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ORIGINAL ARTICLE

Can facial proportions taken from images be of use for ageing in cases of suspected child pornography? A pilot study

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Abstract The age of the victim plays a crucial role for the legal implications concerning pornography. Judges therefore often call on forensic experts to verify the age of individuals depicted on photographs or videos. However, there is no scientifically established protocol available for forensic practice in such cases. The conventional methods such as the evaluation of secondary sexual characteristics provide unsatisfactory results particularly when the legally relevant ages for child pornography (i.e. 14 and 18 years) are concerned. To overcome these limits, a European research group has explored the applicability of facial proportions as an age indicator on images. In this pilot study, standardized facial images of 353 females and 20 males from four age groups (6, 10, 14 and 18 years) were randomly selected for the metric analysis from a large data set including German, Italian and Lithuanian subjects. In this sample, several indices extracted from the frontal and lateral photographs were closely correlated to their respective indices taken from the living individuals. Furthermore, age-related changes were identified for indices taken from the photographs. The discriminant analysis showed that for the pooled sample, 60.3% of the cases were correctly classified into the respective age group. The percentage of correctly classified cases increased in the respective country samples as follows: 69.9% for Germany, 69.4% for Lithuania and 80.5% for Italy. The present study suggests that the metric assessment of the face may be used for age estimation on images. Nonetheless, more work needs to be done in order to verify the reliability of these findings on a large sample.

Keywords Child pornography · Identification · Age estimation · Facial indices · Photographs

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Introduction

Child pornography is a multibillion-dollar business and one of the fastest spreading criminal elements worldwide [1–3]. Inevitably, the demand for child pornography leads to an increase in the number of sexually abused children who are victimized for this purpose [4, 5]. More than 10 million pedo-pornographic images are disseminated through the internet, and their number has increased exponentially over the last years due to the fast and anonymous exchange enabled by the world wide web [1, 2]. For instance, in Germany, the number of cases concerning production, possession and distribution of child pornography increased by 94% between 2006 and 2007 [6]. Similarly, an increase by 93% of the number of websites with pedo-pornographic contents between 2002 and 2004 has been reported by Italian institutions and non-profit organisations, which focus on the protection of minors (www.aquiloneblu.org; www.stop-it.org; www.savethechildren.it; www.enough.org).

Depending on the respective jurisdiction, the legal definitions of child pornography differ worldwide [2, 7, 8] but generally any pornography involving a minor, i.e. a person younger than 18 years is illegal [1]. In 2003, the European Union (EU) Council adopted the Framework Decision 2004/68/JHA on combating the sexual exploitation of children and child pornography where a "child" is any person below the age of 18 years. In several European countries, such as Germany, depiction of children below 14 years is defined as child pornography and depiction of adolescents below 18 years as juvenile pornography.

Therefore, the assessment of the victim's age on photographs has a great importance in verifying the actual perpetration of a crime punishable by law. Moreover, age estimation might be important for the identification of the victim depicted on the images and for establishing the time intervals during which the abuse took place. In order to assess the victim's age on images or videos, gynaecologists, paediatricians or more often forensic pathologists and forensic anthropologists are called on by the magistrates as expert advisors [9–12].

However, to date, there is no scientifically established method for age assessment based solely on images. Particularly if the legally crucial age thresholds (i.e. 14 and 18 years) are considered, conventional methods (i.e. the assessment of secondary sexual characteristics) will have been proven unreliable [13–15].

To overcome these limits, an EU-funded international research group has studied age-related facial growth and development in children and juveniles in terms of the applicability of facial proportions as an age indicator on images [16, 17]. In this pilot study, the possibilities of the metric assessment of facial images with respect to age-related changes are addressed.

Material and methods

Standardized facial images of 353 female and 20 male subjects from four different age groups were randomly selected from a data set of 2,100 photographs from Germany, Italy and Lithuania. This data set was established during the course of two EU-funded projects STOP II and AGIS between 2002 and 2007. The number of the subjects in each age category was as follows: 89 6-year-old, 99 10-year-olds, 85 14-year-old and 100 18-year-old.

The male subjects were included in the category of 6-year-old because there were not enough German and Lithuanian girls measured in this age group. However, statistical tests showed that there are no significant differences in the selected measurements between boys and girls at this age, thus the data could be pooled for further analysis.

For each subject, five standardized photographs were acquired with the focus on *seilion* (the deepest point of the nasal root depression), and the distance between *seilion* and the camera is 1.5 m. The landmark *seilion* was used instead of *nasion* since it can be located more precisely on photographs. The head of the test person was oriented in the Frankfurt plain and photographed in the following positions: left lateral (90°), 45° left, frontal, 45° right and right lateral (90°).

