The own-age bias stems from distinctions in using holistic and part-based information for own- and other-age faces

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This manuscript has been accepted in *Visual Cognition*.
https://doi.org/10.1080/13506285.2026.2669913.

Abstract: It is well established that individuals recognize faces of their own age better compared to others, known as the own-age bias. However, its underlying mechanisms, especially the roles of holistic and part-based information in this bias, still remain underexplored. This study employed a variable viewing position paradigm to examine whether participants used holistic or part-based information in recognition. Specifically, participants were instructed to fixate at either the left or right eye of a target face and then to choose the face they saw earlier among four options: the target face (correct match), a face with congruent peripheral but incongruent central features (holistic match), a face with congruent central but incongruent peripheral features (part-based match), and a fully incongruent face. Undergraduate participants were tested with upright (Experiment 1) and inverted (Experiment 2) faces of young adults (20-year-olds) and children (4-year-olds). Results showed that for upright faces, participants achieved significantly higher accuracy for own-age faces versus other-age faces, demonstrating the own-age bias; critically, this bias was not observed for inverted faces. Additionally, for upright faces, participants made more holistic errors on adult faces than child faces, but more part-based errors on child faces than adult faces. These error patterns disappeared for inverted faces. The findings above suggest that the own-age bias results from a nuanced adjustment in face processing that involves both holistic and part-based information.

Keywords: Own-Age Bias, Holistic, Part, Inversion Effect, Face Recognition

1. Introduction

Humans exhibit a cognitive phenomenon termed the own-age bias (OAB), also known as the own-age effect, other-age effect, or cross-age effect (Rhodes & Anastasi, 2012). This bias entails a superior ability to recognize and remember faces of one's own age groups compared to those of other age groups, a pattern observed across children, young adults, and older adults (Bartlett & Leslie, 1986; Cross et al., 1971; Strickland-Hughes et al., 2020). For example, adults and children aged 7 to 9 exhibited enhanced performance in recognizing and remembering faces of their own age groups relative to faces from other age groups (Hills & Lewis, 2011). Similarly, older adults had better recognition memory for faces of their own age compared to those of younger adults (Lamont, Stewart-Williams, & Podd, 2005; Strickland-Hughes et al., 2020) and child faces (Anastasi & Rhodes, 2005, 2006). OAB also exists in different racial groups, as evidenced by research involving Caucasian and Asian participants in a face recognition task, with both groups displaying a typical age bias (Macchi Cassia et al., 2014). Furthermore, an OAB was observed in nonhuman primates, with adult chimpanzees responding faster and more accurately to adult faces than infant ones (Kawaguchi et al., 2022).

One possible explanation for the OAB is holistic face processing. Holistic processing of faces refers to the integration of different facial parts into a unified whole, resulting in a holistic representation (Tanaka & Gordon, 2011). Researchers posit that variations exist in individuals' holistic processing of faces within their own age group as opposed to faces from other age groups, consequently resulting in discrepancies in their recognition performance across different age groups(Kuefner et al., 2008; Susilo et al., 2009). Evidence from different paradigms has supported the theoretical hypothesis. For example, Susilo et al. (2009) examined children's holistic processing of same-age faces and adult faces using a composite face task. It revealed a significantly stronger composite face effect for own-age faces compared to other-age faces, suggesting a stronger holistic processing for faces of the own age group. Kuefner et al. (2008) used an inverted face task to examine the extent of holistic processing among adults when presented with faces of their own age group, newborn faces, and faces of children aged 3 to 4 years. Results showed that adult participants did not exhibit an inversion effect when presented with newborn faces, suggesting that they did not process them holistically. However, they did display significant inversion effects when presented with adult and child faces, and they processed adult faces holistically more intensely than child faces.

In summary, many studies have shown that there are differences in the holistic level of processing of own-age faces and other-age faces. Researchers have suggested that the own-age bias may be due to differences in how people process faces of different ages - specifically, individuals may process faces of their own age more holistically. However, few studies have directly linked superior recognition performance for own-age faces to stronger holistic processing and further tested this hypothesis. It may be caused by the fact that the current paradigms for measuring holistic processing have certain limitations. For example, the composite face paradigm or the part-whole paradigm necessitates compromising the integrity of the face (Richler &

Gauthier, 2014). This means that the tasks can only assess holistic processing and cannot simultaneously evaluate identity recognition performance. Moreover, the correlation between holistic processing and identity recognition in these two paradigms is weak and unstable (Konar et al., 2010; Richler et al., 2011; Wang et al., 2012). The inverted face paradigm ues intact faces as materials and also measures recognition performance. However, the holistic processing index in this paradigm is calculated by taking the difference between upright and inverted faces, which makes it impossible to independently evaluate the intensity of holistic processing and recognition performance, preventing an assessment of the relationship between the two.

On the contrary, merely considering holistic processing may not be adequate; the processing of part-based information could also contribute to OAB. A study investigating the impact of part-based information on OAB revealed that the processing of faces from other age groups relied more heavily on individual face parts/features such as eyes, nose, and mouth (De Lissa et al., 2014). According to an eye-tracking study, OAB may arise from distinct encoding strategies for faces of different ages (Firestone et al., 2007). The study found that gaze patterns for own-age faces involved a more dynamic visual exploration of the internal parts and longer viewing time on the eye region compared to the other regions of the face (Proietti et al., 2015). Similarly, studies on the own-race bias, similar to OAB, have shown that individuals tend to discriminate facial parts better for faces of their own race than for faces of other races, underscoring the significant role of part-based information in the own-race bias (Wang et al., 2015). While these findings collectively suggest that part-based processing contributes to OAB, the specific mechanisms underlying this contribution in the context of OAB remain underexplored.

To investigate the reliance on holistic versus part-based information in face recognition within a single task, the current research refers to Van Belle's variable viewpoint position paradigm (VVPP; see Figure 1) (Van Belle et al., 2015). In the VVPP, a displayed full face is composed of a combination of two individual faces. One is the central face, which corresponds to the part that the viewer is fixated on in a gaze-contingent manner. The other is the peripheral face, which corresponds to the unfocused area of the face. Subsequently, the two original faces are displayed, and participants are asked to select which face resembles the combined face. If they rely on the fixated part ("part-based responses"), they will choose the central face, and if they rely on the unfocused part ("holistic responses"), they will choose the peripheral face.

