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The assessment of the biological age of children`s characters created in the convention of Japanese animation in forensic practice

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Abstract: Introduction: According to criminal codes of most Western countries, possessing, producing and disseminating of fictional paedopornography is a crime. In light of these laws, the shotacon/lolicon (popular and widely available Japanese animations or comic books showing minors in a sexual context) seems to deserve special mention. There have been several convictions for violations of these laws, however, the methodology of a depicted person's age estimation is still unestablished.

The aim of this study was to assess the suitability of anthropometrical prediction of age to the analysis of characters animated in the Japanese style.

Material and methods: The metric (distance between facial landmarks) and non-metric (type of chin shape) features of 173 animated characters' faces were obtained. Material was collected from 90 most popular Japanese anime series. Measurements were conducted in ImageJ software. The correlations of age and standardized measurements: *en-ex, en-en,* eye height, *pu-prn, pu-sto, pu-gn* were examined. The chin shape was described by three independent 'judges'.

Results and conclusions: Correlations for *pu-prn, pu-sto, pu-gn* and eye height in females and in all males were statistically significant. Age prediction was made using linear regression equations. Good prediction (± 1 year) was obtained for 44% males and 17% females. Prediction within the acceptable range (± 2 years) was achieved for 23% of males and 18% of females. In total, the prediction with an error of no more than ± 2 years was obtained for 67% of males and 35% from females, which is comparable to the results obtained in the study of real children. Moreover, triangular or rounded chin shape was significantly more frequent in boys aged 10–12 years, and square in older boys 16–18 years. Current research provides a basis for developing a methodology for assessing the age of animated characters. There is a need for further research in this area.

Key words: anime, anthropology, child pornography, face, lolicon, measurement

Original article

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Introduction

Child pornography is a significant ethical, social and medico-legal issue (Dayal et al. 2018). The term includes sexually marked materials picturing an individual(s) below the legalage of consent (for sexual activities), which can range from 12 years of age (e.g. China, Mexico, Paraguay) to 18 years of age (e.g. Egypt, Guatemala, Haiti) (Franklin et al. 2015). Currently, the major transmission channel of child pornography is the Internet (a major medium in disseminating child pornographical material (Vitorino et al. 2018)). However, concomitant with modern technological development in the sphere of creating virtual reality, the cultural perception of child pornography is also being transformed. This is reflected in global penal codes. Legal systems pertaining to many Western countries impose legal sanctions for possessing, producing and disseminating not only real images of minors participating in sexual activities, but also graphic representations of fictional characters (Hinton 2014). *Shotacon* and *lolicon* are relevant examples of such representations.

Shotacon and *lolicon* are the genres of *manga* (Japanese style comics) and *anime* (animations), which frequently depict males and females under the age of sexual maturity (usually 8–13 years old) in a sexualised context (Savage 2015). For example, showing intimate relations between children (including siblings) or between a child and an adult (Burdzik 2014). Therefore, these comic genre are pertinent in relation to criminal law (Holloway 2020).

The international legal status of *lolicon* and *shotacon* productions remains unclear. It is worth noting that Japan, where the majority of this sexual genre is produced, is reluctant to prohibit their construction, citing freedom of artistic expression (Holloway 2020). Arguments raised against the criminalization of this type of art genre include the fact that the characters depicted in them are completely fictitious, and no real person participates in the process of their creation. Consequently, they should not be compared with real pornographic materials presenting children (Savage 2015). It is worth noting that Japanese-made *shotacon* and *lolicon* comics that depict children in an erotic or even pornographic way are not part of the illegal black market. They are available through legal mass distribution channels. Examples of such distribution channels are the 'Boku no Pico' franchise (Natural High studio) or 'Enzai' franchise (Adonis / Japan Home Video studio). They are also available outside of Japan (especially on websites that provide fan translations of anime). Due to the nature of the content presented, these comic genre may be considered illegal in most Western countries. Due to easy access to these comic genre, children are especially at risk of exposure to unattended inappropriate content.

In many countries (e.g. Canada, Australia, United Kingdom) there have been cases of convictions issued in connection with the possession or dissemination of fictional child porn (The Sydney Morning Herald 2008; Thompson 2011; Romano 2014). However, in order to make possession of such materials punishable, it is necessary to prove that the presented character is a child under the legal age (Cattaneo et al. 2009). Although, there are a few established methods of living persons' age prediction, there is no methodology suitable for fictional images.

