Comparing the TGD view of color perception to the geometric models of color perception

June 20, 2026

Matti Pitkänen

orcid:0000-0002-8051-4364.
email: matpitka6@gmail.com,
url: http://tgdtheory.com/public_html/,
address: Valtatie 8, as. 2, 03600, Karkkila, Finland.

Contents

Abstract

Gary Ehlenberger sent an interesting link related to the theories of color perception. The notion of color space tries to geometrize hue, lightness and saturation as attributes of color perception. Already Riemann suggested that the Riemannian geometry alone could explain the perceived color differences in terms of a distance in this color space. Schrödinger proposed later a geometric theory of color perception but it has its own problems. Bujac et al have proposed a non-Riemannian geometric model for color perception claiming to solve the problems of the Riemannian models. TGD suggests a quantum theory of color perception involving in an essential way the new physics predicted by TGD.

In this article the TGD view is summarized and compared with the geometric theories of color. The surprising outcome is that the condition that there are 3 colors and their conjugate colors fixes the choice of the internal space $S \subset H = M^4 \times S$ to $S = CP_2$ so that TGD is completely fixed! It is also found that polarization sense can be understood in terms of perceptions related to electroweak quantum numbers identifiable in TGD as color quantum numbers in CP_2 spin degrees of freedom. Also the connection with the findings of Barbara Shipman suggesting a connection between quark symmetries and honeybee dance are discussed.

1 Introduction

Gary Ehlenberger sent an interesting link related to the theories of color perception (see this). It has been known for a long time that colors are not properties of the light or of any stimulus producing color sensation. The notion of color space tries to geometrize hue, lightness and saturation as attributes of color perception. Already Riemann suggested that the Riemannian geometry alone could explain the perceived color differences in terms of a distance in this color space. Schrödinger proposed later a geometric theory of color perception but it has its own problems.

Bujac et al [J2, J1] have proposed a non-Riemannian geometric model for color perception claiming to solve the problems of the Riemannian models. TGD suggests a quantum theory of color perception [L2] involving in an essential way the new physics predicted by TGD.

The theories based on Riemann geometry of color space have however problems.

1. Bezold- Brücke effect (see this) is a phenomenon in which a changing light intensity can make a color appear to shift in hue. Neuroscientists would say the geometric model is simply unrealistic. This effect could be due to varying responses of light-receptors to the increasing light intensity. For instance, decreasing the intensity, the contribution of rods which is white or black increases and the hue changes.

2. The sum of small color differences along a geodesic line connecting two different colors is larger than the perceived color difference: this is known as the problem of diminishing returns and is not consistent with Riemnannian geometry. The principle of diminished returns (Weber-Fechner law) is actually a general principle of sensory perception.

3. There is also a problem with the identification of neutral direction along which the color dominated by white becomes dominated by black. A non-Riemannian variant of color space has been proposed. The link indeed describes a new theory [J1] claiming to solve a basic problem of Schrödinger's geometric theory of color perception. This theory would not rely on Riemannian geometry and claims to solve the also the problem of diminished returns [J2] (see this). The assignment of Weber-Fechner law to the geometry of color space looks to me an implausible idea. However, it would seem to me that the notion of color space is too naive.

In this article the TGD view is summarized and compared with the geometric theories of color. The surprising outcome is that the condition that there are 3 colors and their conjugate colors fixes the choice of the internal space $S \subset H = M^4 \times S$ to $S = CP_2$ so that TGD is completely fixed! It is also found that polarization sense can be understood in terms of perceptions related to electroweak quantum numbers identifiable in TGD as color quantum numbers in CP_2 spin degrees of freedom. Also the connection with the findings of Barbara Shipman suggesting a connection between quark symmetries and honeybee dance are discussed.

2 TGD view of color perception

In the TGD framework, the notion of color space is given up and instead a model of color perception as quantum measurement is developed. This model relies in an essential way to the new physics predicted by TGD but also involves geometrical considerations.

2.1 Color perception as measurement of color quantum numbers

Consider first the general observations motivating the proposal.

1. In TGD inspired theory of consciousness [L7, L8], sensory perceptions can be identified either as the quantum numbers of outcomes of a quantum measurement or their differences for the states in the quantum jumps: for vision both options give 3+3 fundamental colors. It turned out that in zero energy ontology (ZEO) of TGD only the first option is correct: conscious self corresponds to a sequence of "small" state function reductions and sensory qualia correspond to the quantum numbers measured in SSFR and moment of consciousness has duration measured by the geometric time between two subsequent SSFRs.

2. The first option allows two variants. Fundamental colors could correspond to

   (a) the color quantum numbers for quark triplet and their complementary colors to anti-quark triplet.

