**Peer review**

Wodarz, Maria. 2025. “Changes in Color Usage in Children’s Drawings between Ages 2 and 8: A Statistical Analysis.” *Journal of High School Science* 9 (2): 165–83.

I have several concerns that need to be addressed. Also See attached excel file.
1.The problem with the Simpson’s diversity index is the content of the drawing. If one child draws a desert with a lone tree, then the brown/yellow to green ratio is large. However, if another child draws a brown bear in a forest, then the corresponding ratio will be small. This may not have anything to do with cognition or age; rather; it may just be due to the content of the drawing. Explain how you considered this artifact in your data analysis. The color distance is also deficient in this respect. Although, see point 3
2.Cryon sets come in different numbers. How do you know that each child for each year had access to a set containing the maximum (or the same) number of cryons? For example, if a child was presented with a cryon set containing 6 colors, then that is all the colors they would have to use in their drawing. Similarly, if a child was given a cryon set containing 36 different colored cryons, they would have a larger number of colors to choose from. This is a limitation of your study. Please present this under a “limitations” section. Although, see attached spreadsheet where the Percent relative standard deviation (RSD) of children 1 through 4 are calculated by year. Then the SD of these RSD’s is calculated. The greatest value is 8.9 for year 2. This means that the drawings of children 1 through 4 in year 2 were consistent (max inter-child SD=8.9) with regard to the number of colors used. You need to present this calculation in your manuscript as evidence that there was consistency betweeen the drawings of different children for any particular year upto a maximum of 8.9 standard deviation. Also shows that between-child consistency for # of colors generally increases (SD becomes lesser) from year 2 through year 8
3.You state “…..We conclude that surprisingly, the number of colors first increases and the decreases as a child becomes older.” This may be related to the content of the drawing. If the content inherently needs less colors (forest-green-brown) versus more colors for (garden in springtime-more colors for flowers etc.).
4.You state “…..We conclude that the Simpson’s diversity index of colors first increases with age, and then remains constant as a child becomes older…..” This conclusion is again subject to the content caveat.
5.“…According to my data…..” Please write the manuscript in third person, past perfect tense.
6.You need to write a “conclusion” section.
7.You need to write a “perspectives” section. The last paragraph of the current iteration can be included in this section. Also, importantly, please recommend whether these indices that you have measured can be used as surrogates for the diagnosis of ocular diseases that the child may be susceptible to. For example, does a negative deviation from the number of colors in the early years indicate that the child may develop color blindness? Does a deviation from LAB or the Simpson’s diversity index indicate that the child may be susceptible to specific ocular diseases such as Rod-Cone dystrophy, Leber optic neuropathy, Retinal Pigment Epithelial cell dysfunction, Glaucoma, Macular degeneration…….A discussion on this will be extremely useful since if we can detect (the probability of) these diseases well before they occur, lifestyle changes and/or pharmacotherapy can be started well in advance. These ‘photomarkers’ may hence be extremely useful. Please include a discussion on this topic along with pertinent references.
8.The figures need to be of higher resolution.
9.Please describe what software was used for statistical analysis.

10.All referenes need a live link. They need to be consistent. When there are more than 6 authors, the first 6 authors need to be listed along with an et al. Do not use the software numbering to number the references. Instead, number manually.

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**Changes in color usage in children's drawings between ages 2 and 8: a statistical analysis**
**Reply to the reviewer's comments**

I would like to thank the reviewer for reading the paper and providing comments for me. I have worked on the paper more to include all the suggestions. It is great to receive this input.
Below I copied all the comments of the reviewer, together with my answers. The reviewer's comments are marked in blue.
1. The problem with the Simpson's diversity index is the content of the drawing. If one child draws a desert with a lone tree, then the brown/yellow to green ratio is large. However, if another child draws a brown bear in a forest, then the corresponding ratio will be small. This may not have anything to do with cognition or age; rather; it may just be due to the content of the drawing. Explain how you considered this artifact in your data analysis. The color distance is also deficient in this respect. Although, see point 3.
I thank the reviewer for this comment, which points out that there might be other factors than cognition or age, that influence the variety of color contents in a child's drawing. I agree that other factors, such as the drawing's subject, may determine the number and diversity of colors used. In the revised paper, following the reviewer's advice, I have added a new section "Study limitations", where I included a discussion of the different factors affecting contents of a drawing, pointing out that one way to neutralize them is to include more subjects. Please also see my reply to the next point for more details on this section.
*"More generally, a limitation of the analysis presented here is that the number and diversity of colors used by a given child in a given drawing do not just depend on the child's cognitive stage, but also on other factors. One such factor is the subject matter of the drawing. For example, if a child draws a desert, they may choose to use few colors and shades closer together compared to a drawing of a colorful spring flower bed. Another factor is the availability of colors at the moment of the drawing. Whether a child is presented with only 3 crayons or with 36 crayons will make a difference in the color contents of the drawing.*

*In the present study, an inter-child variation analysis showed that between-child consistency was relatively high. In order to improve such consistency further and eliminate the content-dependence and availability-dependence of the results, a larger-scale analysis has to be performed, where the influence of factors such as drawing-contents and color availability will average out."*

