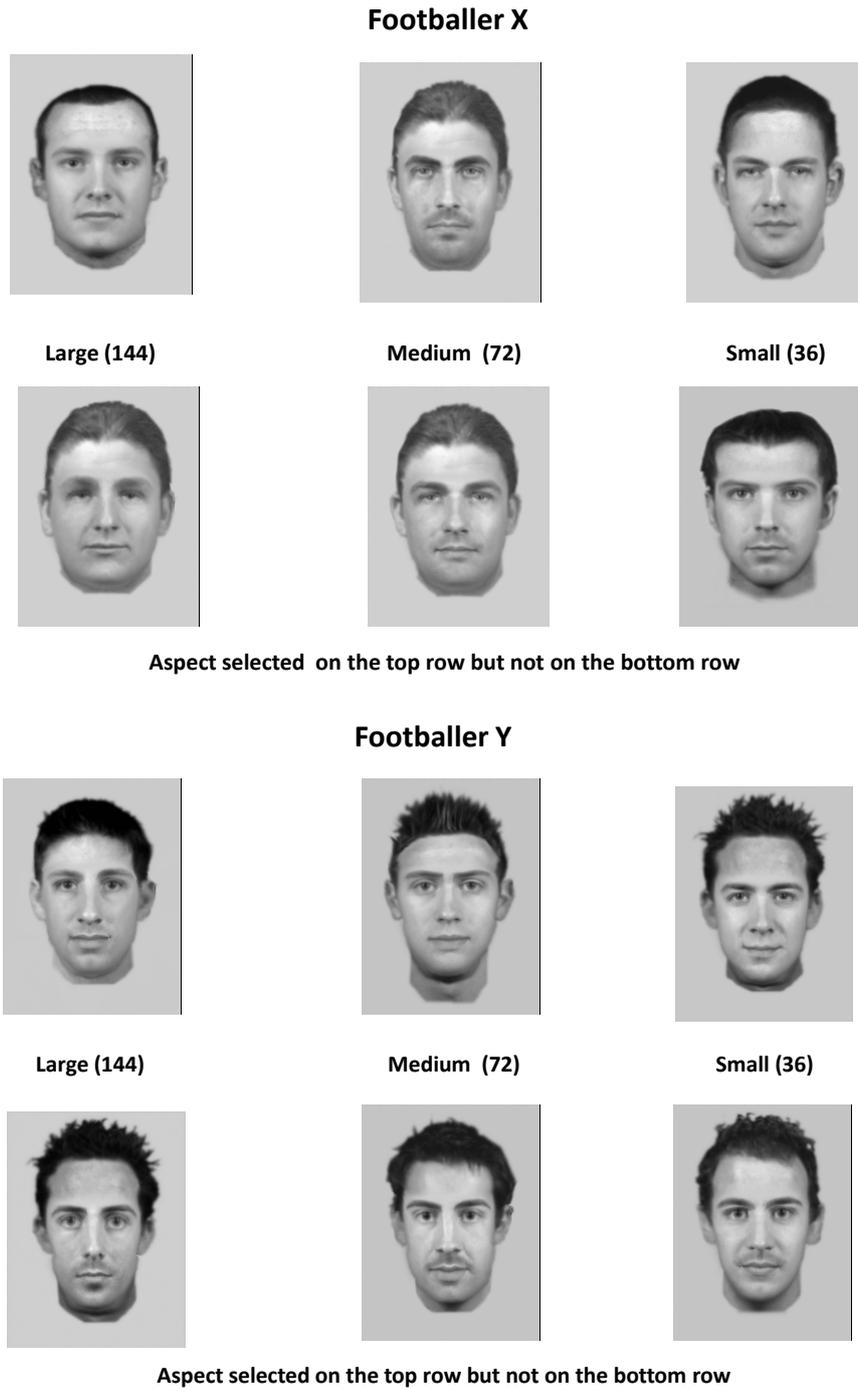


Figure 3: Examples of facial composites of two of the targets in each of the six conditions

Results

The number of times a composite was correctly named was recorded for both the spontaneous naming and the constrained naming. Each participant correctly named all targets; therefore all participants' data was used.