   (b) or to 3+3 pairs of gluons forming a color octet: the 2 states with vanishing color quantum numbers do not have color.

At this moment I cannot distinguish between these options. The number of fundamental colors is however 3+3 only for the symmetries of CP_2.

(a) The sum of the numbers $n(F)) + n(\overline{F})(= 3 + 3)$ of charged states in the fundamental representation F and its conjugate $\overline{F}$ and their number $n(Ad)(= 3 + 3)$ in the adjoint representation are equal for $SU(3)$. For $SO(5)$ equivalent to Sp_2 or B_2, the number $n(Ad)$ of charge states in 10-dimensional adjoint representation is $n(Ad) = 10 - 2 = 4 + 4 = 2n(F)$. This condition does not hold true for any other simple Lie group.

(b) For $SO(5)$ the problem is that F is self-conjugate. Two interpretations are possible: either there are no conjugate colors or that F decomposes to two 2-D representations with 2 complementary colors to give 2+2 colors. Therefore CP_2 is completely unique and it seems that for CP_2 there is an additional symmetry analogous to supersymmetry. Intriguingly, the existence of 3 colors would fix TGD completely!

(c) For $SO(5)$, F corresponds to spinor representation and color would correspond to spin quantum numbers for 4-sphere S^4. For $SU(3)$, F and $\overline{F}$ are realized as color triplet partial waves in CP_2.

The assignment of perceived colors to the quantum numbers characterizing quarks or gluons looks of course complete nonsense in the standard physics framework. The irony is that the properties of QCD color fit nicely with the properties of visual colors and it is this observation which must have motivated the terminology as a kind of joke.

(a) Also black and white would be complementary colors and color black is a sensation produced by dark current, which gives rise to a genuine stimulus in the brain. In its absence there is no sensation of darkness. This would suggest that the notions of lightness and saturation could be reduced to the contribution of black and white colors in the total visual input. The contribution of cones (color sensitive in ordinary sense) and rods involved with night vision would be in the same role. Lightness would be determined by the relative contributions of white and black colors and saturation by the ratio of ordinary colors as compared to that of black and white.

(b) The sums of two color quantum numbers vanish for both triplet and antitriplet: this explains why the third fundamental color can be produced by superposing the other 2 colors.

(c) For the physical states total color quantum numbers vanish by color confinement [L5, L4, L6]. A region of a given color is surrounded by a narrow frame with a complementary color. Could this be related to color confinement?

(d) This model requires that one can speak of color at least in cellular scales. TGD indeed allows colored states in arbitrarily long length scales. The predicted hierarchy of Planck constants makes color symmetries, in particular scaled variants of color symmetries possible in arbitrarily long scales and in living matter the length scale range 10 nm-2.5 μm contains the p-adic length scales for 4 Gaussian Mersenne primes. This number theoretical miracle makes also scaled down possible copies of hadron physics possible in these scales [L6] [K1, K2].

What could be the interpretation of the electroweak quantum numbers, identifiable as spin quantum numbers in the holonomy degrees of freedom for CP_2 and also as color quantum numbers? Could also they define sensory observables?

(a) $H = M^4 \times CP_2$ spinors are tensor products of M^4 and CP_2 spinors [L3, L5, L4]. Quarks and leptons are distinguished by the value ± 1 of the H-chirality as a product of the CP_2 and M^4 chiralities so that these two chiralities are correlated. This implies separate conservation of quark and lepton numbers and that H-spinors are massless in the 8-D sense.

In principle there are 3 observables: quark and lepton numbers, electromagnetic charge, and the M^4 chirality (correlating with CP_2 chirality). Quark and lepton numbers and electromagnetic charge obey super selection rules, being fixed for a given particle so that they cannot define sensory observables.

(b) Only the M^4 chirality can vary. Could electromagnetic circular polarization be its counterpart? Humans can't perceive the polarization of light directly like some insects or marine animals. It is however possible for humans to perceive it using a phenomenon called Haidinger's brush (see this). A subtle, bowtie-shaped visual illusion (yellow and blue) that appears in the center of the visual field when one is looking at a polarized light source, such as a bright blue sky or a white computer screen.

2.2 Findings of Barbara Shipman as support for the TGD view of color perception

In the standard physics framework, the presence of QCD color in the physics of color perception is impossible since the length scale for hadron physics is hadron scale. Topologist Barbara Shipman [A1] has found direct evidence for the appearance of the mathematics of color symmetries of strong interactions in a mathematical model for the dance of honeybee.