In the present study, we follow Rossion's "perceptual field" account as a working framework for interpreting the VVPP. In this account, the perceptual field is defined as the area of vision from which diagnostic information can be extracted for the task, and its size is taken as an index of the range over which facial information is integrated. A wider perceptual field is therefore associated with more holistic processing, whereas a narrower field reflects more local, part-based processing, and central versus peripheral information in the VVPP is treated as an operational measure of how broadly observers extend their task-relevant perceptual window across the face, rather than as a simple equation of visual acuity with face-processing mechanisms.

Van Belle et al. (2015) showed that typical participants chose the peripheral face significantly more often when the faces were upright compared to when they were inverted. In contrast, an individual with prosopagnosia, who has normal peripheral vision but impaired holistic perception, provided responses based on her fixated part nearly 100% (97%). This finding indicates that the disruption of holistic processing (either through inversion or brain damage) leads individuals to rely more on part-based information. In our two subsequent behavioral experiments, we refined this paradigm by instructing participants to focus on a fixation point. After a brief fixation, a combined face was quickly displayed at the gaze point. Participants were then asked to choose which of the two side-by-side faces—the central face or the peripheral face—more closely resembled the combined face (Wang et al., 2023a; Wang et al., 2023b). Our experiments also found that when faces were inverted, participants' selection of the peripheral face decreased (Wang et al., 2023a), and when faces became more familiar, participants' selection of the peripheral face increased (Wang et al., 2023b). These results indicate that this research method can be used to determine whether individuals rely more on holistic or part-based information when recognizing intact faces. However, there are two main drawbacks to this method: 1) This method is a "more similar" task; it does not measure individuals' recognition of faces. 2) This method employs a 2-choice selection process. Due to the constraints of degrees of freedom, an increase in one option necessarily results in a decrease in the other. This limitation makes it impossible to examine scenarios where both options may increase or decrease simultaneously.

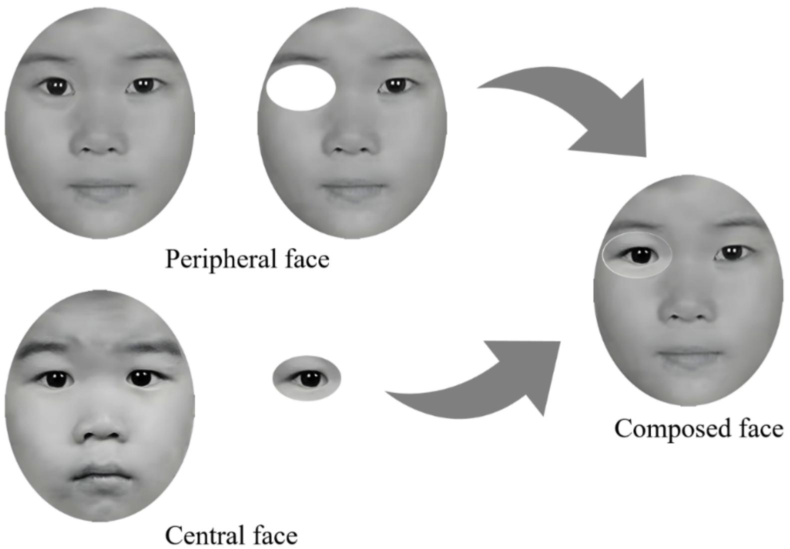

Fig. 1. Examples of peripheral face, central face, and composed face in VVPP. *Note.* Take the left eye as an example. The composed face is created by fusing the central face's left eye area with the peripheral face's non-eye area. The white ellipse in the composed face is a highlight that is not present in the actual images in the experiments.

A new delayed matching task was designed in this study to investigate the role of holistic and part-based information in OAB. The task combined the delayed matching paradigm with the VVPP (Van Belle et al., 2015): participants are first presented with a fixation cross, and then a target face is given at the position of the fixation cross (with either the left or right eye of the target face falling at the position of the fixation cross, the left eye is used as an example in the following), followed by four matching faces (two original and two combined) presented to the participants at the upper left, lower left, upper right, and lower right of the screen respectively. The four types of faces included: complete congruency (the target face), complete incongruency (the distractor face), peripheral congruency with central incongruency (where the area outside the left eye matched the target face while the left eye matched the distractor face), and central congruency with peripheral incongruency (where the left eye matched the target face and the area surrounding it matched the distractor face). The participant's task was to determine which face had just been seen. This paradigm allows us to understand whether people rely more on holistic or part-based information during facial recognition. First, this task serves as a recognition exercise. By evaluating recognition accuracy, we can identify whether participants demonstrate Own-Age Bias (OAB) when recognizing faces. Additionally, there are three types of incorrect options: faces with peripheral consistency, faces with central consistency, and completely incongruent faces. This approach avoids the aforementioned issue of degrees of freedom. By analyzing the error response patterns of participants, we can deduce their preferred type of information reliance. A higher selection rate of faces with peripheral congruency and central incongruency indicates a stronger reliance on holistic information. Conversely, a higher selection rate of faces with peripheral incongruency and central congruency suggests a greater reliance on part-based information. This method directly validates our research hypothesis.

Based on the previous review and the design of the present study, we propose that the participants' performance in recognizing faces of their own age group will be significantly better than their performance in recognizing faces of other age groups, which indicates an Own-Age Bias (OAB). Additionally, we propose the following three possible expectations for the participants' incorrect responses based on existing speculation:

1. If the OAB arises from an increase in holistic processing and a decrease in part-based processing for own-age faces, compared to other-age faces, then participants who recognize own-age faces will be more likely to identify faces with peripheral congruency and central incongruency (holistic information) as target faces and fewer faces with central congruency and peripheral incongruency (part-based information) as target faces (see Figure 2a).

2. If the OAB arises solely from an increase in holistic processing for own-age faces, compared to other-age faces, then participants who recognize own-age faces will be more likely to identify faces with peripheral congruency and central incongruency (holistic information) as target faces, whereas there will be no difference between own-age and other-age faces in terms of recognizing central congruency and peripheral incongruency (part-based information) faces as target faces (see Figure 2b).

3. If the OAB arises from an increase in both holistic and part-based processing for own-age faces, compared to other-age faces, then participants who recognize own-age faces will be more likely to identify both faces with peripheral congruency and central incongruency (holistic

information) and faces with central congruency and peripheral incongruency (part-based information) as target faces (see Figure 2c).