In cases concerning children pornography the age estimation of an individual depicted in photographic, video or other media plays a crucial role (Cunha et al. 2019; Mayer et al. 2014). Currently used methods are based on morphology, dentition or secondary sexual characteristics development. However, all of these are limited by differentiation of growth rate (which may be observed e.g. in endocrine disorders), technical restrictions and costs or inapplicability for every stage of human ontogenesis (Schmerling et al. 2016). In cases involving 2D or 3D materials, the restrictions concern: i) lack of reference point suitable for measuring, ii) poor quality of materials, iii) photo manipulations, iv) characterization and v) widespread depilation of anogenital area (Bednarek 2006; Łabęcka et al. 2011). Currently, the most commonly applied methods for assessing the age of people depicted in images (2D or 3D) use the variability with age of the features of the construction of individual body parts such as a hand or a face. Face proportions are particularly suitable. Anthropometric methods of age estimation are based on distances between facial landmarks, and their dependence on age. Current methods involve both 'manual' and 'automatic' approaches. In the 'manual' approach facial landmarks are positioned by an expert (e.g. Koruga et al. 2011, Borges et al. 2018, Deitos et al. 2020), and their values are further processed in order to obtain the models of craniofacial growth (Ramanathan and Chellappa 2006) that allow to estimate the individual's age from its known facial measurements value. In the 'automatic' approach advanced computer methods are used, like machine learning (Liu et al. 2020, Porto et al. 2020).

The aim of the research was to examine the 'age-related variability' of the anthropometric features of animated characters' faces in order to assess whether it would be possible to predict in this way the age (assigned by author) of character depicted in Japanese comic books or animations.

Materials and methods

Ninety of Japanese anime series were selected by popularity (according to MyAnimeList.net) and occurrence of young characters (according to Animecharacters-database.com) (access: December 2018 – March 2019). One hundred and seventy-three pictures of *en face* shots of characters (86 males and 87 females) in ages 10 years of age to 18 years of age, were obtained respectively according to following inclusion criteria: i) metrical age of an individual was well-known (from anime plot, author's complementary information, character's biographic note), ii) character was a human (without any animal-like features, e.g. cat ears), iii) the sex of each individual was clearly determined, iv) face of the individual was shown as clearly as possible, v) in the cases of significant timelapses the images of an individual from early episodes were selected, vi) the face was as motionless as possible. They were all included in the metric analysis.

Moreover, 16 additional images that did not meet one of the requirements of the metric analysis were included in the non-metric analysis of the chin shape (189 individuals: 96 male and 96 female).

Pictures were examined in ImageJ, a free software suitable for photometry. They were treated as if they were human faces. Anthropometric landmarks (according to Martin and Saller 1957) were positioned at designated points (Fig. 1). The chosen landmarks were: 1) *pu* (*pupillare*) – the center of the pupil; 2) *en* (*entokanthion*) – internal eyelid angle; 3) *ex* (*ektokanthion*) – external eyelid angle; 4) *prn* (*pronasale*) – tip of the nose; 5) *sto* (*stomion*) – oral fissure (in the midline); 6) *gn* (*gnathion*) – lower edge of the mandible (in the midline). In cases where the eyes were drawn without closing the internal and external angles, the *en* and *ex* landmarks were localized in the points that were most inward (*en*) or lateral (*ex*).

The selected landmarks were chosen because they were easiest to identify on the simplified facial model of an anime-style 2D drawing. For practical reasons, the points closely related to the craniofacial bone elements (such as *glabella, zygion, frontotemporale, gonion*) were excluded because there was a higher risk of their incorrect placement. Moreover, the landmarks localized in the points that could change position due to facial expression (such as corners of the lips or landmarks localized on the eyebrows) were also excluded. Additionally, for the purposes of the study, points were defined that mark the height of the eye, defined in the middle of the width of the upper and lower lash lines.

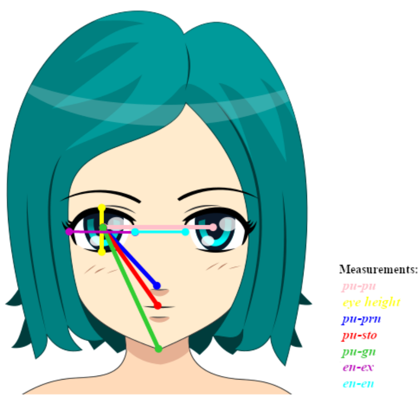

Fig. 1. Measurements between anthropological landmarks. Source: Rafael Javier on Pixabay; in own modification.