(a) The mathematics used by Barbara Shipman [A1] involves so-called momentum maps associated with the symplectic action of a group G, now $SU(3)$ in a space X with a symplectic structure. $SU(3)$ itself, $SU(3)/U(1)\times U(1)$ and CP_2 are examples of the space X. Symplectic action means that the elements of the Lie algebra g of G correspond to Hamiltonians as functions in X. The Lie algebra commutator in g is represented as a Poisson bracket.

The points of Lie algebra g of G can be mapped by exponential map to the points of X and the duality between g and g^* a map of the points of X to the adjoint g^* of g. What this means physically is that n commuting coordinates and the n values of their conjugate coordinates representing conserved charges as Hamiltonians determine the orbit of a point in X.

The space $F = SU(3)/U(1)\times U(1)$ is a 6-D space, which can be identified as the twistor space of CP_2 that is a a bundle having CP_2 as a base and 2-sphere as a fiber. F has also an interpretation as the space for the choices of color quantization axes. F plays a key role in the construction of quantum TGD [L2] and the existence of the twistor space with Kähler structure makes M^4 and CP_2 unique [A2] so that TGD is unique.

A comparison with M^4 helps here. For the rotation group $SO(3)$ acting in $CP_1 = S^2$, the space of quantization axis of angular momentum is $SO(3)/SO(2) = SU(2)/U(1) = CP_1 = S^2$. For Minkowski space M^4 the twistor space is a bundle having M^4 as a base and the 2-D sphere of light-like rays from a given point of M^4 as a fiber.

(b) Also the double coset space $F_1 = CP_2/U(1)\times U(1) = U(2)\backslash SU(3)/U(1)\times U(1)$ is 2-dimensional. Eguchi-Hanson coordinates are standard coordinates for CP_2 [L3]. Since the phase-like angle coordinates of CP_2 associated with $U(1)\times U(1)$ have as conjugates the coordinates r and θ of CP_2, this space does not allow a symplectic structure.

The lower-dimensional case of CP_1 helps to get some idea of the topology of F_1. $U(1)\backslash CP_1/U(1)$ can be identified as a half geodesic from the North Pole to the South pole and is not a symplectic space. The identification as a half-geodesic is not unique since it is determined only apart from local $U(1)$ rotation of the half-geodesic. F_1 has a sphere with 3 circles S^1 as boundaries and also now the identification is unique only modulo local $U(1)\times U(1)$ rotations. The full space CP_1 of quantization axes is needed also at S^2 and also at CP_2 so that F_1 cannot be identified as a kind of reduced space for the quantization axes.

(c) The honeybee dance represents geometric information about the direction and distance of the food source so that only 2-D data are involved. Could the 2-D F_1 code for this information? Perhaps a more plausible option is that since F is a sphere bundle, the points of the fiber sphere S^2 code for the 2-D data, essentially the direction of color quantization axes. The path of the honeybee to the food source would be mapped to a path in S^2 and would represent the history of color perceptions of the honeybee along the path.

Also polarization matters and bees can perceive the polarization of the sunlight (see this) and use this information to determine the direction of the Sun, which is part of the information expressed in the dance of the honeybee.

The path to the food source ends up with detection involving pattern recognition. The color pattern of the food source must play a key role in the recognition. Does the dance also represent this information?

2.3 The role of the twistor space of CP_2 in color perception

The space F is of obvious interest concerning the understanding of color perception.

(a) From a given state characterized by color isospin and hypercharge, one can obtain all possible colored states by making $SU(3)$ color rotations. The action of the elements of the Cartan group $U(1) \times U(1)$ multiplies the state with a mere phase factor so that the physical state is not changed.

Therefore the 6-D space $F = SU(3)/U(1) \times U(1)$ describes the space of all color perceptions for a given irreducible representation of the color group when the choice of quantization axes is allowed to vary? Is the perceived color independent of the choice of the quantization axes but that the probability for a given color quantum numbers in the measurement of color quantum numbers is determined by the state as in quantum measurement theory? This kind of view is suggested by the analogy of the Relativity Principle for color symmetries. For a fixed choice of quantization axes, one has only a discrete set of colors: 3+3 for both quark and gluon states.

(b) For the tensor products of the simplest color states, color representations with a much larger repertoire of color quantum numbers are possible and the number of different hues becomes large. The number of the tensor factors contributing to the observed color, determining the possible dimensions of the irreducible color representations, should correspond to the intensity of light. This should correspond to the physiological situation and large quantum number limit behaving classically.

(c) An interesting challenge is to understand the change of the hue with the increase of the intensity (Bezold- Brücke effect, see this) and therefore with the number of the contributing tensor factors. The increase of the intensity could increase the number of the active tensor factors involved and therefore extend the color palette. The probabilities of the receptors to respond to the incoming light depend on its intensity.

