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Harmony in Design: A Synthesis of Literature from Classical Philosophy, the Sciences, Economics, and Design

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Abstract
Classical theories of harmony have been used to explain phenomena like beauty, happiness, health, virtue, pleasure, peace, and even ecological sustainability. With the intent of making these theories more accessible to designers, this article reviews the conception of harmony from about 500 BCE to the present. It begins with a brief overview of harmony in classical Chinese and Greek philosophy. Then it examines the role of harmony in the renaissance, the scientific revolution, and the early modern period across topics in aesthetics, ethics, physics, politics, and economics. Finally, turning to the 20th century, this article highlights the conceptual function of harmony in psychology, neuroscience, computer science, and design. This synthesis concludes with a review of applications and implications for contemporary designers. An essential conclusion of this article is that harmony involves the integration of diversity into a greater whole; harmony is not pure agreement or "sameness." Overall, we suggest that classical principles of harmony might serve as a theoretical framework to help designers develop a more sustainable and vibrant vision of the future.

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Introduction

As mankind hurtles into the future, we may want to steer our cultural evolution towards a more sustainable path; to do that, it is essential to know where we want to go. It is with this motivation that we aim to unpack an ancient idea: that the concept of harmony offers a guiding value for human society. Musical harmony describes "the phenomenon of combining notes in music to produce a pleasing effect greater than the sum of its parts."[1] Musical harmony is treated as one manifestation of a deeper principle of harmony, which we define as the process of integrating diverse parts into a whole, such that both the parts and the whole are mutually strengthened. Harmony is a theory of fitness—describing the fitting of parts with each other and their fitness within a whole.

This article represents several years of effort to assemble a vast range of sources across multiple disciplines and traditions. To be clear: the concept of harmony is not easily understood and is likely to present mysteries for many decades, centuries, or millennia to come. Nevertheless, we can share meaningful progress in understanding the enigma of harmony and in applying principles of harmony to design. We hope that our investigation shows that harmony is not a "wishy-washy" concept, but rather offers a rich set of clear propositions and testable hypotheses.

How might the classical theory of harmony support contemporary designers? While there are many specific instances throughout this article, three themes are apparent. First, theories of harmony have classically explained several human values like beauty and happiness—values that are concerns for many designers. Second, harmony is an intuitive concept that has enormous explanatory value—it can help designers make sense of complex systems, like the brain or an agricultural ecosystem. Third, harmony offers a multicultural philosophical grounding for the value of diversity. Indeed, the contemporary notion of "diversity and inclusion"[2] is easily conceptualized in terms of harmony—that is, the integration of diverse people into a meaningful whole. Harmony, as a framework, may bring nuance to challenging social topics due to the fact that conflict and its resolution is inherent to the process of harmonization.

In writing this article, we address designers in a broad sense: anyone seeking to transform the present into a more preferred future. Design, to the extent that it is an academic discipline, is young and practical and only rarely engages in philosophy.[3] However, philosophy is important to the extent that it shapes the values and intentions behind design; the purpose of philosophy is not to establish the truth but to support better living. With this framing, we propose that a clear and inspiring theory of harmony may help designers to envision and shape a more harmonious—and more sustainable—future. The harmonization of humankind and nature is, we argue, a concise definition of sustainable design. As will become clear in this article, there are multiple implications of harmony in design ranging from aesthetics to ethics to sustainability.

The Popular Conception of Harmony

As a popular concept, harmony has many connotations such as "concord, accord, attunement, agreement, togetherness and peaceful contentedness."[4]

1 Paul Yaozhu Chan, Minghui Dong, and Haizhou Li, "The Science of Harmony: A Psychophysical Basis for Perceptual Tensions and Resolutions in Music," *Research: A Science Partner Journal* (2019): 1, article ID 2369041, https://doi.org/10.34133/2019/2369041.

2 Patrice M. Buzzanell, "Constituting Intercultural Harmony by Design Thinking: Conflict Management in, for and about Diversity and Inclusion Work," in *Conflict Management and Intercultural Communication: The Art of Intercultural Harmony*, ed. Xiaodong Dai and Guo-Ming Chen (London: Routledge, 2017), 66–84, https://doi.org/10.4324/9781315266916-5.

3 Per Galle, "Philosophy of Design: An Editorial Introduction," *Design Studies* 23, no. 3 (2002): 211–18, https://doi.org/10.1016/S0142-694X(01)00034-5.

4 Chung-Ying Cheng, "On Harmony as Transformation: Paradigms from the I Ching," *Journal of Chinese Philosophy* 16, no. 2 (1989): 125, available at https://philpapers.org/rec/CHEOHA-4.

In our search for a popular definition, we searched for "harmony as a principle of design." Here, Google offered the following response: "Harmony can be described as sameness, the belonging of one thing with another."[5] (Figure 1)

This definition of harmony is concerning. If the pursuit of harmony is simply the pursuit of sameness, then harmony sounds boring—and, frankly, somewhat morally suspect. If harmony leads people to value conformity and sameness, this seems directly opposed to the appreciation of human differences and diversity. A "harmonious future" is completely undesirable if it is shorthand for uniformity or homogeneity; who would support an "anti-diversity" value?