To standardize data, the measurements were divided by reference measurement *pu-pu*. This measurement was selected due to the references in the literature regarding the developmental stability of the pupil, the diameter of which does not increase after 2 years of age (Borges et al. 2018). However, the measurement between the centers of two irises was chosen instead of mean value of iris diameter, in order to avoid possible errors caused by differences in the iris shape, that could be elongated (vertically) in some drawing styles.

The proportion ratios obtained in this method were statistically analyzed using the STATISTICA 13.5 software. The distribution of all features was normal.

Pearson's r coefficient values were calculated for the correlation between age and proportion ratios. The regression equations for age estimation were proposed for each feature, which was statistically significant. The final result (estimated age) averaged the partial results for individual features. Prediction accuracy (Ac) was determined on the basis of the absolute value of the difference between real age (Ar) and estimated age (Ae):

$$\mathrm{Ac} = |\mathrm{Ar} - \mathrm{Ae}|$$

The coordinates of the points obtained in the program were substituted into the Pythagorean formula (Koruga et al. 2011) for the length of the segment, obtaining following measurements: *pu-pu, en-en, en-ex, pu-prn, pu-sto, pu-gn*, eye height.

For the value of $\mathrm{Ac} \leq 1$, the estimation was considered good, and for $\mathrm{Ac} > 1$ and ≤ 2 years – acceptable. Statistically significant results were assumed for $p \leq 0.05$.

Three forms of chin shape were observed: triangular, round and square. The differences in their occurrence in three categories of age (10–12, 13–15, 16–18) were examined using the χ^2 test. Statistically significant results were assumed for $p \leq 0.05$.

Results

Pearson's correlation coefficients (*r*) for all of the examined features in males and for 4 of 6 (*pu-sto, pu-prn, pu-gn* and eye height) in females were statistically significant (Fig. 2, 3). In both sexes there was a tendency to decrease with age the values of proportion indicators related to eye morphology (*en-ex,* eye height) with a simultaneous tendency to increase the indicators of the lower face (*pu-sto, pu-prn, pu-gn*). Features with *r* equal to 0.4 or more were further analyzed by calculating the regression equations (the searched variable was age; table 1).