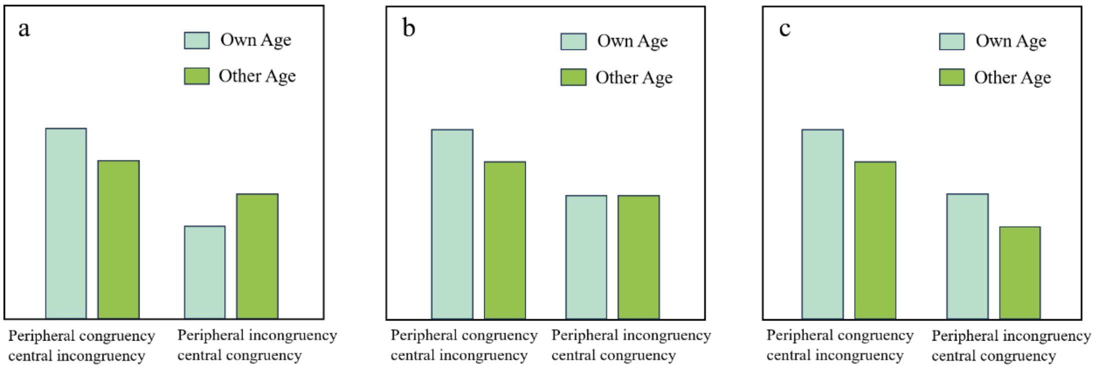

Fig. 2. Three possible experimental results: (a) stronger holistic processing for own-age faces and stronger featural processing for other-age faces; (b) stronger holistic processing for own-age faces and similar featural processing for both types of faces; (c) stronger holistic and featural processing for both own-age faces.

2. Experiment 1

2.1 Method

2.1.1 Participants

Thirty-one college students participated in Experiment 1. All of them were Asian from China (16 females, mean age = 21.8 years, SD = 2.8 years). All participants were right-handed with normal or corrected-to-normal vision. Using GPower (Faul et al., 2007; Faul et al., 2009), we conducted an a priori power analysis for a 2 (Face Age: adult, child) × 2 (Error Type: central vs. peripheral congruency) repeated-measures design, targeting the interaction effect with $\alpha = 0.05$, statistical power = 0.80, and a medium effect size $f = 0.289$ (Rhodes & Anastasi, 2012). The analysis indicated that a minimum of 18 participants would be required. All participants volunteered to take part in the experiment, filled out an informed consent form and a confidentiality agreement before the experiment, and received monetary compensation. The experiment was approved by the Human Research Ethics Committee of the University.

2.1.2 Materials

The experimental materials consisted of 40 grayscale pictures of Asian Chinese faces with neutral expressions. These images were selected from an in-house database maintained by our laboratory and were edited using Photoshop to remove obvious external features such as hair, ears, and accessories (see Figure 1). The faces were split equally between adult and child faces (20 adults, mean age = 20 years; 20 children, mean age = 4 years), and within each age group, half were male and half were female. Each image subtended 314 × 384 pixels on the screen. The child-face images from this database have also been used in prior published work (e.g., Ge et al., 2008). All adult and child models in the database had provided written informed consent for the use of their images in scientific research.

Faces of the same age and gender were paired (one served as Face 1 and the other as Face 0), as shown in Figure 3. For each pair, we created composite faces by combining the peripheral region (the remaining part) of one identity with the central eye region (left or right eye) of the other identity. Specifically, we generated P1C0 (periphery from Face 1, center from Face 0) and P0C1 (periphery from Face 0, center from Face 1) for the left-eye condition, and another P1C0 and P0C1 for the right-eye condition (see Figure 3). Thus, each pair of identities contributed two original faces and four composite faces (two eye positions × two identity combinations), yielding six stimuli per pair and 120 distinct face stimuli in total across the 20 pairs.

Each face image subtended approximately 10.1° (width) × 12.4° (height) of visual angle at a viewing distance of 60 cm, and the central eye region used to define the “central” face area covered approximately 4.0° (width) × 2.7° (height) of visual angle.

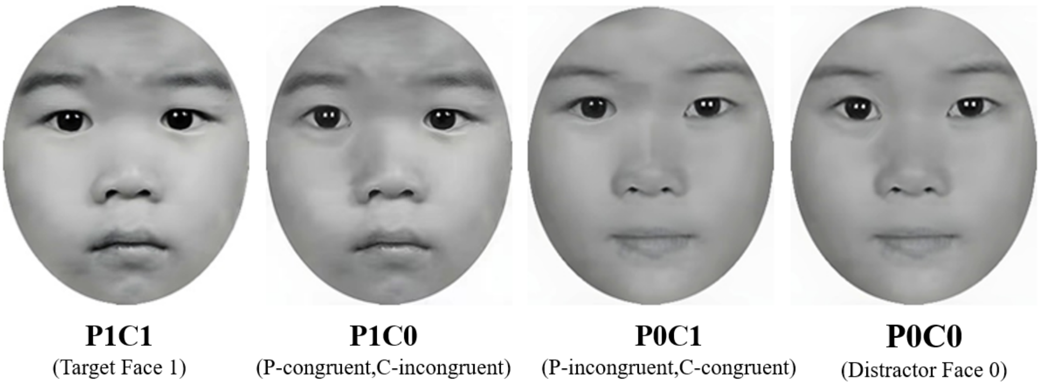

Fig. 3. Example of child faces with gaze directed towards the left eye, where "P" represents the peripheral area of the face and "C" represents the central area of the face. The image shown here is an example constructed according to the same procedures as the experimental stimuli and was not used in the actual experiments.

2.1.4 Procedure

The experiment was administered by E-prime 2.0 in a quiet room with a 17-inch LCD screen (resolution: 1024 × 768 pixels). The stimuli were presented approximately 60cm from the participants. No chinrests were provided during the experiment, as in the previous research (Wang et al., 2023a; Wang et al., 2023b). The presentation of the stimuli and the recording of participants' responses were controlled by E-prime.

As shown in Figure 4, participants performed a four-alternative delayed matching task. In each trial, a fixation point was displayed at the center of the screen for 150 ms, with participants instructed to focus their gaze on it. Subsequently, a target face appeared for 400 ms, positioned so that the center region (either the left or right eye) aligned with the fixation point. This was followed by a 300 ms mask. Following this, four faces appeared on the screen: upper left, lower left, upper right, and lower right, each with varying relationships to the target face - 'complete congruency', 'peripheral congruency with central incongruency', 'central congruency with peripheral incongruency ', and 'complete incongruency'. These faces were displayed for 5000 ms. Participants were asked to select the target face they had just seen by pressing the corresponding keys (F for upper left, J for upper right, V for lower left, and N for lower right). Failure to respond within

5000ms was recorded as an error. Following participant response or timeout, a blank screen was shown for 800 ms before the next trial commenced.