Classically, however, we see a different story: harmony is specifically *not* sameness. Confucius (551–479 BCE) made this expressly clear when he said, "the *junzi* [good person] harmonizes but does not seek sameness, whereas the petty person seeks sameness but does not harmonize."[6] If Confucius needed to clarify this difference, then the misconception of harmony-as-sameness is at least thousands of years old.

In this article, we review many classical and modern sources in order to show the relevance of harmony to contemporary design. We have been pleased to discover that the history of harmony offers a humanistic, perennial, cross-cultural value system that explicitly celebrates diversity. Sameness, conformity, and totalitarianism pose real risks to societies and ecologies; just as "monoculture" farming is more susceptible to disease, cultural homogeneity is ecologically unstable. As we unify the globe through trade and communications, if we want to build a flourishing, sustainable, and resilient future, we must promote biological and cultural diversity. The promise of harmony, as a philosophical theory, is that our differences can be our strengths.

Overview of the Organization of the Article

We have been truly humbled by the challenge of synthesizing the concept of harmony across multiple fields and over thousands of years. This article cannot be a complete review of harmony through the ages, but rather aims to provide a rich and nuanced introduction that can meaningfully assist scholars and design practitioners.

5 Hatch Design, "Principles of Interior Design Part 5: Harmony and Unity," *Hatch Interior Design (Blog)*, accessed February 9, 2022, https://www.hatchdesign.ca/principles-of-interior-design-part-4-harmony-and-unity/.

6 Chenyang Li, "The Confucian Ideal of Harmony," *Philosophy East and West* 56, no. 4 (2006): 586, https://doi.org/10.1353/pew.2006.0055.

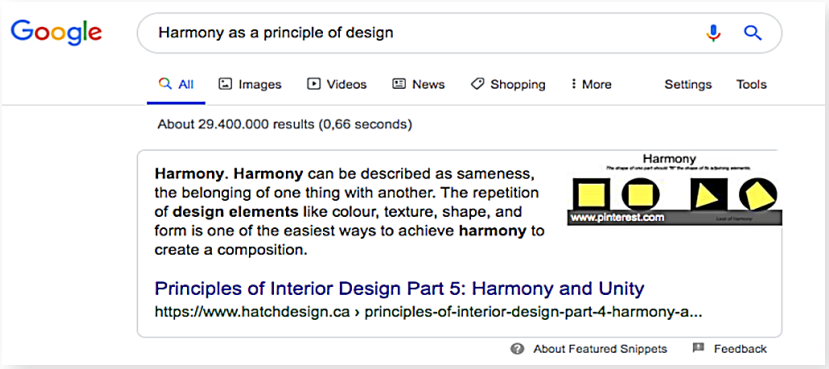

Figure 1
Googling "Harmony as a principle of design" shows the modern conception of harmony as "sameness" in the featured snippet (accessed May, 2021). This definition, however, conflicts with classical definitions of harmony.

Part one of our article provides a historical review. We begin by recognizing our respect for the cross-cultural nature of harmony (e.g., in Native American and African philosophies). Then, we review harmony in classical Chinese philosophy, in classical Greek philosophy and then in the period from the Renaissance to the Early Modern Era.

In part two of our article, we review the conceptualization of harmony in the modern era with sections covering psychology, neuroscience, computer science, and design.

In part three, we review applications of harmony for the individual, for interpersonal relationships, for society, and for ecological sustainability. Then, we summarize our key findings, identify limitations to the theory of harmony and suggest future research. Finally, we conclude with a call to action for the use of harmony theory to inform design visions for achieving harmony between our technological society and our natural world.

Part One: Historical Review

After conducting a historical review that largely focuses on harmony in Classical China and Western Europe, we feel it is necessary to preface this work by recognizing that harmony is not only a Western or Eastern tradition.[7] Harmony plays a major role in Native American philosophies like the Navajo "hózhó" philosophy of beauty, well-being, and social order.[8] Harmony is also a component of the Cherokee belief system: "it is the responsibility of human beings while they are on earth to maintain harmony and to restore harmony when it becomes broken."[9] Harmony is also claimed as a wellness philosophy of African origin.[10] Because the philosophy of harmony can be found in so many cultures [**RP.1**],[11] there is much opportunity for future work to bring light to these traditions.

Harmony in Eastern Philosophy

In 2005, the People's Republic of China adopted the idea of a "Harmonious Society" as *the* central objective of the government and enshrined it in the constitution of the party.[12] Following a 2,500-year-old philosophical tradition, the scholar Chenyang Li describes harmony as "probably the most cherished ideal in Chinese culture."[13] As mentioned in the introduction, Confucius' idea of harmony (*he* 和) is explicitly distinguished from uniformity or sameness (*tong* 同). Shi Bo(史伯, ca. 700 BCE) describes the vitality of harmony and the dull and deadening nature of sameness:

> "A single sound is nothing to hear, a single color does not make a pattern, a single taste does not satisfy the stomach, and a single item does not harmonize.… [S]ameness does not advance growth.… If one uses the same thing to complement the same thing, it is a dead end.…"[14]

This is an early argument that sameness is not harmony; differences are required. [**RP.2**] Harmony of diversity is lively; sameness without difference is dead. To harmonize a system means to establish a mutually supportive relationship among the different parts and the whole [**RP.3**]; in contrast, sameness strives for eliminating differences.