2. Cryon sets come in different numbers. How do you know that each child for each year had access to a set containing the maximum (or the same) number of cryons? For example, if a child was presented with a cryon set containing 6 colors, then that is all the colors they would have to use in their drawing. Similarly, if a child was given a cryon set containing 36 different colored cryons, they would have a larger number of colors to choose from. This is a limitation of your study. Please present this under a "limitations" section. Although, see attached spreadsheet where the Percent relative standard deviation (RSD) of children 1 through 4 are calculated by year. Then the SD of these RSD's is calculated. The greatest value is 8.9 for year 2. This means that the drawings of children 1 through 4 in year 2 were consistent (max inter-child SD=8.9) with regard to the number of colors used. You need to present this calculation in your manuscript as evidence that there was consistency betweeen the drawings of different children for any particular year upto a maximum of 8.9 standard deviation. Also shows that

between-child consistency for # of colors generally increases (SD becomes lesser) from year 2 through year 8.

Thank you so much for providing a mathematical way to evaluate inter-child consistency. I have now included this calculation in the paper, please see the new section, "Between-child consistency" and the new Table 2 that shows the calculations. The new text is as follows:

*"The color number data of Table 1 were also used to perform an analysis of between-child consistency, see Table 2. For each child, i, in each age group, a, the average ($\mu_i^a$) and the standard deviation ($\sigma_i^a$) of the number of colors were calculated, and then the percent relative standard deviation was determined as*

$$RSD_i^a = 100\% \times \frac{\sigma_i^a}{\mu_i^a}.$$

*Then, the inter-child standard deviation of their RSD's was determined, see the last line of Table 2. This quantity is the highest (8.9%) for the youngest age, and it becomes lower in older age-groups. All in all, these results show a high level of between-child consistency in the number of colors used. "*

I also made a new section describing the limitations of this study, when I talk about children possibly not always having access to the same number of colors. The new text is as follows:

**"*Study limitations*.**

*While the three metrics used here (the number of colors, Simpson's diversity index, and perceptual color distance) provide useful information about the color content of children's drawings, each of these metrics has limitations. The number of colors is the simplest metric, but it lacks information of color distribution. Simpson's diversity index uses colors' frequencies of use, but it does not contain information on color differences: for example, it cannot distinguish between color contents of a drawing that contains 3 shades of pink at frequencies 10%, 20%, and 70%, and a drawing that uses 10% pink, 20% green, and 70% blue. Finally, the average perceptual color distance, while focusing on color differences, does not use color numbers or frequencies of usage.*

*More generally, a limitation of the analysis presented here is that the number and diversity of colors used by a given child in a given drawing do not just depend on the child's cognitive stage, but also on other factors. One such factor is the subject matter of the drawing. For example, if a child draws a desert, they may choose to use few colors and shades closer together compared to a drawing of a colorful spring flower bed. Another factor is the availability of colors at the moment of the drawing. Whether a child is presented with only 3 crayons or with 36 crayons will make a difference in the color contents of the drawing.*

*In the present study, an inter-child variation analysis showed that between-child consistency was relatively high. In order to improve such consistency further and eliminate the content-dependence and availability-dependence of the results, a larger-scale analysis has to be performed, where the influence of factors such as drawing-contents and color availability will average out."*

Please also see my replies below, where I refer to this section.

3. You state "…..We conclude that surprisingly, the number of colors first increases and the decreases as a child becomes older." This may be related to the content of the drawing. If the content inherently needs less colors (forest-green-brown) versus more colors for (garden in springtime-more colors for flowers etc.).

I agree that the number of colors used by each child in their drawings is driven not only by their developmental stage, but also by the content of the drawing (as well as the number of crayons given to them, as noted above). I have included a discussion of this issue among the limitations of the study, please see above.

4. You state "…..We conclude that the Simpson's diversity index of colors first increases with age, and then remains constant as a child becomes older….." This conclusion is again subject to the content caveat.
I agree, and this is part of the new discussion of the study's limitations, which I added, please see above.
5. "…According to my data….." Please write the manuscript in third person, past perfect tense.
Thank you for this remark, I have corrected the paper according to this style requirement.
6. You need to write a "conclusion" section.
A conclusion section is now written:
*"This study analyzed the variation in color usage in children's drawings between the ages of 2 and 8 through statistical evaluation of extracted color data. Three distinct measures of color diversity were employed: the total number of colors used, Simpson's diversity index, and the average perceptual distance between colors in the Lab color space. The findings indicate a shift in color usage patterns between early childhood (ages 2–4) and later childhood (ages 4–8). During the earlier developmental phase, all three measures exhibited a statistically significant increase, suggesting greater exploratory behavior in color selection. However, in the later phase, while color diversity remained stable, both the total number of colors and the perceptual color distance decreased, indicating a transition from uninhibited experimentation toward a more structured and realistic artistic representation. These trends align with established neurodevelopmental patterns, including changes in brain mass relative to body size, which exhibit a similar trajectory during early childhood."*