We employed several techniques to keep the foveas of the participants fixed on a specific location while displaying the combined face: (1) Participants were instructed to focus on the fixation point, and when the combined face appeared, its central region (either the left or right eye) aligned with the previous fixation point, as illustrated in Figure 4. (2) The fixation point was presented for 150 ms, preventing participants from shifting their gaze. (3) Upon the presentation of the combined face, participants could not move their fixation from the central area, as the face was displayed for just 400 ms, shorter than the time of two fixations.

Participants underwent a practice session to ensure comprehension of the task before the formal experiment. The experiment comprised two blocks focusing on adult faces and child faces, with the sequence of these blocks counterbalanced among participants. Each block entailed 20 identities, two fixation positions (the left eye, the right eye), and four target locations (upper left, lower left, upper right, and lower right), resulting in a total of 160 trials per block. Consequently, the entire experiment consisted of 320 trials, with a 30-second break after every 80 trials.

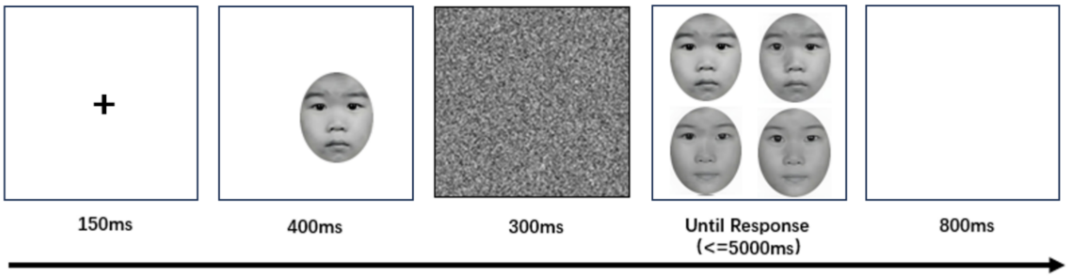

Fig. 4. Schematic illustration of a trial sequence in Experiment 1. Taking the left eye as an example, a single trial begins with the presentation of a fixation point at the center of the screen, followed by the presentation of a face, positioning its left eye at the fixation point. Next, a mask is displayed to eliminate the perceptual afterimage. After this, four faces are presented: the target face (upper left), a face with peripheral congruency consistency but an incongruent left eye (upper right), a face with a congruent left eye but an incongruent periphery (lower left), and a distractor face (lower right). Participants are required to make a selection within 5000 ms, after which a blank screen is displayed.

2.1.5 Analysis

To examine the own-age effect, we first compared participants' accuracy in matching adult and child faces using paired-sample t tests. Responses were then classified into four types based on their congruency with the target face: complete match (correct response), central congruency, peripheral congruency, and complete incongruency. To isolate the source of errors, we focused on central congruency and peripheral congruency errors for further analysis. Correct responses and completely incongruent errors were excluded. In correct responses, the selected face fully matched the learned face in both part-based and holistic information, making it impossible to determine the underlying strategy. In completely incongruent errors, the selected face shared no part-based or holistic similarity with the learned face, providing no information about strategies. Thus, we analyzed selection rates of central congruency and peripheral congruency errors to determine whether participants relied more on part-based or holistic information for identity matching.

A 2 (Face Age: adult/child) × 2 (Error Type: central/peripheral congruency) repeated-measures ANOVA was conducted. To avoid bias caused by higher accuracy for adult faces (which reduces absolute error rates), raw percentages were not used directly; instead, selection ratios were calculated using a standardized approach (see below for details).

$Rate_{Peripheral\ congruency}$ = the frequency of selecting faces with peripheral congruency but central incongruency / the total number of errors;

$Rate_{Central\ congruency}$ = the frequency of selecting faces with peripheral incongruency but central congruency / the total number of errors.

2.2 Results

A paired samples t-test was conducted with accuracy as the dependent variable. The results showed a significant own-age bias, t (30) = 3.45, p = 0.002, Cohen's d = 0.62, indicating that participants' performance in recognizing adult faces (M_{adult} = 0.505, SE_{adult} = 0.013)was significantly better than that of child faces (M_{child} = 0.459, SE_{child} = 0.015) (see Figure 5).

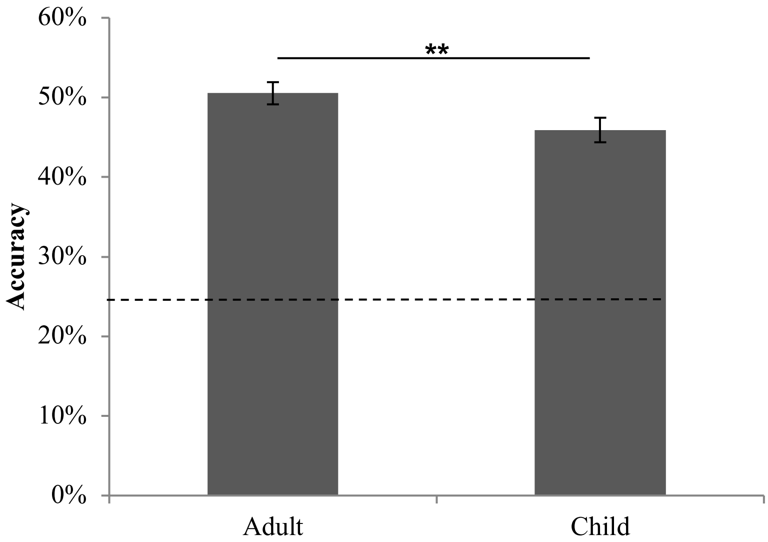

Fig. 5. Accuracy of Recognizing Upright Adult and Child Faces. The dashed line indicates the expected response rate (25%). Error bars indicate one standard error from the mean.