7 Presenting harmony as having the characteristics of a perennial wisdom: Miftachul Huda et al., "Building Harmony in Diverse Society: Insights from Practical Wisdom," *International Journal of Ethics and Systems* 36, no. 2 (2020): 149–65, https://doi.org/10.1108/IJOES-11-2017-0208.

8 Michelle Kahn-John and Mary Koithan, "Living in Health, Harmony, and Beauty: The Diné (Navajo) Hózhó Wellness Philosophy," *Global Advances in Health and Medicine* 4, no. 3 (2015): 24–30, https://doi.org/10.7453/gahmj.2015.044; David R. Hodge, Gordon E. Limb, and Terry L. Cross, "Moving from Colonization toward Balance and Harmony: A Native American Perspective on Wellness," *Social Work* 54, no. 3 (2009): 211–19, https://doi.org/10.1093/sw/54.3.211; Randy S. Woodley, *"The Harmony Way": Integrating Indigenous Values within Native North American Theology and Mission* (PhD dissertation, presented to the Faculty of Asbury Theological Seminary, Wilmore, Kentucky, 2010), 72, available at https://www.proquest.com/openview/abe82df6202c1e0f67c1224d30f9f487/1?pq-origsite=gscholar&cbl=18750.

9 Randy S. Woodley, *Shalom and the Community of Creation: An Indigenous Vision* (Grand Rapids, MI: Eerdmans Publishing, 2012), 79.

10 David O. Igbokwe and R. J. E. Ndom, "Harmony-Disharmony Therapy: A Treatment Method of African Origin," *Nigerian Journal of Clinical Psychology* 6, no. 1-2 (2008): 70, available at http://eprints.covenantuniversity.edu.ng/id/eprint/6386.

11 In this article, reflective propositions will be indicated by the capitalized letters "RP" in square brackets. [RP.1] is a proposition about harmony. To support clarity, these reflective propositions will be identified, numbered, and then compiled at the end of different sections of the article.

12 Kin-man Chan, "Harmonious Society," in *International Encyclopedia of Civil Society*, ed. Helmut K. Anheier and Stefan Toepler (New York: Springer, 2010), 821–25.

13 Li, "The Confucian Ideal of Harmony," 583, abstract.

14 Ibid., 584.

Table 1 **Chapter 42 of the "Dao De Jing" offers a relationship between yin/yang and harmony.**

道生一，	The Dao (道) creates the one.	Way-making (Dao) gives rise to continuity,
一生二，	The one creates the two.	Continuity gives rise to difference,
二生三，	The two creates the three.	Difference gives rise to plurality,
三生万物。	The three creates all things.	And plurality gives rise to the manifold of everything that is happening.
万物负阴而抱阳，	All things have Yin (阴) and Yang (阳)	Everything carries yin on its shoulders and yang in its arms,
冲气以为和。	producing the flow of energy (*qi* 气) for harmonization (*he* 和).[a]	And blends these vital energies (*qi*) together to make them harmonious (*he*).[b]

[a] This column was translated by the authors.
[b] Laozi, *Dao De Jing: A Philosophical Translation*, trans. and comment. Roger T. Ames and David L. Hall (New York: The Ballantine Publishing Group, 2003), 142.

15 **Editorial note: There are various translations of the names of ancient Chinese scholars, and their books are translated in many ways. Laozi is also known as Lao Tzu or Lao Tse. His classic titled *Dao De Jing* has been translated in various ways. Other well-known translations include *Tao Te Jing* and *The Classic of the Way and Virtue*. Where this article refers to a scholar, a classic book, or a term in the running narrative, the editors use current Chinese practice with the name appearing in Pinyin followed by simplified Chinese characters in parentheses.**

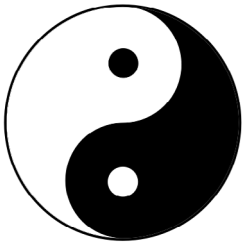

Figure 2
Yin-Yang, the classical symbol of harmony: the integration of the opposites to create a whole.

Daoism and Yin Yang

Daoism (or Taoism) is one of the major historical schools of Chinese thinking, along with Confucianism and Buddhism. Dao (道) is often translated as "way"—like a path or an approach. Laozi(老子)[15] was the older contemporary of Confucius; sources indicate that they met around 500 BCE.[16] According to the historian Sima Qian (司马迁, ca. 145–86 BCE), Laozi was the wise and virtuous keeper of the archival records for the Zhou kingdom. But, after witnessing the decline of Zhou, Laozi sought to leave the court as an old man and live as a hermit. As the story goes, the border guard refused to let him pass until Laozi paid a toll: writing down his wisdom for the people. The book Laozi wrote, known as the *Dao De Jing*[17] (道德经, also translated as *The Classic of the Way and Virtue*[18]), serves as the foundational document for Daoism.