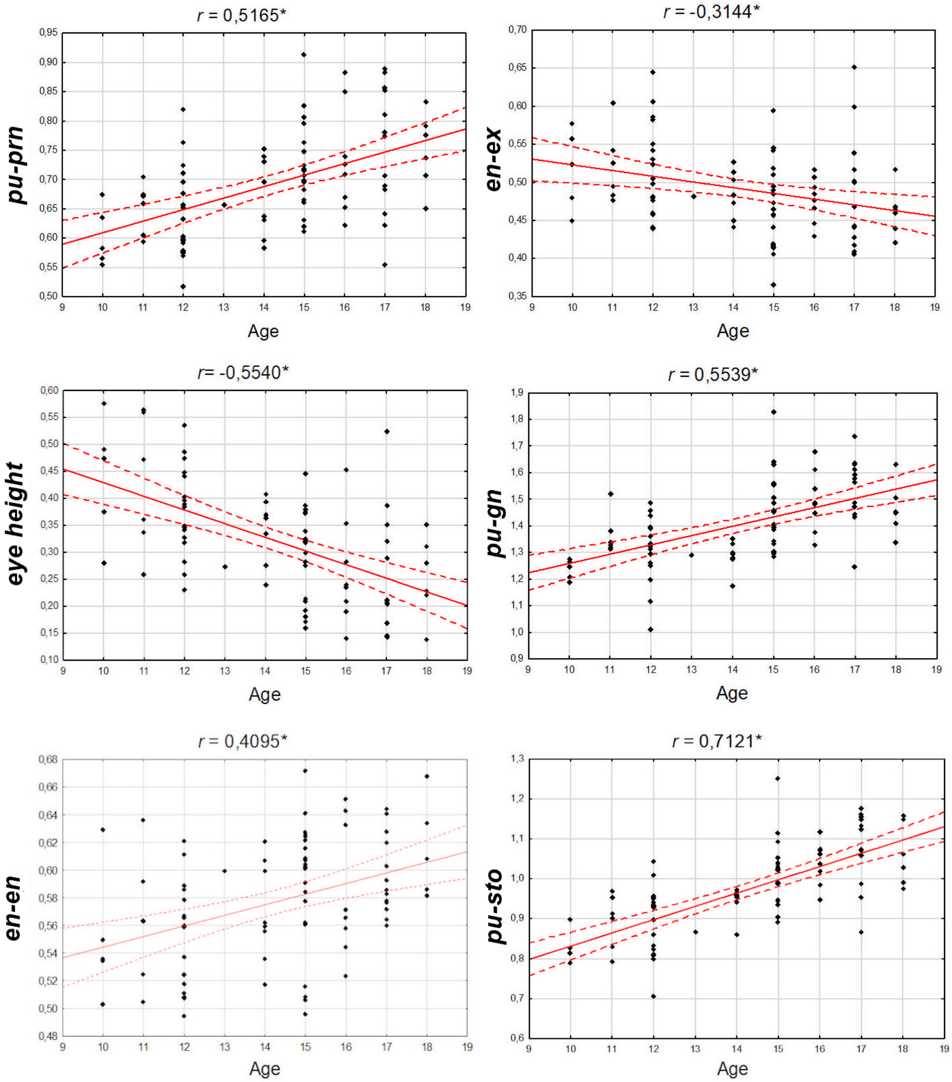

Fig. 2. Correlation diagrams of analyzed metrical features – males (* – statistically significant, $p<0.01$).

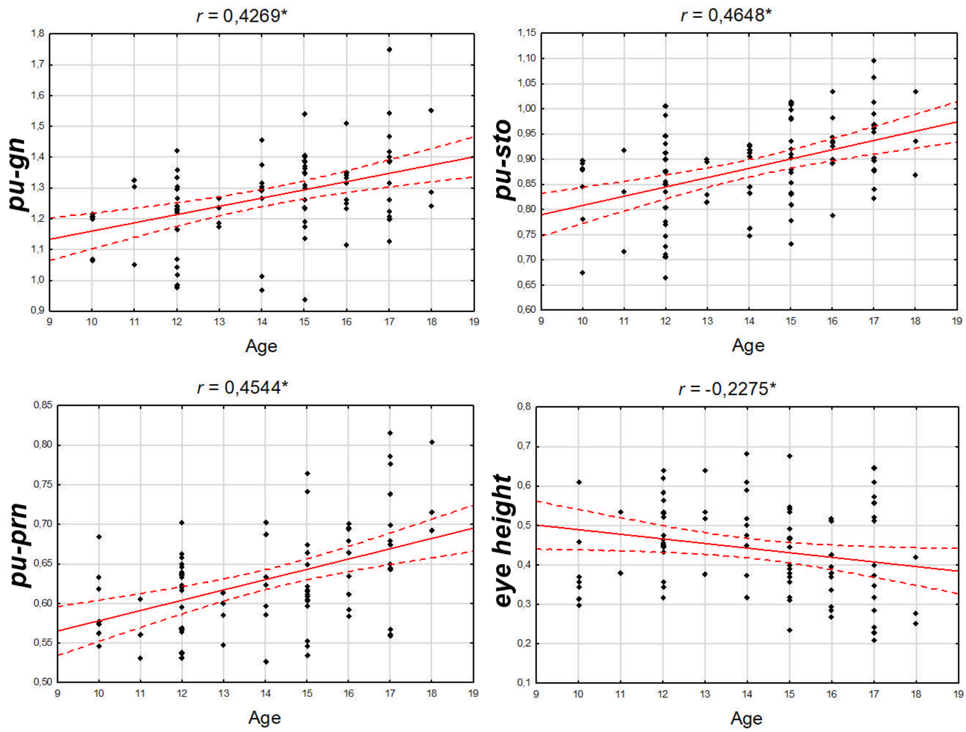

Fig. 3. Correlation diagrams of analyzed metrical features – females (* – statistically significant, $p<0.01$).

The final result was achieved by determining the arithmetic mean of the age obtained in each prediction based on the following equations:

For males:

$$\frac{\sum(Ae_{eye\,height} + Ae_{pu-sto})}{5} + \frac{\sum(Ae_{pu-prn} + Ae_{pu-gn} + Ae_{en-en})}{5}$$

For females:

$$\frac{\sum(\mathrm{Ae}_{pu-sto} + \mathrm{Ae}_{pu-prn} + \mathrm{Ae}_{pu-prn})}{3}$$

The estimated age of the individuals, the accuracy of which was then assessed, was obtained by applying combined methods: i) with the use of five indicators – for male, ii) with the use of three indicators – for female, in accordance with the above-mentioned equations.