7. You need to write a "perspectives" section. The last paragraph of the current iteration can be included in this section. Also, importantly, please recommend whether these indices that you have measured can be used as surrogates for the diagnosis of ocular diseases that the child may be susceptible to. For example, does a negative deviation from the number of colors in the early years indicate that the child may develop color blindness? Does a deviation from LAB or the Simpson's diversity index indicate that the child may be susceptible to specific ocular diseases such as Rod-Cone dystrophy, Leber optic neuropathy, Retinal Pigment Epithelial cell dysfunction, Glaucoma, Macular degeneration…….A discussion on this will be extremely useful since if we can detect (the probability of) these diseases well before they occur, lifestyle changes and/or pharmacotherapy can be started well in advance. These 'photomarkers' may hence be extremely useful. Please include a discussion on this topic along with pertinent references.
I would like to thank the reviewers for this excellent suggestion. I have included a discussion of these extensions in a new Perspectives section, together with some references to relevant publications. The new text is as follows:
"*Another extension of this work lies in evaluating whether the color-based indices measured here, namely, the number of colors used, Simpson's diversity index, and perceptual color distance, could serve as early indicators or "photomarkers" of visual system abnormalities or neurodevelopmental disorders. For instance, significant deviations from typical trajectories in color usage, such as unusually low color diversity or small perceptual distances between colors, may reflect atypical development of the visual system, including cone cell function or cortical color processing. This raises the possibility that children at risk for color vision deficiency (e.g., congenital red-green defects) might exhibit restricted color palettes in their drawings well before standard Ishihara testing would detect them (21), or that early rod–cone dystrophies could manifest as altered perceptual color distances due to selective cone loss (22). Likewise, subtle changes in color discrimination have been documented in presymptomatic Leber hereditary optic neuropathy and dominant optic atrophy (23).*
*Given the strong link between artistic output and neurovisual development (1,2,20), further research could investigate whether deviations in these color usage metrics correlate with clinical or subclinical markers of ocular diseases (24). If validated, such tools could become valuable, non-invasive*

*screening methods to flag potential vulnerabilities early, enabling timely lifestyle interventions or medical follow-up. Future longitudinal studies linking color metrics in children's drawings with visual and neurological assessments may help establish a predictive framework for identifying such conditions*."

8. The figures need to be of higher resolution.

Thank you very much for pointing out the resolution issue. I have made improvements in the quality of the figures.

9. Please describe what software was used for statistical analysis.

To assess trends in various measures of color usage, linear regression analysis was conducted using the online statistical tool GraphPad by Dotmatics (Ref. 13) as well as Google sheets. This is explained at the end of Materials and Methods section, subsection "Linear regression and statistical significance".

10. All references need a live link. They need to be consistent. When there are more than 6 authors, the first 6 authors need to be listed along with an et al. Do not use the software numbering to number the references. Instead, number manually.

I have made the necessary changes in the references. Thank you.

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Thank you for addressing my comments. I am happy with all your responses. However, I have some minor outstanding issues:

1.Please present content in relevant sections of the manuscript. For example, the Tables and calculations should go in the "results" section. Please check for other mis-categorized content.

2.Please remove "….. The hypothesis was proved partially correct….." A hypothesis is either null or alternate (given a p-value); in the scientific context; it cannot be partially true or partially false.. If you cannot quantitate the hypothesis, I suggest you remove all references to the word and context of "hypothesis".

3.Please include an RSD row in Table 1.

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**Changes in color usage in children's drawings between ages 2 and 8: a statistical analysis**
**Reply to the reviewer's comments**

I would like to thank the reviewer for re-reading the paper and providing additional useful comments. In the revision, I followed all the advice and made the modifications to the text.

Again, in the reply below, the reviewer's comments are marked in blue.

Thank you for addressing my comments. I am happy with all your responses. However, I have some minor outstanding issues.

Thank you!

1. Please present content in relevant sections of the manuscript. For example, the Tables and calculations should go in the "results" section. Please check for other mis-categorized content.

Thank you, I agree that these tables should be among the results. I have moved them, and I also moved the "Between-child consistency" analysis in the Results section.

2. Please remove "….. The hypothesis was proved partially correct….." A hypothesis is either null or alternate (given a p-value); in the scientific context; it cannot be partially true or partially false.. If you cannot quantitate the hypothesis, I suggest you remove all references to the word and context of "hypothesis".

I removed all the mentions of the word "hypotheses", because this word was not used scientifically. There were several places where I used it before, including the abstract, the Introduction, and the Discussion. For example, in the abstract, the new text reads:

"*Although it was initially expected that color variety would increase steadily with age, the data reveal a two-phase trajectory*."

The new text in the introduction is this:

"*Naively, one expects that as children grow older, the number of colors they use in their artwork will increase, accompanied by greater complexity in color selection and diversity. This expectation is based on two key considerations*."
In the discussion the new text is as follows:
"*The initial premise of this research was only partially supported by the findings. It was proposed that as a child's brain develops in size and complexity, this progression would be reflected in an increase in both the number and complexity of colors used in their drawings. To evaluate this idea, the study examined changes in three key measures:…*"
3. Please include an RSD row in Table 1.
I have included this. Thank you again for serving as a reviewer.

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Accepted. Thank you for addressing my comments.