In chapter 42 of the *Dao De Jing*, the concepts of Yin and Yang are introduced (Table 1).[19] The philosophy of Yin and Yang involves the creation of wholeness through the dynamic interaction between seemingly opposing forces. For instance, light and shadow are counterparts and every wave must have a peak and trough. Yin Yang theory is clearly expressed in its modern symbol (Figure 2), where the dark represents Yin and the light represents Yang. Yin needs Yang to exist and Yang needs Yin to exist. There is a small portion of Yang (the light spot) in Yin, and there is also a small portion of Yin in Yang (the dark spot). When Yin and Yang are in balance, the system that they form together is in harmony. Yin Yang is a symbol of harmony: the integration of apparently conflicting forces to make a whole. [**RP.4**]

Levels of Harmony

According to the scholar Chenyang Li,[20] Confucius introduced a program for cultivating harmony at multiple levels in *The Great Learning*(大学): harmony can be cultivated at the level of the individual (e.g., in the body, mind, or in one's varied pursuits), at the level of interpersonal relationships, at the

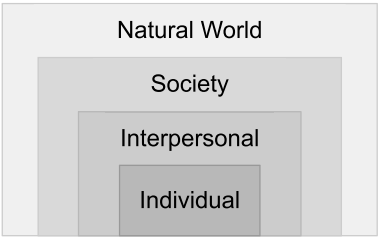

Figure 3
A Confucian framework for designing harmonious systems. Harmonious or inharmonious interactions can occur within or between different levels. Thus, one can investigate harmony within the natural world (e.g., the health of ecosystems) or investigate harmony *with* the natural world (e.g., the relationship of a society to the natural world). © 2022 J. Derek Lomas.

level of society (e.g., between different groups of people), or at the level of the natural world. [**RP.5**] At any of these interconnected levels, harmony describes how diversity can be balanced and integrated into a greater whole. Personal happiness requires a person to attain inner harmony—but also harmony with other people, with society and with nature. This framework of nested levels of harmony is presented in Figure 3.

Personal Level: Self-cultivation was a fundamental ideal in Confucian thought. One becomes a virtuous person through harmonization by balancing their flow of energy (*qi* 气) and avoiding extremes. One's internal harmony is reflected by their peace of mind and the lack of internal harmony results in anxiety (*yu* 郁). Confucius said, "the morally refined person is open and at ease, whereas the petty person is constantly anxious."[21] Harmony, here, offers an early philosophical basis for mental health.

Interpersonal Level: Confucius emphasized the importance of interpersonal harmony, as in "when the family is harmonized, everything thrives."[22] Harmony between individuals occurs when different actions and feelings align with one another and when inevitable conflicts resolve. Harmonious interpersonal relationships involve coordination and mutual affection.

Society Level: Confucius claimed that the goal of state governance is to harmonize society. For Confucius, ritual (*li* 礼) and music (*yue* 乐) were tools for achieving harmony in a state; common social rituals and virtuous leadership would allow individuals to take "the right path." Here, peace between societies is conceived as a higher level of harmony.

Natural World Level: Confucianism and Daoism view human society as a part of an overarching natural system. Humans should not fight nature but act in harmony with it. Following the Dao allows humanity and nature to be integrated together.[23]

Harmony as a Dynamic Process

One of the four classics of Confucianism is the *Zhong-Yong*(中庸), also translated as *The Doctrine of the Mean*, which is attributed to Confucius' only grandson Zisi (子思, 483–402 BCE). It describes harmony as a dynamic state, as opposed to a simple equilibrium:

"While there are no stirrings of pleasure, anger, sorrow and joy, the mind may be said to be in the state of equilibrium [*zhong* 中]. While those feelings have been stirred, and they act in the due degree, there ensues what may be called the state of harmony [*he* 和]. This equilibrium is the great root from which grow all the human actings in the world, and the harmony is the universal path [Dao 道] which they all should pursue."[24]

In other words, all things naturally reach equilibrium: that is the "great root." But harmony is not the same as equilibrium. Instead, it is a dynamic phenomenon. It is not about stillness, but activeness "in the due degree." Thus, harmony should not be conceived as a static state but a *dynamic equilibrium*. [**RP.6**] For instance, harmony in a song is not just a single state but is the dynamic integration of all the parts of the song into a whole.

16 Alan Chan, "Laozi," in *The Stanford Encyclopedia of Philosophy Archive,* ed. Edward N. Zalta (Stanford, CA: Stanford University, 2018), https://plato.stanford.edu/archives/win2018/entries/laozi/.

17 Laozi, *Dao De Jing: A Philosophical Translation*, trans. and comment. Roger T. Ames and David L. Hall (New York: The Ballantine Publishing Group, 2003).

18 Lao-tzu, *The Classic of the Way and Virtue: A New Translation of the Tao-te Ching of Laozi as Interpreted by Wang Bi*, trans. Richard John Lynn (New York: Columbia University Press, 1999).

