Juvenile Age Estimation from Facial Images

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Ethical approval was received for the collection of facial photographs and the subsequent age estimation study. Approval was granted by the University of Dundee Ethics Committee.

Participants who donated facial photographs used in this study also provided additional consent for the publication of their images.

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Abstract

Age determination from images can be of vital importance, articularly in cases involving suspected child sexual abuse (CSA). It is imperative to determine if an individual depicted in such an image is indeed a child, with a more concise age often sought, as this may affect the severity of offender sentencing.

The aims of this study were to establish the accuracy of visual age estimation of the juvenile face in children aged between 0-16 years and to determine if varying levels of exposure to children affected an individual's ability to assess age from the face. An online questionnaire consisting of 30 juvenile face images was created using SurveyMonkey®.

The overall results suggested poor accuracy for visual age estimation of juvenile faces. The age, sex, occupation and number of children of the participants did not affect the ability to estimate age from facial images. Similarly, the sex and age of the juvenile faces did not appear to affect the accuracy of age estimation. When specific age groups are considered, sex may have an influence on age estimation, with female faces being aged more accurately in the younger age groups and male faces more accurate after the age of 11 years, however this is based on a small sample.

This study suggests that the accuracy of juvenile age estimation from the face alone is poor using simple visual assessment of images. Further research is required to determine exactly how age is assessed from a facial image, if there are indicators, or features in particular that lead to over- or under-estimation of juvenile age.

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Novelty Statement

This is one of the first studies to consider visual age assessment from the face alone, with external features and influences removed. It has been shown that experts have no standardised method for age estimation from photographic images in forensic scenarios, although the face is suggested as one of the useful features utilised. This research is the first to consider whether or not exposure to juvenile faces though either the work or home environment provides an advantage in age estimation from photographic images.

Highlights

- Visual age estimation of children's faces reveals poor accuracy at 33%.
- Participants living with children do not achieve higher results in ageing from facial images.
- Individuals working with children also show low accuracy of age assessment from facial images.
- Differences in accuracy of age estimation were observed for male and female faces when considering age groups 0-5 years, 6-10 years and 11-15 years old.

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1. Introduction

Age estimation in the living can be carried out physically via the skeletal analysis of wrist x- rays, dental development or through the assessment of the Tanner stages of sexual maturation (1, 2). However, when only a photographic image is available for consultation this process becomes significantly more challenging. In cases involving pornographic images suspected to depict children, it is of great importance to be able to assess if the individual in the image is indeed a child, thus indicating the crime of child sexual abuse (CSA) (3). A more precise age is often required to determine the severity of offender sentencing and may be used in the identification of the victim (4, 5). Age evaluations could aid the sequencing of images, when there are several images present which have been taken over a period of time (6).

The availability of child pornographic images has grown exponentially with the development of the internet resulting in millions of images of CSA, which are shared and downloaded online (4, 7, 8). Consequently, there has been a rise in the number of cases in which an expert has been called upon to give an age assessment from a photograph of alleged CSA (4, 5). Experts may include individuals such as paediatricians, gynaecologists, forensic pathologists or forensic anthropologists (3, 4), although this remains a very contentious area with only very recent attempts to provide guidelines for use in age estimation from photographic images (9-11).

Visual assessment of age from pornographic images has been based on the evaluation of the Tanner stages of development and other sexual maturity indicators, with the face also suggested to be an important feature for analysis (8, 12). However, studies have shown that age estimation from secondary sexual characteristics is inaccurate, with wide variability in the choice of features believed to be most important in age assessment (8). Growth and sexual maturation can be affected by many factors such as environmental factors, obesity and malnutrition, population differences and even individual biology can influence the rate and timing of sexual maturation (4, 5, 13). In addition, the assessment of sexual maturation may be confused, as adults may remove features such as pubic and axillary hair in order to appear younger.

The use of anthropometrics to estimate the age of a child from facial photographs has been tested by a group of European researchers (6, 13). These studies have been carried out with the aim of being able to define an age, or age range from the faces of individuals present in images of alleged child pornography. Cattaneo and colleagues conducted a pilot study into the use of facial proportions as a method of estimating age (3). They achieved an average accuracy of 60.3% individuals placed into the correct age group. However, they only used four age groups based on images of individuals at 6, 10, 14 and 18 years. As they only studied individuals at single ages, with a four year gap between groups, this may have accentuated the differences between individuals from each of the groups and the true differences between individuals at each year between 6-18 years may not be significantly different.