To assess the validity of the method, the difference between the age assigned to the character and the age estimated anthropometrically was assessed in each case. Since the age assigned to the characters was a natural number (number of years), and it is not possible to refine this value (e.g. by calculating the number of months lived or indicating the exact date of birth that can be related to the date of measurement), the cases of difference that did not exceed 1 year (absolute value) were considered a good estimation accuracy. Cases where the difference did not exceed 2 years (absolute value) was considered acceptable.

Table 1. The equations of regression for age prediction

Feature	Males	Females
en-ex	–	–
eye height	$\frac{0.68291-[eye\ height]}{0,0253}$	–
pu-sto	$\frac{[pu-sto]-0.49883}{0.03324}$	$\frac{[pu-sto]-0.62375}{0.01844}$
pu-prn	$\frac{[pu-prn]-0.41247}{0.01967}$	$\frac{[pu-prn]-0.44807}{0.01301}$
pu-gn	$\frac{[pu-gn]-0.90978}{0.03492}$	$\frac{[pu-gn]-0.89280}{0.02675}$
en-en	$\frac{[en-en]-0.46760}{0.00767}$	–

The good estimation accuracy (Ac ≤ 1) was observed in 44% (n=38) of males and 17% (n=15) of females (table 2). The acceptable estimation accuracy (Ac >1 and ≤ 2) was observed in 23% (n=22) males and 18% (n=16) of females. To summarize, the age of 67% of males and 35% of females was estimated with error no higher than 2 years. For each regression separately, the best results were observed for the measurement *pu-sto*, with almost 1/3 of the analyzed material (31%) classified correctly, that is within ± 1 year range. Slightly worse results (27%) were given by age estimation based on *pu-gn* feature.

There were statistically significant differences in the incidence of chin shapes in the three age categories (in males only) (table 3, Fig. 4). A significant over-representation of the square shape was observed in the oldest age category (16–18); this shape was not present in any other group, which may make it an indicator of the male character >16 years of age. Moreover, the round and triangular shape was observed more often in younger males.

Table 2. Age prediction accuracy

Age prediction accuracy (Ac)	Males		Females	
	N	%	N	%
Good (Ac ≤ 1)	38	44	15	17
Acceptable (Ac >1 and ≤ 2 years)	20	23	16	18
Unacceptable (Ac >2 years)	28	33	56	65
TOTAL	86	100	87	100

Table 3. Chin shapes in three age categories of males (*Fo* – frequency observed, *Fe* –frequency expected); $\chi^2 = 10.47$; $df = 4$, $p = 0.03$

Age group		Chin shape			Total number
		Triangular	Round	Square	
10–12	*Fo*	21	13	0	34
	Fo – Fe	+1.88	+1.31	– 3.19	
13–15	*Fo*	19	10	2	31
	Fo – Fe	+1.56	– 0.57	– 0.90	
16–18	*Fo*	14	10	7	31
	Fo – Fe	– 3.44	– 0.66	+ 4.09	
Total number		54	33	9	96

Fig. 4. Types of chin shape in males: A – triangular (source: *Bakuman*), B – round (source: *Inuyashiki*), C – square (source: *Haikyū!!*).

Discussion

In the present study, good (± 1 year) predictive accuracy was obtained for 44% of males and 17% of females. Taking into account the cases where the accuracy of the estimate was within the limit value (± 2 years), the estimated biological age for 67% of males and 31% of females oscillated around the acceptable value, with a departure of no more than two years. It should be noted that in the case of animated characters it is not possible to accurately determine the age (date of birth), which reduces the likelihood of accurately predicting at the age of a living child.

It is noteworthy that the accuracy of age prediction with the proposed method was much more precise for males. This may be due to female faces undergoing less modifications during sexual maturation; secondly, female faces share more pedamorphic features with childen's faces, while male faces show more differences with the latter. Furthermore, the morphological neoteny of females is associated with their perception as being physically attractive (Palumbo et al. 2017). These features have been invariably depicted in artistic works spanning millenia. Therefore, it may be more difficult to assess the age of young female animated characters.

It should also be noted that the results obtained for individual regression equations were not convergent – better results were obtained for both sexes by using equations including measurements of the lower face (*pu-gn, pu-sto, pu-prn*). Interestingly, the estimates based on *pu-gn* and *pu-sto* ratios were more accurate for male characters. This coincides with the knowledge of the maturation and facial morphology of living people – higher testosterone levels, especially pubertal (Hodges-Simeon et al. 2016), for males imply stronger masculinization, as well as a higher mandibular shaft, with subsequent relatively longer lower face. This conclusion corresponds with the results of the χ^2 test relating to diverse male chin morphology. The square shape – clearly suggesting higher masculinization (Sayegh et al. 2019) – was significantly more frequent in older males (over 16 years of age). This type of chin presentation was absent in many female and younger male images, which suggests that this feature could be a feasible indicator of male characters who have already sexually matured. A similar feature (not included in this study) may be the marking of the laryngeal cartilage in the neck outline, which is more pronounced in sexually mature men (Franklin 2015).