To analyze participants' error response patterns, a 2 (Face Age: adult and child) x 2 (Error Type: peripheral congruency and central congruency) repeated-measures ANOVA was conducted with the percentage of responses out of the total number of errors as the dependent variable. It was found that the main effect of Face Age was marginally significant, $F(1,30) = 3.98$, $p = 0.055$, $\eta_p^2 = 0.12$. The main effect of Error Type was significant, $F(1,30) = 109.79$, $p < 0.001$, $\eta_p^2 = 0.79$. Faces with peripheral congruency($M_{peripheral}$ = 0.609, $SE_{peripheral}$ = 0.017) had a higher proportion of error responses than faces with central congruency($M_{central}$ = 0.223, $SE_{central}$ = 0.013). More importantly, the interaction between Face Age and Error Type was significant, $F(1,30) = 11.92$, $p = 0.002$, η_p^2 = 0.28, shown in Figure 6.

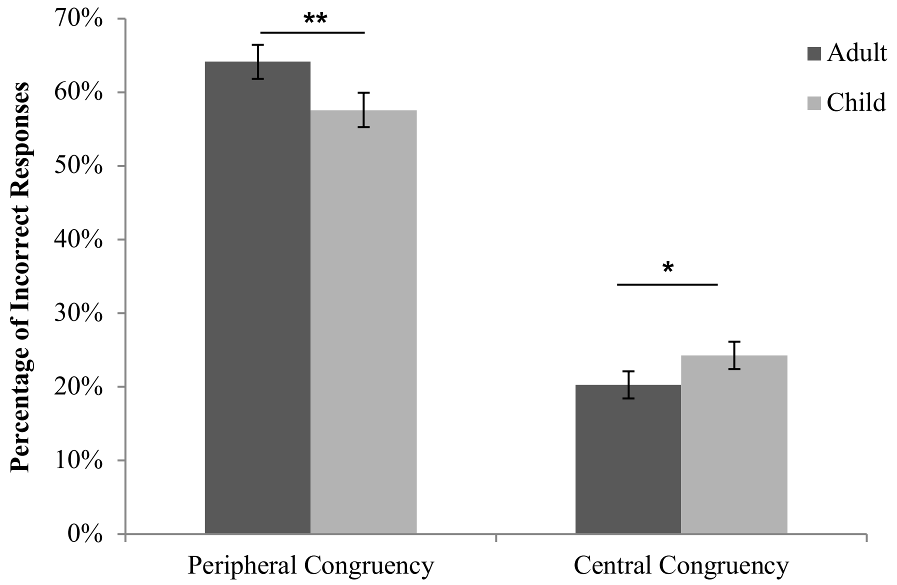

Fig. 6. The Percentage of Incorrect Responses to Recognizing Upright Adult and Child Faces

To examine the interaction between Face Age and Error Type, we conducted simple effect analyses. The results revealed a significant effect of Face Age on errors involving "peripherally congruent but centrally incongruent" faces, $t(30) = 3.64$, $p = 0.001$, Cohen's d = 0.51. Participants showed a higher tendency to select the faces with peripheral congruency in the adult face condition than in the child face condition, indicating a greater reliance on holistic information for recognizing faces of their own age. Similarly, when errors occurred with centrally congruent faces, a significant effect of Face Age was observed, $t(30) = -2.68$, $p = 0.012$, Cohen's d = -0.40. In this case, participants tended to choose the faces with central congruency more often when identifying child faces compared to adult faces, suggesting a stronger dependence on part-based information for recognizing other-age faces.

2.3 Discussion

In Experiment 1, participants made more errors on peripherally congruent distractors (holistic errors) for adult faces than for child faces, but more errors on centrally congruent distractors (part-based errors) for child faces than for adult faces. These results indicate that the own-age bias arises from a modulated interplay of holistic and part-based processing: while both age groups are processed holistically, own-age faces elicit stronger holistic reliance compared to other-age faces, whereas other-age faces involve relatively greater part-based contributions. However, an alternative explanation could be that these error patterns reflect low-level physical differences between child and adult faces (e.g., relative feature sizes or contour shapes), despite our control of overall face size by elliptical cropping. To rule out this confound, Experiment 2 used inverted faces. Critically, upright and inverted faces are physically identical—only their orientation differs. If the error patterns in Experiment 1 were driven by physical differences, we would expect identical results in

Experiment 2.

Inversion is well-established to disrupt holistic face processing and modulate age biases in recognition. A body of evidence demonstrates that face inversion either eliminates or severely impairs holistic processing(Hole, 1994; Goffaux & Rossion, 2006; Rossion & Boremanse, 2008; Rosenthal et al., 2018). Specifically, inversion weakens the integration of facial features into a unified whole, forcing reliance on part-based analysis (Goffaux & Rossion, 2006). Critically, inversion also attenuates the own-age bias: studies such as Kuefner et al. (2008) showed that while upright faces elicited superior recognition for own-age faces, this bias vanished when faces were inverted, suggesting that the own-age bias is tightly coupled with holistic processing. Given these findings, we derived a prediction for Experiment 2: If the own-age bias observed in Experiment 1 stems from differential holistic/part-based processing (rather than physical differences), inversion should eliminate the recognition advantage for own-age faces, and equalize error patterns between adult and child faces (i.e., no more holistic bias for adult faces or part-based bias for child faces).

This design thus provides a clear dissociation between low-level perceptual accounts and cognitive processing explanations for the own-age bias.

3. Experiment 2

3.1Methods

3.1.1 participants

Thirty-one college students participated in Experiment 2. All of them were Asian from China (20 females, mean age = 21.0 years, SD = 2.3 years). All participants were right-handed with normal or corrected-to-normal vision. The experiment was approved by the University's Human Research Ethics Committee.

3.1.2Materials

In Experiment 2, the materials were the same as those in Experiment 1, but they were inverted.

3.1.3 Design and Procedure

The experiment was a 2 (Face Age: adult, child) × 2 (Error Type: peripheral congruency, central congruency) two-factor within-participants design.

The procedure used in Experiment 2 was identical to the one used in Experiment 1.

3.2 Results

A paired-sample t-test with accuracy as the dependent variable revealed that the accuracy in recognizing adult faces (M_{adult} = 0.397, SE_{adult} = 0.017)was comparable to that of child faces (M_{child} = 0.390, SE_{child} = 0.015), $t(30) = 0.67$, $p = 0.510$, Cohen's d = 0.12, meaning that the age bias disappeared. The results are shown in Figure 7.