A more recent study (13) found 7 anthropometric indices which show a correlation with age of 0.7 or above, with no relevant differences between male and female face measurements. The authors noted that the use of photo-anthropometry is cautioned against and suggested that pose differences may affect the comparison of facial indices. Videos and images of CSA are often low quality, many being recorded on mobile phones, and faces may be captured from varying angles, poses and distances from the camera (6). These differences make it difficult to directly compare measurements, such as proportions and distances between features, to the standards created in these studies for each age, or age group. Moreover, the facial landmarks from which measurements are taken may not be readily visible in lower quality images. The placement of facial landmarks have already been shown to display varying degrees of inter-observer error, even when placed on high quality images (8).

Anthropometric methods concerning juvenile ageing from the face have shown promising results, but may not be applicable to low quality images, or when there are significant variations in pose or expression, while automated methods of facial ageing are still restricted in their ability to classify juvenile facial age with any real precision (14). A recent study demonstrated the ability of an automated system to estimate age with a mean absolute error of 1.47 years. Visual assessment of age was also made by experts and lay-persons with mean absolute errors of 1.63 and 1.84 years respectively, however, only female children aged between 10 -19 years old were considered in this study (6).

The current study aimed to assess human ability to estimate juvenile age from facial photographs of children aged between 0-16 years. In particular, differences in accuracy of age estimation were assessed for faces of different ages and for both sexes. White European face photographs were used in this study, as facial ageing can vary between populations and there is evidence that an own-race effect may exist in age estimation of faces, similar to that found in facial recognition, although this has not been tested extensively (15). Increased exposure to juveniles through working or living environments was recorded in order to test the hypothesis that, "participants who spend more time in the presence of juveniles of varying ages will score higher accuracy in the estimation of age from juvenile faces."

2. Materials and Methods

An online questionnaire was created using SurveyMonkey® and consisted of a selection of 30 face photographs of white European children covering the age range 0 – 16 years, with equal numbers of male and female faces. The images were taken from a larger database of known-age images provided retrospectively by adult participants (99 female and 141 male). The database consisted of multiple images (mode = 4) of each participant between the ages of 0-16 years, with a total of 1623 images across all individuals. The images were a mixture of black and white (n=5) and full colour

(n=25), frontal face photographs. These varied in quality as photographs were collected retrospectively and thus image acquisition could not be controlled. Where possible, full frontal face images of good quality, with close to neutral expression were utilised. All images were cropped, using Adobe Photoshop CS5.1, so that only the face and hair remained (see figure 1). This was to ensure that only the face and head were considered for age estimation, with all external features, such as clothing, being extracted.

Figure 1: (top image) Example of single age type question; (bottom image) example of age range type question

The main section of the questionnaire required participants to provide an age assessment for each of the juvenile faces. Of the 30 questions in this section, 20 required a single age estimate to be given (e.g. 3 years old), while 10 questions asked for an age range to be chosen from four predetermined age cohorts. The choice of age groups were; 0-5 years, 6-10 years, 11-15 years and 16-20 years and were chosen based on important dental and growth markers. There was no imposed time limit for completion of the questionnaire.

In addition, participants were asked to provide details of the number and age of any children currently living in their household. Occupation was also recorded before being grouped into one of three categories; "works with children", "does not work with children" or "child" for those individuals under 18 years of age. This allowed for assessment of results split by individuals who are exposed to juvenile faces on a daily basis against those who have little to no contact with children day-to-day. The majority of individuals whose occupation involved working with children were teachers. Ethical approval from the University of Dundee research ethics committee was received for this research and all participants provided informed consent prior to completing the questionnaire.

3. Results

A total of 504 individuals completed the survey, aged between 17 – 82 years with a mean age of 31 years. Table 1 details the numbers of participants by sex, occupation and those who had children living in their household during completion of the questionnaire.

Table 1: Participant demographics

Question	**Participant Responses *(number of participants)***		
Sex	Male *(136)*	Female (*368)*	
Occupation	Works with children *(41)*	Does not work with children *(461)*	Child *(2)*
Children Living in Household	Children 0-5 years *(66)*	Children 6-10 years *(40)*	Children 11-15 years *(30)*

Overall results were poor with an average accuracy of 33% correct across all questions, with only 3 individuals answering more than 50% of questions correctly. For single age questions the mean percentage of correct responses was 16.5% (rising to 42.8% when permitting a response +/-1 year from true age) and 65.5% for age range questions across all participants. On further investigation, it was apparent that responses to single age estimation questions varied considerably (figure 2), with overestimation of age by up to 14 years and underestimation by as many as 8 years from true age. Mean accuracy of age estimation was higher for colour images (35%) than for black and white images (22%), however there was a much larger proportion of colour images used in the study, with only 3 single age questions and 2 age range questions using black and white images across the whole questionnaire.