Spontaneous naming

Table 1 displays the means and standard deviations for the spontaneous naming. As the amount of correctly named composites was recorded, the maximum score was eight. The overall spontaneous naming appears to be low and the differences between databases are small.

Table 1: Means (and Standard Deviations) for Correct Spontaneous Naming for Composites Constructed in Each Database

	Small (36)	Medium (72)	Large (144)	Average
Use Facial Aspect: Yes	1.13 (0.99)	0.25 (0.46)	0.75 (1.16)	0.71 (0.87)
Use Facial Aspect: No	0.63 (0.74)	0.00 (0.00)	0.38 (0.74)	0.34 (0.50)
Average	0.88 (0.87)	0.13 (0.23)	0.56 (0.95)	

A 2 x 3 between subjects ANOVA revealed a significant main effect for database size [$F(2, 42) = 3.72$, $p < .05$, $\eta_p^2 = .15$]. When a Bonferroni adjustment was made for the number of comparisons, it was found that the small database was significantly correctly named more often than the medium database [$MD = .750$, $p < .05$]. There were no significant differences between the medium and large database [$MD = .437$, $p = .360$], and the small and large database [$MD = .313$, $p = .791$]. The ANOVA also revealed a non-significant main effect for aspect [$F(1, 42) = 2.72$, $p = .104$, $\eta_p^2 = .06$], and the interaction between size and aspect was also non-significant [$F(2, 42) = .102$, $p = .903$, $\eta_p^2 = .01$].

Constrained naming

Table 2 displays the means and standard deviations for constrained naming; again the maximum score is eight. There appears to be little difference, regardless of database size and selection of the facial aspect.

Table 2: Means (and Standard Deviations) for Correct Naming for Constrained Naming for Composites Constructed in Each Database

	Small (36)	Medium (72)	Large (144)	Average
Use Facial Aspect: Yes	4.00 (2.07)	3.25 (1.28)	3.38 (1.77)	3.54 (1.71)
Use Facial Aspect: No	2.88 (1.36)	4.50 (1.20)	3.13 (0.99)	3.50 (1.18)
Average	3.44 (1.71)	3.88 (1.24)	3.25 (1.24)	

A 2 x 3 between subjects ANOVA revealed a non-significant main effect for size [$F(2, 42) = .74$, $p = .482$, $\eta_p^2 = .06$] and aspect [$F(1, 42) = .01$, $p = .923$, $\eta_p^2 = .00$]. The ANOVA also revealed a non-

significant main effect for the interaction between size and aspect [$F(2, 42) = 2.60, p = .086, \eta_p^2 = .110$].

Discussion

Overall, spontaneous and constrained naming was very low and no significant differences were apparent in the constrained naming task. The spontaneous naming task showed a significant difference between the size of the databases, indicating that the smallest database produced more accurate composites than the medium sized database.

Although it may be assumed that more faces would lead to more variability and therefore a more accurate composite would be constructed, the present study did not produce this outcome. It is possible that the larger database leaves the witness feeling overwhelmed by the amount of variation, yet when there is a decrease in the variation this appears to be somewhat beneficial, and not dissimilar to work conducted by Sirovich and Kirby (1987).

With regard to the previous study conducted by Skelton et al. (2012), the current study appears to show some similarities in the results. The largest database, a model consisting of 144 faces, does not appear to enhance the accuracy of a composite, regardless of whether the aspect is selected or not. Similarly, selecting the aspect does not appear to interfere with the accuracy of composites in any database, which could be explained by the use of holistic tools, which can also adjust the width of the face. Once the facial aspect is selected, restricting the height and width of the face, then holistic tools can alter this face if the height and width is not accurate. Selecting the aspect therefore does not affect the quality of the face as any wrong information can be amended later.