In addition to photographs, the data set also includes the respective "in vivo" measurements of the head and face of each subject. The measurements on living persons were defined according to Martin and Saller [18] (Table 1).

Facial measurements were taken from frontal and right lateral images using the Adobe Photoshop CS4 "Ruler Tool". However, the landmarks on a 2D image and a 3D subject cannot be directly comparable since the landmarks on a subject are identified through palpation, whereas on a 2D image this is not possible. Some adjustments were therefore made to the definitions of the landmarks and the distances when applied to photographs. For example, the bizygomatic width was defined as the distance between the most laterally visible points of the cheekbones. The landmarks and distances applied on images are depicted in Fig. 1 (frontal and right lateral images).

Next, 43 indices were calculated from the above measurements. The statistical tests were carried out using IBM SPSS Statistics 18.

Pearson's correlation analysis was used to determine the correlation between the "in vivo" and the "in photo" facial indices. All "in photo" indices were analysed using ANOVA to determine the differences between the age groups. Twenty-three indices taken from photographs were identified through the above statistical procedure to be suitable for further analysis, i.e. they showed continuity (i.e. the index values increased or decreased continuously with age) and significant differences between age groups in the pooled sample. Consequently, 18 indices taken from the frontal images (enen-pupu, pupu-exex, alal-pupu, pupu-ftft, pupu-zyzy, enen-exex, enen-alal, enen-ftft, enen-zyzy, alal-exex, exex-ftft, exex-zyzy, alal-ftft, alal-zyzy, chch-zyzy, chch-sesn, chch-sesto, ftft-zyzy) and two indices taken from lateral images (prnsn-seprn, prnsn-sesn) were excluded.

Finally, a discriminant analysis based on these selected indices was conducted to show if and how precisely the age can be estimated by the calculation of facial indices from the available 373 images.

Results

The results are presented in Tables 2 and 3. Table 2 shows the means for "in vivo" and "in photo" indices with a

Table 1 Definitions of distances measured in living persons

Measurement number (Martin and Saller [18])	Description (frontal landmarks)	Measurement number (Martin and Saller [18])	Description (right lateral landmarks)
12	Interpupillary distance (pu-pu)	21c[a]	Nasal height (se-sn)
9	Intercanthal width (en-en)	23[a]	Nasal bridge length (se-prn)
10	Biocular width (ex-ex)	19[a]	Physiognomic upper facial height (se-sto)
13	Nose width (al-al)	22	Nasal depth (prn-sn)
14	Labial width (ch-ch)	29	Physiognomic ear length (sa-sba)
6	Bizygomatic width (zy-zy)	30	Physiognomic ear width (pa-pra)
4	Distance bifronto temporalis (forehead width) (ft-ft)		
21c[a]	Nasal height (se-sn)		
19[a]	Physiognomic upper facial height (se-sto)		

[a] The landmark *seilion* was used instead of *nasion* since it can be located more precisely on photographs

significantly positive correlation for the pooled sample. These indices also showed continuity and significant differences between the defined age groups (Table 2), which proved them applicable as indicators for an age assessment.

The discriminant analysis based on the 23 indices showed that for the pooled sample, 60.3% of the cases were correctly classified into the respective age group. After splitting the sample by country, the percentage of correctly classified cases increased as follows: 69.9% for the German sample, 69.4% for the Lithuanian sample and 80.5% for the Italian sample.

Discussion

The issue of ageing victims on suspected pedopornographic videos or photographs represents a crucial step in the legal practice. However, the conventional techniques used for age estimation, which are largely based on the evaluation of secondary sexual characteristics, have proven not only to be highly inaccurate but also to be ill-used for the estimation of the chronological age of the depicted individuals [13–15, 19–21]. The use of Tanner stages for the development of pubic hair, genitalia and breasts for ageing individuals on images has been severely