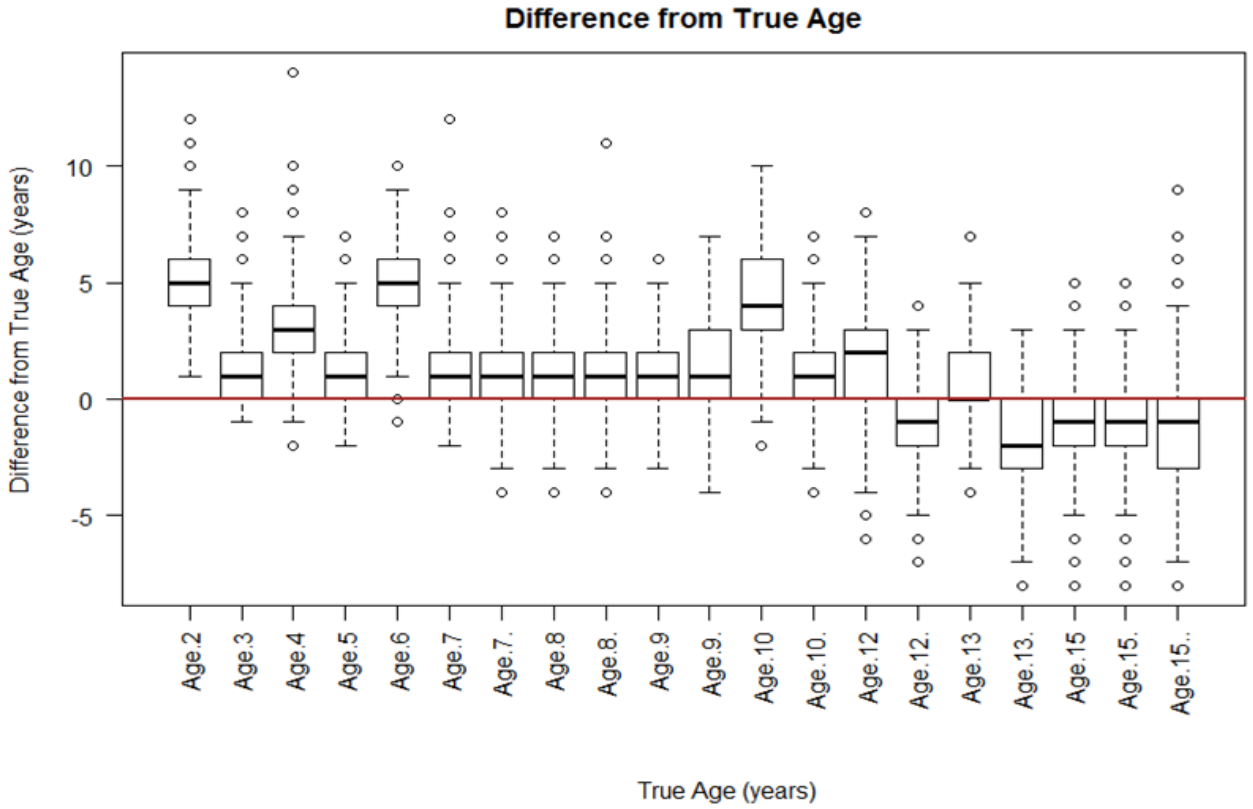

Figure 2: Single year age estimates shown as number of years difference from true age, where 0 = correct response

Following the assessment of the overall accuracy and spread of responses, any factors which may affect age assessment were analysed. These were split into *participant variables*, including age, sex, occupation and number of children living within a participant's household and *juvenile variables*, such as age and sex of the child within the image, to determine if this had any influence on age estimation. Results for both sets of variables are given below.

3.1. *Participant Variables*

The age and sex of participants did not appear to have any effects on age estimation, with no visible correlation between the age of the participant and their ability to estimate age from facial images.

Working with children did not improve age assessments: individuals whose occupation involved working with children scored an average accuracy of 33%, those who did not work with children achieved 35% and the two individuals who fell into the "child" category for occupation scored the highest accuracy at 37%. Similarly, the presence of children in a participant's household did not improve their ability to estimate age from a face, regardless of whether the age group of the children in the household matched the age group of faces being assessed.