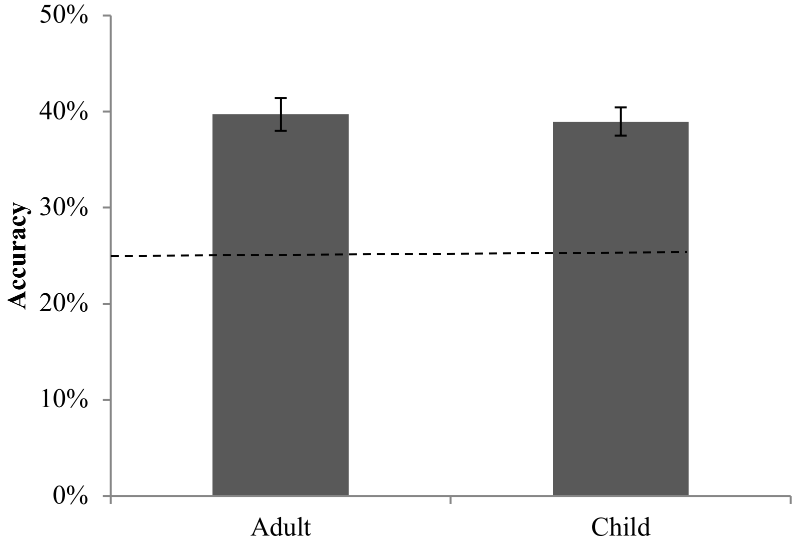

Fig. 7. Accuracy of Recognizing Inverted Adult and Child Faces. The dashed line indicates the expected response rate(25%). Error bars indicate one standard error from the mean.

To analyze participants' error response patterns, a 2 (Face Age: adult and child) x 2 (Error Type: peripheral congruency and central congruency) repeated-measures ANOVA was conducted with the percentage of responses out of the total number of errors as the dependent variable. Results showed that the main effect of Face Age was not significant, $F(1,30) = 0.94$, $p = 0.339$, $\eta_p^2 = 0.03$. The main effect of Error Type was significant, $F(1,30) = 29.92$, $p < 0.001$, $\eta_p^2 = 0.50$. Faces with peripheral congruency ($M_{peripheral} = 0.476$, $SE_{peripheral} = 0.017$) had a higher proportion of error responses than faces with central congruency($M_{central} = 0.286$, $SE_{central} = 0.011$). The interaction between Face Age and Error Type was not significant, $F(1,30) = 1.50$, $p = 0.230$, $\eta_p^2 = 0.05$. The results are shown in Figure 8. As predicted, Experiment 2 revealed that face inversion eliminated both the recognition advantage for adult faces and the asymmetric error patterns.

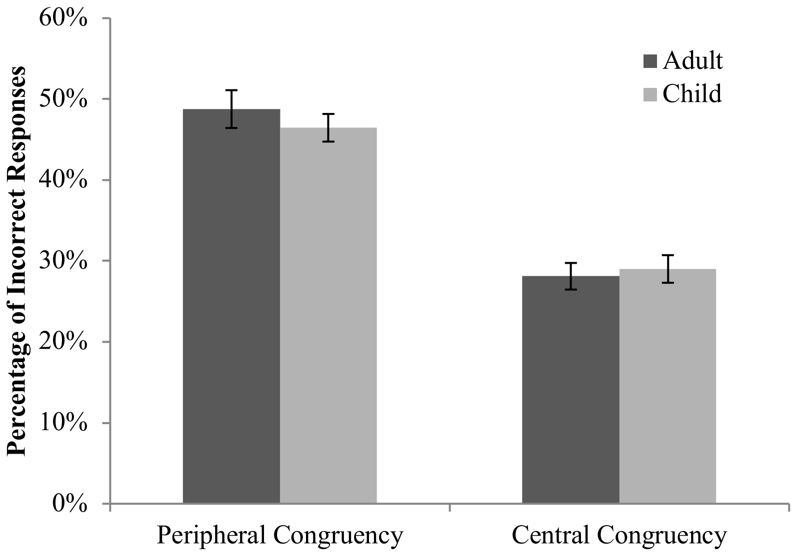

Fig. 8. The Percentage of Incorrect Responses to Recognizing Inverted Adult and Child Faces

3.3 Combined Analysis of Experiment 1 and Experiment 2

To examine whether the age effect differs between upright and inverted faces, we conducted combined analyses with Face Orientation (upright vs. inverted) as a between-subjects factor and Face Age (adult vs. child) as a within-subjects factor. Given that the sample size was not determined a priori for these between-experiment comparisons, these analyses were not formally powered and should be regarded as exploratory. Detailed statistics are reported in the Supplementary Materials.

For accuracy, a 2 (Face Orientation: upright, inverted) × 2 (Face Age: adult, child) ANOVA revealed significant main effects of Face Orientation and Face Age, as well as a significant interaction between them. Accuracy was higher for adult than for child faces and higher for upright than for inverted faces, and the own-age advantage was present for upright but not inverted faces.

For error patterns, a 2 (Face Orientation) × 2 (Face Age) × 2 (Error Type: peripheral-congruent vs. central-congruent) ANOVA on error proportions showed significant main effects of Face Age, Error Type, and Face Orientation, and significant interactions between Error Type and Face Orientation, and between Face Age and Error Type. Across conditions, participants made more peripheral-congruent than central-congruent errors, and this holistic bias was stronger for adult than for child faces, particularly for upright faces. Inversion reduced the proportion of peripheral-congruent errors and increased the proportion of central-congruent errors, indicating a shift from holistic to more part-based responding.

4. General Discussion

This study investigated the holistic processing hypothesis of the own-age bias (OAB) by analyzing adult participants' recognition performance and error patterns when identifying upright and inverted faces of adults and children. Our key findings reveal three main patterns: (1) When faces were upright, participants demonstrated higher recognition accuracy for adult faces compared to child faces, confirming the presence of an OAB. However, this bias disappeared when faces were inverted, as recognition performance became equivalent across age groups. (2) Adult participants showed differential reliance on holistic vs. part-based information. For upright faces, participants made more errors on peripherally congruent distractors (holistic errors) for adult faces than for child faces, but more errors on centrally congruent distractors (part-based errors) for child faces than for adult faces. Critically, this dissociation vanished under inversion, implying that the OAB is tied to orientation-sensitive processing strategies. (3)Inverted faces were recognized less accurately than upright faces. Moreover, inversion reduced holistic errors while increasing part-based errors across faces from both age groups. These results indicate that the own-age bias (OAB) reflects a fine-tuned adjustment in processing weights, rather than a categorical shift between strategies: while both age groups are processed holistically, own-age faces elicit stronger holistic reliance compared to other-age faces, whereas other-age faces involve relatively greater part-based contributions.