A new finding seems to be apparent in the current study: using a smaller database could improve the quality of a composite as the results indicate there was a significant difference with the spontaneous naming task. This is a particularly useful finding, as composites created by witnesses to a crime are identified spontaneously. The current finding therefore implies that less variability, rather than more variability, could lead to a more accurate composite. However, it is important to remain cautious of these findings, as there were no differences found with the constrained naming task. This may be due to the targets themselves and the list of names used as a trigger in the constrained naming task, meaning that 'guessing' was easier and a process of elimination may have been used.

The lack of research into this area, other than that conducted by Skelton et al. (2012), made it difficult to make predictions about which database would produce the most accurate composites. The frequency of correct naming (12.5%) for the current study appears to be much lower than that of previous work (Frowd et al. 2005, 2008, 2011, 2012). One explanation for this could be the target set used, of which two individuals were spontaneously named more often, regardless of the database size or use of aspect. It could be suggested that these faces are more distinctive, creating a more accurate composite, leading to a higher naming rate, without viewing the target as a prompt. However, it could also be suggested that there may be an exposure effect to these faces, as both these particular targets are in the public eye more than others.

Another explanation for the low naming rate could be due to the 48 hour delay between viewing the target and constructing the composite. Frowd et al. (2012) imposed a 22 – 26 hour delay which resulted in a naming rate of around 40%, as this delay allows less time for interference with the memory for the target. However, Frowd et al.'s research (2008 and 2011), which explores the success of EvoFIT with field trials (real cases which have led to arrests), have found high success rates with EvoFIT: 25.4% and 38.5% arrests when combined with an improved interviewing method. As police forces usually ask witnesses to construct composites around 2 days after they have witnessed a crime, it suggests that the 48 hour delay may not have such a large effect on the naming in this study.

Differences exist between studies constructed in a laboratory and witnesses creating a composite for a real crime situation. For example, witnesses of a crime will feel that creating a composite will help bring a perpetrator to justice, therefore feel that their role as a constructor is much more important than research participants. Furthermore, research participants are less likely to invest more of their time in creating a composite; the average construction time in this exercise was under an hour. In field trials by Frowd et al. (2011), composites took up to an hour and a half to construct.

Another difference between real crimes and work conducted in a laboratory is how the witness views the target. When a witness sees a perpetrator they see a real 3D face, from a variety of angles and often in motion, whereas a participant in a research test views a still 2D image from one angle. It could be that processing a 2D face is different from processing a 3D face; perhaps 2D faces are not processed holistically as 3D faces appear to be (Frowd et al. 2004). This could be a useful implication for future research, to determine the differences between viewing a photograph, video footage and a staged event.

Further work in this field might include the addition of video footage rather than still photographs, and to collect distinctive ratings to select targets, hence avoiding distinctive faces being recognised more often. It may also be possible to compare different smaller databases; a more accurate composite could be created from a database consisting of 54 faces, for example.

Conclusion

The current study determined that decreasing the variability may have a positive effect on the accuracy of a facial composite created in EvoFIT. A small database consisting of 36 faces in EvoFIT appears to identify more composites than the medium database (72 faces). Selecting the facial aspect has very little effect on the quality of a composite and the constraining task found no significant results. The current research shows some similarities with Skelton, Frowd & Greenwood's (2012) work, but further research needs to be conducted to determine how to create a more accurate facial composite.

Note

Readers of this research paper may be interested in two further articles, published in *Diffusion* Volume 2, Issues 1 & 2 (2009), which explore the construction of facial composites:

Sian Davies, 'The effects of stress levels on the construction of facial composites', *Diffusion* 2:1, 16-20 (print version 2010). Available online at: <http://atp.uclan.ac.uk/buddypress/diffusion/?p=1763>

and Danielle McKay, 'Improving the identification of composite images using sketch-like faces',

Diffusion 2:2, 51-57 (print version 2010). Available online at:

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Flickr. 'Eigenfaces' image available online at:

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