3.2. *Juvenile Variables*

A linear regression of juvenile age against the accuracy of age estimation for each of the single age questions was conducted. The results showed a very weak correlation (R^2 = 0.108) for increased accuracy of age estimation in older faces (see figure 3). It was noted that there were three outliers present. On removal of the three outliers the linear regression presented with a close to horizontal line, suggesting that there is no correlation between the age of the juvenile face and the accuracy of age estimation from the face.

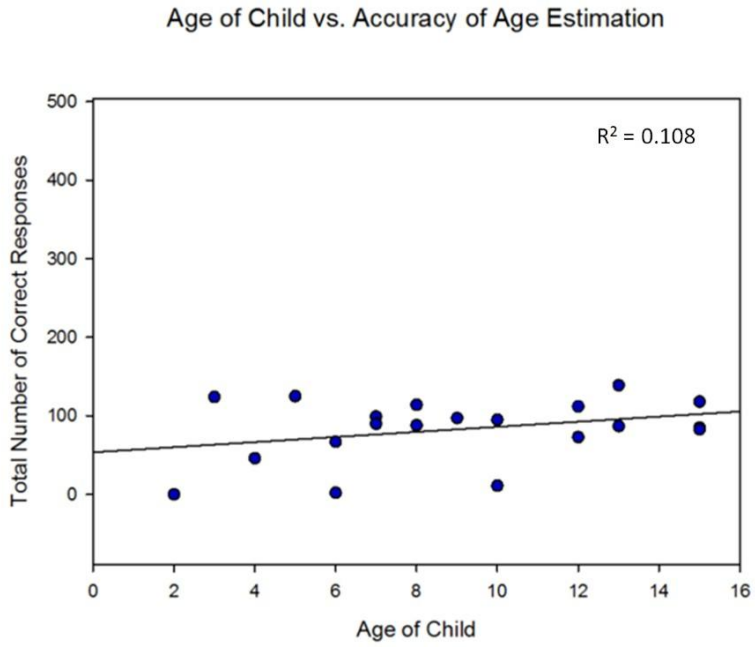

Figure 3: Age of juvenile vs. accuracy of age estimation

Finally, the accuracy of age estimation for faces grouped by both sex and age cohort were examined[1]. Table 2 displays the numbers of male and female faces within each age group. Interestingly, there appeared to be differences in the accuracy of age estimation of male and female faces when grouped by age (see figure 4). For juveniles aged 0-5 and 6-10 years, female faces were aged more accurately than male faces, with the reverse true for the older age group, 11-15 years. It is possible that this is related to the changes associated with puberty in males. In females, the face is reaching its adult configuration by approximately 11-12 years, whereas in males, they are still to undergo significant changes in facial dimensions, driven by androgens during the pubertal growth spurt. This may result in more discrete changes in facial

[1] There were too few individuals in the oldest age group (16-20 years) for comparison

shape during the years 11-15 and possibly beyond. It is important to note that removal of the three outliers reduces the difference in age estimation accuracy between males and females in both the 0-5 and 6-10 year age groups. Moreover, the grouping of individuals by age and sex has resulted in smaller numbers within each category and further tests on a larger sample would be required to fully investigate these apparent effects.

Table 2: Number of male and female face images within each age cohort

Age Group (years)	Male	Female	Total
0-5	4	4	8
6-10	6	6	12
11-15	4	5	9
16-20	1	0	1