19 We offer the following interpretation of this highly esoteric wisdom. The One (or oneness), which is the unity of a whole, is created through the Dao. The unity of the whole enables differentiation—that is, only with a whole can there be a distinction or contrast between the things that are part of the whole and the things that are not. This contrast or differentiation produces the Two (or twoness), the Yin and the Yang. Then, with differentiation there is the possibility of interaction. The interaction between contrasting things is the Three (or threeness); all things are then made from interactions. All things have unity (as wholes), polarity (the Yin and the Yang), and emergent interactions (the quality of threeness). The continued flow of energy between contrasting elements

(the Yin and the Yang) enables the harmonization of all things.

20 Chenyang Li, "The Philosophy of Harmony in Classical Confucianism," *Philosophy Compass* 3, no. 3 (2008): 423–35, https://doi.org/10.1111/j.1747-9991.2008.00141.x.

21 Ibid., 429.

22 Ibid.

23 Yueh-Ting Lee, Honggang Yang, and Min Wang, "Daoist Harmony as a Chinese Philosophy and Psychology," *Peace and Conflict Studies* 16, no. 1 (2009): 68–81, https://doi.org/10.46743/1082-7307/2009.1103.

24 Jungho Suh, "The Confucian Doctrine of the Mean, the Optimality Principle, and Social Harmony," *Society and Economy* 42, no. 1 (2020): 61, https://doi.org/10.1556/204.2020.00004.

25 Charles Le Blanc trans., *Huai-Nan Tzu: Philosophical Synthesis in Early Han Thought* (Hong Kong: Hong Kong University Press, 1985), 2.

26 A separate article focusing on a review of resonance in physics, social science, AI and robotics is forthcoming: James Derek Lomas et al., "Resonance as a Design Strategy for AI and Social Robots, Frontiers in Neurorobotics" (under review).

27 Le Blanc, *Huai-Nan Tzu*, ix.

28 Ibid., 192.

29 Laozi, *Dao De Jing*, 38.

30 For a historical review, see Renkui Cai, Dashu Ni, and Jianguo Wang, "Rice-Fish Culture in China: The Past, Present, and Future," in *Rice-Fish Culture in China*, ed. Kenneth T. MacKay (Ottawa: International Development Research Centre, 1995), 3–5.

31 Jian Xie et al., "Ecological Mechanisms Underlying the Sustainability of the Agricultural Heritage Rice-Fish Coculture System," *PNAS* 108, no. 50 (2011): E1384–85, https://doi.org/10.1073/pnas.1111043108.

32 Confucius, *Confucian Analects, The Great Learning, and The Doctrine of the Mean*, vol. 1 of *The Chinese Classics*, 3rd ed., translation with exegetical notes and dictionary of all characters by James Legge (Hong Kong: Hong Kong University Press, 1960), 427.

Relation between Harmony and Resonance

Huai-nan Tzu(淮南子) is a book that was presented as a gift from the Prince of Huainan to the Emperor Wu of Han Dynasty (141–87 BCE). It contains a diverse compilation of debates about the nature of leadership and the conditions necessary for socio-political harmony. As "Taoist-oriented political utopianism," the work serves as "a handbook for the instruction of an enlightened ruler and his court."[25] The book also contains one of the first descriptions of the scientific phenomenon of sympathetic resonance[26] and its relationship to musical harmony:

> "When the lute-tuner strikes the kung note [on one instrument], the kung note [on the other instrument] responds; when he plucks the chiao note [on one instrument], the chiao note [on the other instrument] vibrates. This results from having corresponding musical notes in mutual harmony."[27]

Resonance, based on shared similarities, is the counterpart to harmony; harmony can emerge from natural resonances. [**RP.7**] The translator summarizes the meaning in the following manner: "The most perfect form of government is that of non-action [*wu-wei* 无为], for it operates through the natural resonance (*kan-ying*) of all things."[28] Thus, harmony can emerge naturally from non-action (*wu-wei*). [**RP.8**]

Wu-wei means non-action but it does not mean doing nothing. This Daoist approach to harmony advocates for "noncoercive action"[29] and the elimination of unnecessary human intervention, based on a deep understanding of the Dao (the way). This is because too much human intervention can produce opposite outcomes. The contemporary expansion of industrialized agriculture, which substantially increased the use of chemical fertilizer and pesticides might be an example of excessive human effort. When humans seek to dominate nature so fully, it can end up hurting both nature and humans.