The first finding of this study was that when faces were upright, participants were more accurate at recognizing adult faces compared to child faces, suggesting the presence of an OAB. However, when faces were inverted, there was no significant difference in the accuracy between adult and child faces, indicating the disappearance of the OAB. These results are consistent with previous studies (Anastasi & Rhodes, 2005, 2006; Kuefner et al., 2008; Lamont et al., 2005; Macchi Cassia et al., 2014; Rhodes & Anastasi, 2012) that have also shown an own-age bias. For instance, Kuefner et al. (2008) demonstrated an OAB in adult participants recognizing adult faces better than newborn and child faces when the faces were upright, but this bias disappeared when the faces were inverted. The presence of an own-age bias in upright faces cannot be attributed to differences in the stimulus material, as the physical properties of the face stimuli were the same in both upright and inverted conditions. The OAB for upright faces likely arises from individuals' greater experience with faces of their own age, as people are exposed to upright faces more frequently in their daily lives and have more experience with faces of their own age than faces of other ages.

Another crucial aspect of this study involved directly investigating whether there are differences in the information individuals rely on to recognize faces of their own age and faces of different ages based on their error response patterns. The findings revealed that for upright faces, participants exhibited a significant tendency to misidentify holistically similar distractors (peripherally congruent/centrally incongruent faces) as target faces when recognizing own-age faces - a pattern that was markedly stronger compared to other-age face recognition. Conversely, part-based errors (centrally congruent/peripherally incongruent faces) were less frequent for own-age than other-age faces. Importantly, both age groups still showed more holistic than part-based errors overall, indicating that while holistic processing remains dominant for all faces, the strength of this reliance is modulated by face age. Interestingly, when faces were inverted, this biased recognition pattern dissipated, suggesting that the distinct face processing styles observed when identifying faces of one's own versus other ages are a product of experience. As individuals are typically exposed to upright faces of their own age, the processing advantage derived from experience diminishes when faced with inverted faces. The results of this study lend support to the hypothesis that age-related effects are underpinned by a preference for holistic processing when recognizing own-age faces. The notion of experience-based holistic processing serves as a foundational theory akin to the own-race bias and has garnered substantial empirical support (Hancock & Rhodes, 2008; Rossion & Michel, 2011; Sulikowski et al., 2023; Wang et al., 2019; Yates & Lewkowicz, 2023). Our 2019 study scrutinized this theory by utilizing faces from different categories to assess differences in Chinese participants' holistic processing of faces within their own racial group (Chinese faces), other racial groups (Caucasian faces), and non-human faces (monkey faces) using the composite face effect(Wang et al., 2019). The results indicated a gradual decline in holistic processing levels corresponding to decreasing experience. In a study conducted by Yates et al. (2023), it was observed that children aged 4 to 6 exhibited heightened composite face effects when presented with more familiar adult faces. This observation suggests a positive correlation between children's exposure to adult faces and an increase in holistic processing levels. On the other hand, a study by Sulikowski et al. (2023) employing the inverted face paradigm revealed a pronounced face inversion effect when human adults encountered primate faces compared to the faces of other animals. Furthermore, under the composite face paradigm, human adults exhibited a stronger composite face effect for human faces and a weaker effect for primate faces. These findings imply that individuals are inclined towards holistic processing for faces they are more familiar with. The collective findings underscore the applicability of the experience-based holistic processing hypothesis to various face biases. They emphasize that experience modulates face processing styles, transcending specific face characteristics such as race, species, or age. This underscores the non-specific nature of experience in shaping face-processing mechanisms.

The study revealed that participants' recognition of faces of different ages primarily differed quantitatively rather than qualitatively. Identifying own-age and other-age faces both showed robust inversion effects, with a greater inversion effect observed for own-age faces compared to other-age faces. These results align closely with prior studies involving child participants (child vs. adult faces; Susilo et al., 2009), adult participants (young adult vs. older adult faces; Wiese et al., 2013), and adult participants (child vs. adult faces; Kuefner et al., 2008). Furthermore, when faces were upright, participants showed more holistic than part-based errors in recognizing their own- and other-age faces. This implies that individuals rely more on holistic information to identify adult and child faces, albeit with a stronger reliance on own-age faces. These findings are consistent with previous work using inversion paradigms to probe age-specific holistic processing. Kuefner et al. (2008) found that adults showed face inversion effects for adult and child faces but not for newborn faces, and a larger inversion effect for adult faces than for child faces, and that the inversion effect was larger for adult than for child faces, indicating that adult participants can holistically process adult and child faces but not newborn faces. Adults with little experience of child faces showed a larger inversion effect for adult than for child faces, whereas kindergarten teachers with extensive child-face experience showed similar inversion effects for both age groups, underscoring the role of experience in modulating holistic face processing. Such experience-driven effects on facial holistic processing were also observed in racial bias studies, where faces from one’s own race elicit stronger holistic processing than faces from other races(Rossion & Michel, 2011). Taken together, these converging findings suggest that individuals rely on a largely unified face-processing system for their own- and other-age faces, with performance differences arising from experience-induced tuning of that system to the faces most frequently encountered in daily life. This tuning begins early in infancy, as shown by 3-month-olds’ ability to recognize faces from multiple races and the subsequent perceptual narrowing toward own-race faces by 9 months (Kelly et al., 2007, 2011), and appears to persist into adulthood (Kuefner et al., 2008; Norell et al., 2015) and older age (He et al., 2011; Strickland-Hughes et al., 2020).

Our findings can be interpreted at two complementary levels. At a face-specific level, the greater proportion of peripheral-based errors for own-age faces, and the disappearance of this pattern under inversion, suggest that adult observers engage a wider perceptual field and stronger holistic integration for own-age faces than for other-age faces. At a more general level, the same pattern can be described as a difference in the breadth of the attentional/perceptual window: observers allocate a broader attentional focus to own-age faces, thereby relying more on information outside the foveated region. We thus view the VVPP as capturing both the spatial extent of attention and the integration of face information within that window, and we acknowledge that our behavioral data alone cannot fully dissociate these components. Future work combining the VVPP with independent manipulations of attention (e.g., spatial precues, dual-task interference) or applying analogous tasks to non-face stimuli will be important to test the relative contribution of domain-general attentional control versus face-specific holistic mechanisms.