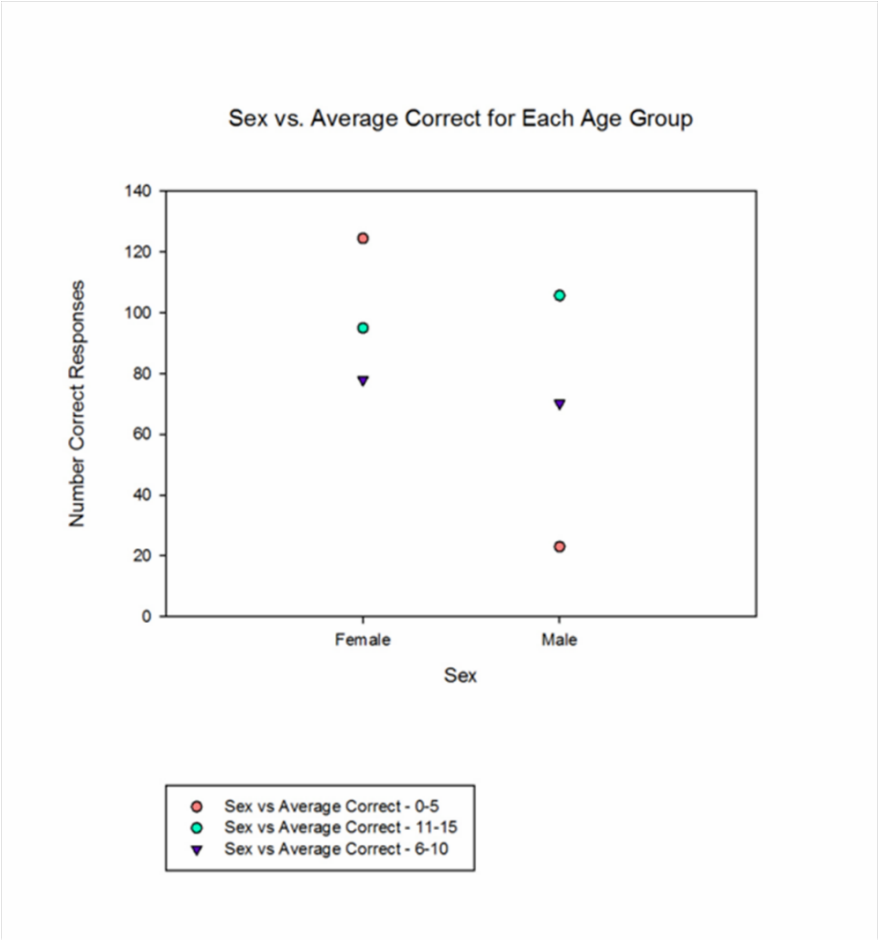

Figure 4: Accuracy of age estimation for male and female faces grouped by age

4. Discussion

The overall accuracy of visual age estimation was very low, at approximately 33% correct responses, with only three individuals scoring more than 50% accuracy. It is undoubtedly difficult to estimate age to an exact year and it has been shown that the percentage of correct responses to single age questions increased from 16.5% to 42.8% when allowing for estimates one year above or below true age. However, the results also demonstrate that age estimations varied wildly across questions, with age assessments over and under-estimating age by as many as 14 years. In cases of child sexual exploitation, misclassifying the age of a child by even a year could affect the severity of offender sentencing. In addition, when asked to place an individual within a 5 year age range results were also relatively low, 65.5%. It was questioned whether or not the largest age estimation errors were due to the reduced quality of some images, however, there appear to be large individual errors in age estimation across all questions, regardless of any differences in image quality and not restricted to any particular individual or group of individuals. The results indicated that age was estimated more accurately from colour images rather than those in black and white, however only a small number of the images used in this study were in black and white and it is suggested that further research be carried out to investigate these findings.

Neither working nor living with children improved age estimation within any of the age categories; suggesting that exposure to children's faces does not provide an advantage in age estimation. There were no effects of sex on accuracy for either the participants or for the faces they were viewing, while there was a very low correlation for increased accuracy of age estimation in older children.

Females were aged more accurately in the 0-5 years and 6-10 years groups and males were aged correctly more often than females in the 11-15 years cohort. This may be due to the cessation of facial growth in females during this age group and the male pubertal growth spurt resulting in more discrete (visible) changes in the male face during this period.

The results have shown that the hypothesis suggesting that individuals who spend more time in the presence of juveniles will score higher accuracy in the estimation of age from juvenile faces is false. Exposure to juvenile faces through occupation or within the household does not appear to improve the accuracy of age estimation from the face.

5. Conclusions

This study has demonstrated that juvenile age estimation from the face is currently of very low accuracy when using visual observation alone. Although higher accuracy was achieved for age range estimation, this was still poor and large variations in accuracy were observed throughout the questionnaire, which could not be attributed to variations in image quality or individual participant ability. Moreover, "passive" exposure to children's faces through workplace and/or home life did not

provide an advantage in juvenile age assessment from facial photographs.

These results are particularly important for those dealing with age estimation in a forensic context, including suspected CSA material, as the results demonstrate that a simple morphological assessment is not suitably objective or accurate enough to provide a reliable estimate of age. Further research is required to analyse the process by which individuals assess age from a facial photograph, to determine if there are specific indicators, or features, that result in the over- or under-estimation of age by such a large degree.