A Classical Example of Harmony in Chinese System Design

In fish-rice farming, the fish and the rice develop together. Each promotes growth in the other. This demonstrates how humans might incorporate principles of harmony into the design of a stable food system (Figure 4). Practiced in China for at least 2000 years,[30] this example of systemic design exploits a mutually beneficial relationship between rice and fish. Fish growth is enhanced by the shaded, cool water in the rice paddy. Rice growth is enhanced by the fish excrement (a nutritious fertilizer containing nitrogen, phosphorus and potassium); and the fish mutually benefit from the cleaner water. An additional mutual benefit: the rice attracts insect pests which the fish eat. A recent study found that a fish-rice system can produce just as much rice as an industrially farmed monoculture setup, but with 68% less pesticide and 24% less chemical fertilizer.[31] There is a kind of beauty to a harmonious system like this. Nothing is waste or purely negative, even the fish excreta and pests. How might designers capture this beauty and the natural principles behind it, in order to create mutually beneficial interactions and complementary resource use? Such harmony in the fish-rice farming is also considered in *The Doctrine of the Mean*, a classic manifestation of equilibrium—where "all things are nourished together without their injuring one another."[32]

Figure 4
A picture of fish-rice farming. Image by Kembangraps at Wikimedia Commons, 2015; licensed under CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0/).

Summary of Reflective Propositions from Classical Eastern Philosophy

The concept of harmony has played a substantial and visible role in Chinese design practice for the last 2,500 years in areas ranging from architecture (the iconic Temple of Supreme Harmony in the Forbidden City in Beijing), political systems (the current constitution of the Chinese Communist Party), and agriculture (fish-rice farming). From our review, we offer the following reflective propositions:[33]

[**RP.1**] Harmony is a perennial wisdom found in many cultures—in the East, West, and beyond.

[**RP.2**] Harmony is not sameness; harmony requires differences.

[**RP.3**] Harmonization can be defined as the process of integrating diverse parts into a more functional whole.

[**RP.4**] Yin Yang offers a symbol of harmony, the integration of apparently conflicting forces.

[**RP.5**] Harmony occurs at multiple levels, such as at an individual level, at an interpersonal level, at a societal level, and at the level of the natural world.

[**RP.6**] Harmony is not the same as equilibrium; it is a dynamic equilibrium. Harmony is a moving process that unfolds over time.

[**RP.7**] Resonance, based on shared similarities, is the counterpart to harmony. Harmony can emerge from natural resonances.

[**RP.8**] Harmony can emerge naturally from non-action (*wu-wei*).

Harmony in Western Philosophy

The notion of harmony in classical Western philosophy is remarkably similar to its classical Eastern counterpart. One of the earliest philosophical discussions

33 **Choosing the term "reflective propositions" because they are not necessarily embedded within the source texts, but rather emerge from our reflections upon the source texts.**

of harmony comes from Heraclitus (535–475 BCE), who claimed that harmony emerged from contradicting opposites — giving the example of the tension and release of a bow. One of his fragments reads, "Opposition brings concord. Out of discord comes the fairest harmony."[34] Musical dissonance is an important part of musical harmony—much of the beauty and power of music comes from the resolution of dissonance not just the "having" of consonance. [**RP.9**] Similarly, the resolution of conflict or tension gives stories meaning and a greater sense of wholeness. This idea that harmony is produced by the reconciliation of opposites or the resolution of conflicts seems to be visible in the allegories of Greek mythology: the goddess Harmonia was the daughter of Ares (the god of war) and Aphrodite (the goddess of love).[35]

The idea of harmony as "differences, resolved" is made clear and explicit by the Pythagorean philosopher Philolaus (470–385 BCE). "Harmony is generally the result of contraries: for it is the unity of multiplicity, and the agreement of discordances."[36] This is the first known instance of a concept that is now known as "unity in variety," which continues to play a role in scientific theories of beauty, thousands of years later.[37] From these early Greek sources, harmony is understood to arise from the resolution of conflict and unity in variety. [**RP.10**]

Pythagoras and the Search for Numbers in Harmony

The role of diversity is common between classical Greek and classical Chinese conceptions of harmony — which is striking, considering the distances between these cultures. However, the classical Greek conception of harmony complements the Chinese perspective with an articulation of harmony as a mathematical entity. The Pythagorean school, specifically, introduced the idea that the qualitative experience of harmony can be quantitatively defined. Later in this article we present how the Pythagorean-Platonic legacy directly triggered the scientific revolution — at least, that is claimed in the writings of Copernicus, Kepler, Galileo, and Newton.

We now wish to share the story of Pythagoras (562–472 BCE)[38] because it helps illustrate the potential for a mathematical understanding of harmony — and because of his early and notable example of diversity and inclusion as a form of harmony. [**RP.11**] Pythagoras is known to schoolchildren throughout the world because of the Pythagorean theorem, which describes the peculiar relationship between the sides of a right triangle ($a^2 + b^2 = c^2$). Yet, few know that Pythagoras had a broad and seminal influence on western philosophy, science, and culture.

Born on the powerful Greek island of Samos, Pythagoras was a multi-ethnic child prodigy. One story recounts that he was once cast out of the youth Olympics for being too effeminate; yet, undeterred, he joined the men's event and won — due to his introduction of new boxing techniques.[39] As a young man, Pythagoras spent some 20 years traveling the world to gather knowledge from diverse cultural sources and to be initiated into various religious mystery cults, such as the Egyptian priesthood. Around age 40, Pythagoras founded a new school and communal society in Croton, Italy. The first generation of Pythagoreans included an astonishing array of historical figures, including Democedes of Croton (the personal doctor of the King of Persia[40]), Alcmaeon of Croton

34 Heraclitus, *The Complete Fragments: Translation and Commentary and The Greek Text*, trans. William Harris (Humanities and the liberal arts: Greek language and literature: Text and commentary, 1994), 45, available at https://fliphtml5.com/jmfd/opdc/basic.