(d) It is also possible to construct color multiplets in F consisting of color eigenstates. Two degrees of freedom correspond to 2 angle variables related to color quantum numbers and the remaining 4 to additional degrees of freedom which should geometrically relate to CP_2. Are these multiplets realized physically as the twistor lift of TGD suggests [L1]?

A note about the role of CP_2 coordinates is in order. Induced classical electroweak gauge fields depend on gradients of CP_2 coordinates. The CP_2 part of the trace of the second fundamental form, involving second derivatives of CP_2 coordinates, is vanishing except at the 3-D edges of the space-time surface at which minimal surface property fails: it has quantum numbers of the Higgs field. The 2 complex CP_2 coordinates appear as such in the spinor harmonics associated with CP_2.

2.4 What could happen in color perception?

What could happen in color perception identified as quantum measurement.

(a) Does the perceived color correspond to the sum of the colors quantum numbers assignable to the color sensitive receptors reducing to the quark or gluon level? How are the common color quantization axes determined?

(b) Is the choice of the quantization axes for a given individual determined somehow? In TGD, electroweak interactions are color interactions in the spin degrees of freedom for CP_2 and color isospin and hypercharge correspond to electroweak isospin and hypercharge. The directions of the latter quantization axes are fixed. This would mean that the directions of color quantization axes are always the same. If so, the perceived color would be determined by the sums of the discrete color quantum numbers for receptors.

(c) If the individual states in the tensor product have different color quantization axes, their states are not color eigenstates for the choice of quantization axes made in the tensor product. The state would decompose to a direct sum of irreducible color representations. State function reduction would occur and give rise to a state with definite color quantum numbers. One might hope that the outcome is highly unique at large color quantum number limit. One should however understand what determines the choice of the quantization axis for the entire tensor product.

(d) Is it possible to test which option is correct? After images change color could this be due to different choices of the quantization axes or is it a genuine change of the analog of sensory input determining the after image?

REFERENCES

Mathematics

[A1] Shipman B. The geometry of momentum mappings on generalized flag manifolds, connections with a dynamical system, quantum mechanics and the dance of honeybee, 1998. Available at: `https://math.cornell.edu/~oliver/Shipman.gif`.

[A2] N. Hitchin. Kählerian twistor spaces. *Proc London Math Soc*, 8(43):133–151, 1981.. Available at: `https://tinyurl.com/pb8zpqo`.

Neuroscience and Consciousness

[J1] Bujack R et al. The Geometry of Color in the Light of a Non-Riemannian Space. *Computer Graphics Forum*, 44(3).

[J2] Bujack R et al. The non-Riemannian nature of perceptual color space. *PNAS*, 116(18), 2022.Available at: `https://www.pnas.org/doi/full/10.1073/pnas.2119753119`.

Books related to TGD

[K1] Pitkänen M. New Physics Predicted by TGD: Part I. In *p-Adic Physics*. *https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: `https://tgdtheory.fi/pdfpool/TGDnewphys1.pdf`, 2023.

[K2] Pitkänen M. New Physics Predicted by TGD: Part II. In *p-Adic Physics*. *https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: `https://tgdtheory.fi/pdfpool/TGDnewphys2.pdf`, 2023.

Articles about TGD

[L1] Pitkänen M. Questions about twistor lift of TGD. Available at: `https://tgdtheory.fi/public_html/articles/twistquestions.pdf`., 2017.

[L2] Pitkänen M. Dance of the honeybee and New Physics. Available at: `https://tgdtheory.fi/public_html/articles/Shipmanagain.pdf`., 2018.

[L3] Pitkänen M. Reduction of standard model structure to CP_2 geometry and other key ideas of TGD. https://tgdtheory.fi/public_html/articles/cp2etc.pdf., 2023.

[L4] Pitkänen M. About Dirac equation in $H = M^4 \times CP_2$ assuming Kähler structure for M^4 . https://tgdtheory.fi/public_html/articles/HJdireq.pdf., 2025.

[L5] Pitkänen M. About the structure of Dirac propagator in TGD. https://tgdtheory.fi/public_html/articles/dirprop.pdf., 2025.

[L6] Pitkänen M. Comparing the S-matrix descriptions of fundamental interactions provided by standard model and TGD. https://tgdtheory.fi/public_html/articles/hadroQCDTGD.pdf., 2025.

[L7] Pitkänen M. The recent view of TGD inspired theory of consciousness and quantum biology. https://tgdtheory.fi/public_html/articles/consc2025.pdf., 2025.

[L8] Pitkänen M. Answers to the questions of Vasileios Basios and Marko Manninen in Hypothesis Refinery session of Galileo Commission. https://tgdtheory.fi/public_html/articles/MarkoBasios.pdf., 2026.