Experience plays a vital role in altering and refining the processing of facial information. The study indicates that increased exposure to faces of one's own age enhances the holistic information processing of those faces, but at the cost of weaker information processing about the parts of these faces. Furthermore, the orientation of faces and error types interact in a noteworthy manner. There is a heightened reliance on holistic information for upright faces and a more pronounced emphasis on part-based information for inverted faces. This is inconsistent with some recent findings, which suggested that expertise in facial processing boosts both holistic (configural) and featural processing of faces. Wang et al. (2015) proposed that the upper face region is an area of expertise in face recognition. This implies that individuals achieving expertise in processing a specific facial region experience heightened perceptual sensitivity within that area, leading to an increased capacity for processing configural and featural information. Hayward et al. (2013) also used the scrambled/blurred Task and found that individuals tend to process featural and configural information more effectively for faces of their own race compared to other races, indicating enhanced sensitivity to two types of information. In contrast to prior studies, the current study reveals that as individuals rely more on holistic information for recognizing faces of their own age and upright faces, their reliance on part-based information diminishes relative to faces of different ages and inverted faces. This discrepancy may be due to both types of information competing for attention and resources within the same task in our study. In previous studies, holistic and part-based information were separated, requiring participants to identify faces based on either feature changes or holistic changes. The simultaneous involvement of both types of information in our study may have led to competition and a need for increased attentional resources. Guo Dan et al. (2017) found an OAB in the "complete attention" condition when participants were asked to pay full attention to face recognition without any interference. However, the OAB disappeared in the "distributed attention" condition, suggesting that attentional resources affect age bias in some way. Taken together, these findings suggest that expertise enhances individuals' ability to process both holistic and part-based information in a specific type of face. In summary, these findings suggest that expertise enhances individuals' ability to discern both holistic and part-based information in expertise faces. However, in the process of actual face recognition, both holistic and part-based information are concurrently present; the perceptual system adjusts its reliance on particular information, exhibiting a shift towards greater dependence on holistic information and reduced reliance on parts.

Finally, previous studies on OAB have primarily focused on examining differences in holistic processing of age-specific faces without directly investigating whether there are differences in the information people rely on when recognizing faces of different ages. Therefore, this study's main contribution lies in utilizing a novel experimental paradigm to analyze participants' error responses, offering a more direct insight into how own-age and other-age faces are processed. One limitation, however, is the use of only a single age group of participants (adults), due to the task's difficulty, which raises questions about generalizability. Future research should adjust task difficulty to include children and older adults in order to examine whether similar error-based processing patterns emerge across the lifespan.

The location of the fixation cross could also be important. For example, research on the own-race bias has shown that different visual processing strategies are effective for recognizing White and Black faces: White participants tend to fixate on the eye region, whereas Black participants tend to fixate on the nose region and directing White participants' first fixation toward the nose improves recognition of Black faces (Hills et al., 2013; Hills & Pake, 2013). Additionally, this study assessed face processing only when focusing on the eyes, but results may differ when attention is directed to other parts, such as the nose or mouth. For instance, Hills et al. (2011) used an old/new recognition task, observing participants' recognition of upright and inverted faces under no-cue/cue-eye/cue-mouth conditions. They discovered that for inverted faces, cueing the eyes led to significantly higher recognition accuracy than no cueing or cueing the mouth, suggesting a reduced inversion effect when focused on the eyes compared to the mouth. These findings together indicate that changes in fixation location can induce qualitative or quantitative changes in face processing, and future studies could therefore examine age-specific face processing while observers are cued to fixate the eyes, nose, or mouth. Future studies could also manipulate the response format—for example, presenting each test face one at a time instead of in a four-alternative array—to minimize mutual exclusivity between holistic and part-match responses and to test whether the present error-type pattern generalizes across different decision structures.

A further methodological limitation is that we did not record eye movements, but instead guided fixation via a central cross and brief stimulus presentations. This instruction-based approach lacks the real-time precision of gaze-contingent paradigms, and our conclusions should be interpreted in light of this constraint. At the same time, the present procedure was designed to make large eye movements unlikely (400-ms target exposure, randomized mapping of the central face region to the left or right eye), and converging evidence suggests that it effectively captures the intended processing differences. In particular, our previous behavioral adaptations of the perceptual field/VVPP paradigm, which used very similar timing parameters (500ms fixation display followed by 500ms stimulus presentation - longer durations than used here, Wang et al., 2023b), showed that holistic processing (indexed by peripheral-congruent selections) increased with face familiarity and was strongly reduced by inversion (Wang et al., 2023a; Wang et al., 2023b)—patterns that closely mirror those observed in gaze-contingent implementations (Van Belle et al., 2015). We therefore view our fixation control as strongly supported, although not definitively demonstrated, and future work combining the present task with eye tracking will be important to verify fixation compliance more directly and to rule out possible microsaccadic shifts during prolonged fixation.

5. Conclusion

In summary, the present study conducted two experiments and revealed differences in adult participants' recognition performance and recognition mode for faces of different ages, which were influenced by face orientation. When the faces were upright, an age bias was observed where participants relied more on holistic information when recognizing faces of their own age than those of other ages, and relied more on part-based information when recognizing faces of other ages compared to their own age. In contrast, when the faces were inverted, this recognition modality bias disappeared along with the age bias. The current study demonstrates that age bias stems from a fine adjustment in face processing, involving both holistic and part-based information.

Acknowledgments

Not applicable.

Authors' contributions

YS, GZ, JS, YP, LY, HJ, and ZW conceptualized and designed the study and wrote the manuscript. GZ, JS, YP, and ZW collected the data, performed the statistics, and wrote the first draft. All authors read and approved the final manuscript.

Funding

This research was supported by the Major Humanities and Social Sciences Research Projects in Zhejiang higher education institutions(2024QN133) and the Zhejiang Provincial Natural Science Foundation of China (LY20C090010, LY19C090006).

Availability of data and materials:

The data and materials for all experiments are available at https://www.scidb.cn/s/IvYZjm.
None of the experiments was preregistered.

Declarations

Ethics approval and consent to participate

All participants consented to taking part in the study. The experiment was approved by the Ethics Committee of Zhejiang Sci-Tech University (Ethics No. 201709P01).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Grammarly and Deepseek to improve language and readability. After using these tools, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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