35 Edward A. Lippman, "Hellenic Conceptions of Harmony," *Journal of the American Musicological Society* 16, no. 1 (1963): 3–35, https://doi.org/10.2307/829917.

36 Philolaus, "Fragments of Philolaus," in *The Pythagorean Sourcebook and Library: An Anthology of Ancient Writings Which Relate to Pythagoras and Pythagorean Philosophy*, compiled and translated by Kenneth Sylvan Guthrie, edited by David Fideler (Grand Rapids, MI: Phanes Press, 1987), Kindle edition.

37 "Paul Hekkert Delivers TU Delft's Foundation Day lecture," *TU Delft News*, January 15, 2020, https://www.tudelft.nl/en/2020/io/january/paul-hekkert-delivers-tu-delfts-foundation-day-lecture.

38 Philip Thibodeau, *The Chronology of the Early Greek Natural Philosophers* (North Haven, CT: Codsmographia.net, 2019), available at http://arks.princeton.edu/ark:/88435/dsp0137720g809.

39 Ibid., 132.

40 Leonid Zhmud, *Pythagoras and the Early Pythagoreans*, trans. Kevin Windle and Rosh Ireland (Oxford: Oxford University Press, 2012), https://doi.org/10.1093/acprof:oso/9780199289318.001.0001.

("the father of neuroscience"[41]) and Milo of Croton. Milo, trained by Pythagoras, won six consecutive Olympic games in wrestling over a 24-year period[42]—more than any other individual athlete in history, even in the modern era.

Pythagoras was supposedly the first to refer to himself as a *philosopher*[43] (lover of wisdom). Yet, what seems especially wise today was his reputation for racial and gender inclusivity; his friend Abaris was non-Greek (perhaps east Asian[44]) and the Pythagorean community included a large number of female philosophers, such as Theano and Myia (who are credited with theories of harmony in families and in child development[45]). Aristoxenus, a student of Aristotle, recorded that Pythagoras gave the credit for his moral philosophies to the female priestess Themistoclea (the Oracular Pythia of the Temple of Apollo at Delphi).[46] This degree of inclusiveness in philosophy would be unmatched for thousands of years. He even extended his ethical concerns beyond people: he was an ethical vegetarian and stories recount his protection of animals.[47]

The growing power of the Pythagoreans attracted enemies and their community was massacred *en masse*—twice. No writings of Pythagoras or the early Pythagoreans survive. One of the last Pythagoreans was Archytas, the democratically elected "philosopher king" of Tarentum. Archytas is famous for designing a robot[48] (a steam-powered flying "dove"[49]), for devising three dimensional mathematical proofs, and for authoring the first text on the subject of mechanical engineering.[50] Beyond these technical achievements, he was a friend to the philosopher Plato—Archytas successfully freed him from slavery under Dion, the king of Syracuse.[51] Through Archytas, Plato was deeply influenced by Pythagorean ideas. As a result, scholars refer to their ideas as the Platonic-Pythagorean tradition.[52]

Harmonies in Number

What did the Pythagoreans believe? Aristotle summed up their core belief as "All is Number."[53] While philosophers at the time claimed that the underlying substance of material reality was either air, water, fire or spirit, the Pythagoreans believed that the underlying substance of reality was *mathematics*. As there are harmonious structures within basic mathematics, like the wholeness of various geometric forms (Figure 5), these harmonies are expected to manifest themselves in the physical cosmos. [**RP.12**] *Kosmos*, a Greek word referring to the beauty of the world (echoes in "cosmetics"), was supposedly coined by Pythagoras.[54]

The Pythagorean Quadrivium,[55] which includes Arithmetic, Geometry, Music, and Astronomy, expresses how the harmony in numbers can produce various "wholes" or forms. Arithmetic deals with the harmony of numbers, geometry deals with the harmony of numbers in space, music with the harmony of numbers in time, and astronomy (or cosmology) deals with the harmony of numbers in space and in time. The Renaissance instructional system of the Seven Liberal Arts was composed of the quadrivium combined with the Platonic trivium (Grammar, Rhetoric, and Logic).

Harmony and the Birth of Empirical Science

The Pythagoreans advanced the science of harmony through a quantitative and empirical investigation of mathematical intervals and harmonious sounds.

41 Adam M. Zemelka, "Alcmaeon of Croton — Father of Neuroscience? Brain, Mind and Senses in the Alcmaeon's Study," *Journal of Neurology and Neuroscience* 8, no. 3 (2017): 190, https://doi.org/10.21767/2171-6625.1000190.