Previous research has suggested that experts, with presumed knowledge of juvenile growth and development, achieve higher accuracy of age estimation from images than laypersons, however the results of the current study suggest that caution must be employed when using morphological methods of age assessment, as not only is the process a subjective one, but it has also been shown to be highly error prone.

A study comparing the abilities of professional experts such a paediatricians, and laypersons, which documents variations in the method of age estimation, including any preferences for particular features, may be useful in confirming whether or not professional knowledge of facial growth and development, alongside frequent contact with children, provides an advantage in age assessment. This may also help to determine whether or not training could be developed to improve visual age estimation, however much further research is required and additional measures should be considered. Anthropometric assessment of facial images is currently being examined as a possible method for age estimation and this may provide a useful tool in improving age assessment from facial images.

6. References

1. Schmeling A, Reisinger W, Geserick G, Olze A. Age estimation of unaccompanied minors: Part I. General considerations. Forensic science international. 2006; 159:S61-S4.

2. Ritz-Timme S, Cattaneo C, Collins M, Waite E, Schütz H, Kaatsch H-J, et al. Age estimation: the state of the art in relation to the specific demands of forensic practise. International Journal of Legal Medicine. 2000;113(3):129-36.

3. Cattaneo C, Obertová Z, Ratnayake M, Marasciuolo L, Tutkuviene J, Poppa P, et al. Can facial proportions taken from images be of use for ageing in cases of suspected child pornography? A pilot study. International Journal of Legal Medicine. 2012;126(1):139-44.

4. Cattaneo C, Ritz-Timme S, Gabriel P, Gibelli D, Giudici E, Poppa P, et al. The difficult issue of age assessment on pedo-pornographic material. Forensic Science International. 2009;183(1–3):e21- e4.

5. Stathopulu E, Antony Hulse J, Canning D. Difficulties with age estimation of internet images of south-east Asian girls. Child Abuse Review. 2003;12(1):46-57.

6. Ratnayake M, Obertová Z, Dose M, Gabriel P, Bröker HM, Brauckmann M, et al. The juvenile face as a suitable age indicator in child pornography cases: a pilot study on the reliability of automated and visual estimation approaches. International journal of legal medicine. 2014;128(5):803-8.

7. Aiken M, Moran M, Berry M, editors. Child abuse material and the Internet: Cyberpsychology of online child related sex offending. 29th Meeting of the INTERPOL Specialist Group on Crimes against Children Lyons, France; 2011.

8. Cummaudo M, Guerzoni M, Marasciuolo L, Gibelli D, Cigada A, Obertovà Z, et al. Pitfalls at the root of facial assessment on photographs: a quantitative study of accuracy in positioning facial landmarks. International Journal of Legal Medicine. 2013;127(3):699-706.

9. Mayer F, Arent T, Geserick G, Grundmann C, Lockemann U, Riepert T, et al. Age estimation based on pictures and videos presumably showing child or youth pornography. International journal of legal medicine. 2014;128(4):649-52.

10. Mayer F, Arent T, Geserick G, Grundmann C, Lockemann U, Riepert T, et al. Age estimation based on pictures and videos presumably showing child or youth pornography—reply to Arlan L. Rosenbloom. International journal of legal medicine. 2015;129(4):833-.

11. Rosenbloom A. Age estimation based on pictures and videos presumably showing child or youth pornography. International journal of legal medicine. 2015;129(3):621-2.

12. Rosenbloom AL. Inaccuracy of age assessment from images of postpubescent subjects in cases of alleged child pornography. International Journal of Legal Medicine. 2013:1-5.

13. Cummaudo M, Guerzoni M, Gibelli D, Cigada A, Obertovà Z, Ratnayake M, et al. Towards a method for determining age ranges from faces of juveniles on photographs. Forensic Science International. 2014;239:107.e1–107.e7

14. Geng X, Zhou Z-H, Smith-Miles K. Automatic age estimation based on facial aging patterns. Pattern Analysis and Machine Intelligence, IEEE Transactions on. 2007;29(12):2234-40.

15. Dehon H, Brédart S. An 'other-race' effect in age estimation from faces. Perception. 2001 Sep 1;30(9):1107-13.

7. Figure Captions

- Figure 1: (top image) Example of single age type question; (bottom image) example of age range type question
- Figure 2: Single year age estimates, shown as number of years difference from true age, where 0 = correct response
- Figure 3: Age of juvenile vs. accuracy of age estimation
- Figure 4: Accuracy of age estimation for male and female faces grouped by age

8. Table Captions

- Table 1: Participant demographics

- Table 2: Number of Male and Female face images within each age cohort