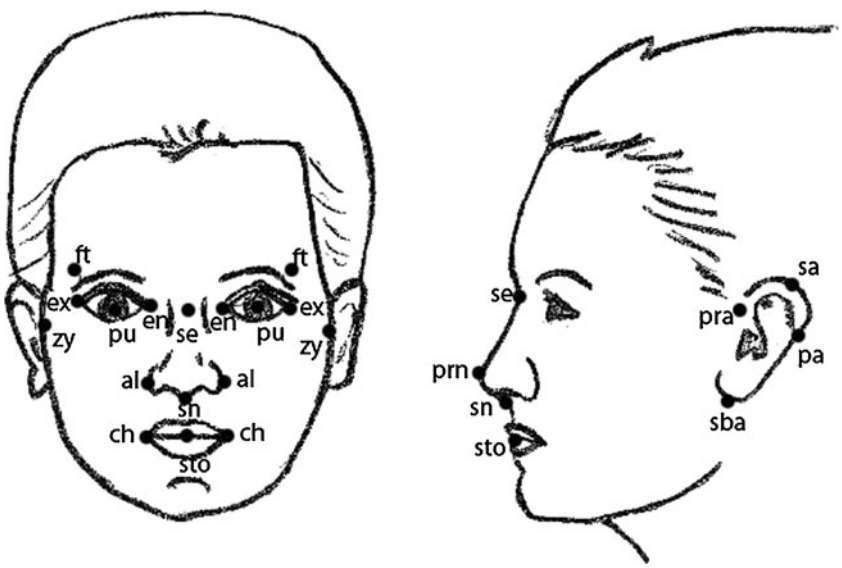

Fig. 1 Definitions of the landmarks and the distances applied to photographs

Table 2 Mean and standard deviation of "in vivo" and "in photo" indices with the Pearson correlation coefficient

Indices	Mean in vivo (SD)	Mean in photo (SD)	CC Pearson
sesn-pupu	81.5 (11.7)	75.3 (6.8)	.393*
pupu-sesto	86.8 (9.8)	91.7 (6.2)	.402*
enen-sesn	68.2 (11.8)	71.6 (9.0)	.423*
enen-sesto	47.2 (6.8)	49.0 (4.9)	.415*
sesn-exex	51.0 (5.8)	50.9 (4.9)	.555*
sesto-exex	73.2 (5.9)	74.1 (5.4)	.512*
alal-sesn	69.6 (10.1)	75.2 (7.9)	.607*
alal-sesto	48.2 (5.1)	51.5 (4.1)	.555*
chch-pupu	81.6 (10.3)	73.5 (6.6)	.500*
chch-exex	51.2 (4.6)	49.7 (4.6)	.458*
enen-chch	67.5 (8.9)	73.2 (8.0)	.497*
alal-chch	68.9 (7.1)	76.9 (7.0)	.615*
chch-ftft	42.3 (4.6)	43.2 (4.7)	.291*
sesn-ftft	42.3 (5.5)	44.3 (4.5)	.590*
sesto-ftft	60.5 (5.7)	64.3 (5.2)	.391*
sesn-zyzy	37.4 (6.4)	35.4 (3.4)	.671*
sesto-zyzy	53.4 (6.9)	51.4 (3.9)	.726*
sesn-sesto	69.7 (5.1)	68.8 (3.6)	.432*
Lateral seprn-sesn	87.4 (6.3)	83.7 (4.5)	.583*
Lateral sesn-sesto	69.7 (5.1)	70.2 (3.5)	.463*
Lateral seprn-sesto	61.0 (6.8)	58.8 (4.7)	.700*
Lateral prnsn-sesto	28.9 (4.9)	28.2 (2.9)	.401*
Lateral prapa-sasba	57.4 (5.6)	57.9 (5.9)	.397*

*$p<0.01$, level of significance

Table 3 Mean and standard deviation of the selected "in photo" indices for the four different age groups (ANOVA results)