The issue of assessing biological age is problematic not only in relation to fictitious images, but also to real persons. Łabęcka et al. (2011) (in a study of more than 200 children patients) attempted to develop a comprehensive age assessment method (based on the structure of the face, body, degree of laryngeal cartilage development and hair development and many others). However, its accuracy was unsatisfactory (9% males and 39.4% females classified correctly). In a study by Cattaneo et al. (2011) on the assessment of age based on facial morphology 69.9% of German children, 69.4% of Lithuanian children and 80.5% of Italian children were classified correctly. However, the individual age of study subjects was not taken into account, and only four age groups were considered: 6, 10, 14 and 18 years old. According to Ferguson and Wilkinson (2017), the visual age estimation of children by various groups of judges revealed an inadequate accuracy (33%). It is noteworthy, that even methods involving advanced algorithms may be able to provide moderate results in automatic age estimation. For instance 58.4% hitting ratios in a method proposed by Iga et al. (2003).

Research involving subjective expert judgments may be biased by past experience, individual beliefs, or socialization. The use of digital technologies can reduce this bias, as exemplified in Demonstrator software, which was more successful in assessing the age of 10–19 years old females in comparison with forensic experts (Retnayake et al. 2013).

In forensic practice, the biological age of the shown individuals is often assessed based on the degree of development of secondary sexual characteristics. However, this method is subject to a significant risk of error, which has been controversial. While incorrect classification of a child as an adult is rare, reverse errors can be made approximately 67% of cases (Franklin et al. 2015). This problem was highlighted by Cattaneo et al. (2009), where 11 photographs of adult pornographic actresses (of known age) were shown for evaluation to a group of experts composed of pediatricians, forensic experts and gynecologists. Only 22% of pediatricians, 25.5% of gynecologists and 60% of forensic doctors working in Italy and 5% of pediatricians, 9% of gynecologists and 51% of German forensics made a proper assessment. Such discrepancies may result from differences in educational levels, but also from inter-population differences widely documented in literature during puberty. However, Franklin et al. (2015) state: "inter-population differences in age of puberty that are widely documented in the literature". It has been suggested that it is easier to mistake an adult as a child than vice versa (especially if it is before the onset of puberty).

Inter-individual and ethnic diversity in relation to the rate puberty challenges the reliability of secondary sexual characteristics as feasible indicators of biological age. Characteristics of Japanese anime hair style and sporadic presence of so-called *futari* (representation of hermaphrodites with often overdeveloped sexual characteristics) may exclude this method out of assessing the age of images from the productions of *shotacon* and *lolicon*.

Informational sources on the age of depicted individuals may also be secondary elements resulting from the context of the comic, such as specific school uniforms (characteristic males' *gakuran* and females' *sērā-fuku*) suggesting educational stage (Arunrangsiwed 2015), speech patterns (e.g. personal pronouns '*boku*' and '*ore*' used by males of different age) and other elements belonging to the cultural region. In addition, given the popularity and universality of *doujinshi* (so-called 'fan art'), character recognition and indication of a source that was a prototype for pornographic material could allow verification of an author's information on the character (including age).

Interest in art forms, such as anime and manga, is steadily increasing in the West (Hinton 2014), which is manifested in their popularity in mass media, such as TV or Netflix. The popularity of manga and anime have been instrumental in the spread of comic based eroticism via the mass media. As Arunrangsiwed (2015) indicates, the phrase '*hentai*' has been googled with an average frequency of 13.6 million times a month, which may contribute to the spread of child animated pornography. These facts indicate a sharp shift in perceptions of eroticism and pornography, and the growing importance of fictional works. Equally disturbing are current robotic trends in developing sexualised child-shaped robots or dolls (Chatterjee 2020). This has created a 'gray area' in which there is a greater possibility for child sexual abuse related to the production of fictional child pornography. Due to the illegal status of animated pornography internationally, creating and improving methodologies for assessing it is an important research area.

In conclusion, while this study's method does not allow for a highly precise assessment of the age of animated characters, the results achieved can be comparable with the accuracy of the estimation documented for the images of living persons. Consequently, this method should be treated as a basis for further development of established protocols.

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