Indices	6 years Mean (SD)	10 years Mean (SD)	14 years Mean (SD)	18 years Mean (SD)
sesn-pupu	70.1 (5.4)	74.8 (6.0)	76.9 (6.1)	79.2 (5.9)
pupu-sesto	94.8 (5.4)	92.4 (6.1)	90.5 (5.5)	89.3 (6.2)
enen-sesn	78.5 (8.0)	71.7 (8.9)	69.7 (7.6)	66.8 (7.3)
enen-sesto	51.8 (4.2)	49.3 (5.5)	48.2 (3.9)	46.9 (4.5)
sesn-exex	47.1 (3.7)	50.8 (4.3)	51.9 (4.6)	53.7 (4.4)
sesto-exex	71.1 (3.7)	73.8 (5.1)	74.9 (5.5)	76.3 (5.7)
alal-sesn	81.0 (7.8)	75.7 (6.7)	74.4 (6.7)	70.3 (6.4)
alal-sesto	53.5 (3.9)	51.9 (3.8)	51.4 (3.6)	49.4 (4.1)
chch-pupu	70.3 (6.9)	72.3 (5.5)	75.7 (6.6)	75.8 (5.7)
chch-exex	47.3 (4.9)	49.1 (3.9)	51.1 (4.3)	51.4 (4.0)
enen-chch	78.5 (7.9)	73.9 (6.9)	70.9 (7.5)	69.7 (6.8)
alal-chch	80.9 (7.4)	78.2 (6.5)	75.6 (6.3)	73.4 (5.6)
chch-ftft	40.7 (4.9)	42.5 (4.2)	44.6 (4.5)	45.0 (4.0)
sesn-ftft	40.5 (3.1)	43.9 (3.9)	45.3 (4.3)	47.0 (3.7)
sesto-ftft	61.1 (3.6)	63.8 (4.7)	65.4 (5.8)	66.7 (4.9)
sesn-zyzy	32.5 (2.5)	35.2 (3.1)	36.4 (3.1)	37.3 (2.9)
sesto-zyzy	49.1 (3.0)	51.1 (3.8)	52.5 (4.0)	52.9 (3.9)
sesn-sesto	66.2 (3.1)	68.8 (2.8)	69.3 (3.2)	70.5 (3.7)
Lateral seprn-sesn	80.5 (4.2)	83.0 (3.4)	84.5 (4.0)	86.5 (4.3)
Lateral sesn-sesto	67.8 (2.9)	70.0 (2.5)	71.3 (3.0)	71.8 (3.8)
Lateral seprn-sesto	54.6 (3.7)	58.1 (3.2)	60.2 (3.8)	62.0 (4.5)
Lateral prnsn-sesto	26.8 (2.6)	27.7 (2.3)	29.0 (2.9)	29.3 (3.1)
Lateral prapa-sasba	59.6 (6.0)	58.4 (5.4)	57.3 (6.6)	56.6 (5.1)

All indices showed statistically significant differences ($p<0.000$) between age groups

criticized considering the large inter-individual and inter-population variability observed in sexual maturation. [21–26]. Furthermore, it is impossible to compare the evaluation of photographic staging with a complete medical examination. On pictures, several characteristics, such as pubic or axillary hair might be altered through shaving or other methods of hair removal [19]. The evaluation of the dental status is of crucial importance in the age assessments of living individuals. However, on images, even if the subject's mouth happens to be open, it is very difficult to obtain enough information to correctly evaluate the developmental stage of the dentition [27]. In general, poor picture quality and low resolution provide further obstacles for the age assessment of individuals depicted on images compared to the direct examination of living individuals [13, 17].

Nevertheless, in case of pornography, the question of age of the depicted person(s) involved in the sexually explicit activities is the major factor for legal prosecution [8, 9]. Despite this fact, there is currently no scientifically established procedure for age estimation of individuals on images. Because of the shortcomings of the existing methods, a group of researchers from Germany, Italy and Lithuania has focused their attention on the face, in order to verify if age-related information can be obtained from the growth changes of the facial proportions of children and juveniles up to 21 years [16]. For this purpose, a large data set including facial photographs and anthropometric data from 3- to 21-year-old males and females was acquired.

Anthropometric studies on craniofacial growth were previously conducted mainly to describe the normal development of the head and face and simultaneously facilitate the identification and diagnosis of developmental anomalies [28–36], but the possibility of using facial measurements for forensic purposes has been explored only recently. The present pilot study aims to verify whether the metric assessment of facial proportions on images of children and adolescents could be of use for forensic age estimation.

The results of this pilot study seem to be promising for two main reasons. The first reason refers to the fact that many indices extracted from the frontal and lateral photographs are closely correlated to their respective indices taken from the living individuals. This means that the age-related changes in facial growth, which can be observed in living individuals, are also reflected in the photographs. The second reason refers to the independent observation that several indices taken from the photographs seem to be closely correlated with age.

However, in the present study, only four age groups—6, 10, 14 and 18 years—were examined. The 373 mostly female facial images were selected randomly for the metric analysis. Therefore, if the sample size was to be enlarged and more age groups were to be included, it is possible that the results would differ in terms of accuracy.

The discriminant analysis based on 23 facial indices showed that for the pooled sample, 60% of the cases could be correctly classified into the respective age group. After splitting the sample by country, the percentage of correctly classified cases increased, reaching 80% for the Italian sample. These differences may be due to different growth rates within these three samples in the four age groups. Thus, Italy may rate best because the differences are more evident for the age groups chosen for this study than it is the case in the Lithuanian and German samples. However, this observation needs to be verified on a larger sample.

The present study attempts at pointing a way towards a more accurate age estimation of subjects portrayed on suspected pedo-pornographic material. Accuracy not necessarily implies a small error, but it would be satisfactory, in a scenario where no method at the moment can give a result with a known error range, to devise a method which could give an objective estimate of age albeit with a large (known) error. Nonetheless, more work needs to be done in order to verify the reliability of these findings on a large sample including more age categories.

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