42 Nigel Spivey, *The Ancient Olympics* (Oxford: Oxford University Press, 2005), 59.

43 Zhmud, *Pythagoras and the Early Pythagoreans*.

44 Peter Kingsley, *A Story Waiting to Pierce You: Mongolia, Tibet, and the Destiny of the Western World* (Point Reyes Station, CA: Golden Sufi Center, 2010).

45 Mary Ellen Waithe, "Early Pythagoreans: Themistoclea, Theano, Arignote, Myia, and Damo," in *A History of Women Philosophers*, ed. Mary Ellen Waithe (New York: Springer, 1987), 11–17, https://doi.org/10.1007/978-94-009-3497-9_2.

46 Caterina Pellò, "Women in Early Pythagoreanism" (PhD dissertation, University of Cambridge, 2018), https://doi.org/10.17863/CAM.24346; Sarah B. Pomeroy, *Pythagorean Women: Their History and Writings* (Baltimore, MD: Johns Hopkins University Press, 2013).

47 Zhmud, *Pythagoras and the Early Pythagoreans*.

48 Sánchez-Martín F. M. et al., "Historia de la robótica: de Arquitas de Tarento al robot Da Vinci (Parte I) [History of Robotics: From Archytas of Tarentum Until Da Vinci Robot (Part I)]," *Actas Urologicas Espanolas* 31, no. 2 (2007): 69–76, https://doi.org/10.1016/s0210-4806(07)73602-1.

49 "Archytas made a wooden model of a dove with such mechanical ingenuity and art that it flew; so nicely balanced was it, you see, with weights and moved by a current of air enclosed and hidden within it." Aulus Gellius, *Attic Nights*, trans. John C. Rolfe (Cambridge, MA: Harvard University Press, 1927).

50 Thomas Nelson Winter, "*The Mechanical Problems* in the Corpus of Aristotle" (Faculty Publications, Classics and Religious Studies Department, University of Nebraska, 2007), article no. 68, available at https://digitalcommons.unl.edu/classicsfacpub/68; Hariharan Palayapalayam Ganapathi et al., "Surgical Robotics: Past, Present and Future," in *Operative Atlas of Laparoscopic and Robotic Reconstructive Urology*, 2nd ed., ed. Vipul R. Patel and Manickam Ramalingam (Cham: Springer, 2017), 3–11, https://doi.org/10.1007/978-3-319-33231-4_1.

51 Carl A. Huffman, *Archytas of Tarentum: Pythagorean, Philosopher and Mathematician King* (Cambridge: Cambridge University Press, 2005).

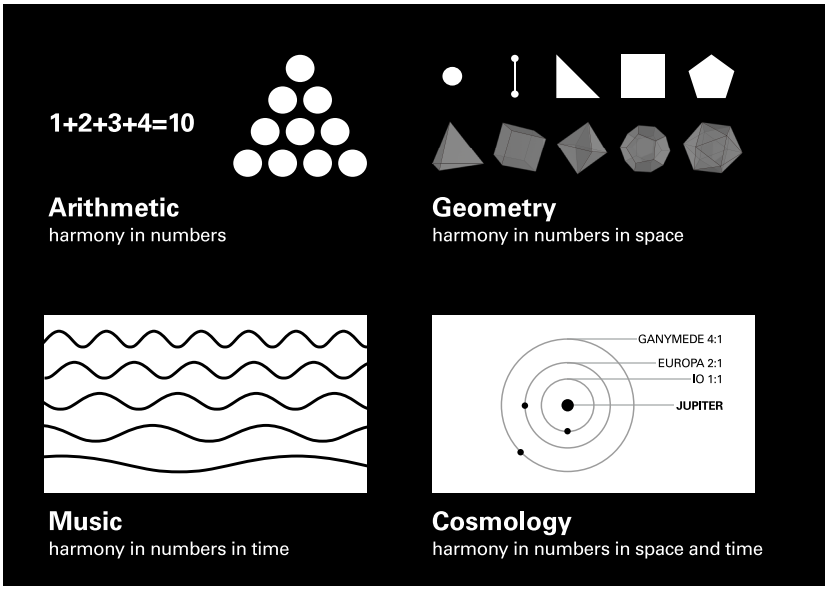

Figure 5
The Pythagorean Quadrivium shows how harmonies in numbers create "wholes" in arithmetic, geometry, music, and the natural world. The triangular figure is the Tetractys, an esoteric Pythagorean symbol, which shows the harmony in numbers 1 + 2 + 3 + 4 = 10. The Tetractys is also, coincidentally, found in the ten diamonds of the logo of the Louvre, the museum of fine art in Paris.

Plato describes how the Pythagoreans would "measure audible concords against one another" in order to "search for numbers in those audible concords."[56] The connection between the *qualitative* experience of harmony and the *quantitative* mathematics of harmony remains an enigma today.

The Pythagoreans can be credited with conducting the first hypothesis-driven scientific experiment;[57] that is, they used empirical experimentation to validate a mathematical model. [**RP.13**] Their basic proposal was that fundamental harmonies in numbers should produce harmonies in sound. The numbers 1 and 2, for instance, have the quality of a musical octave (a ratio of 1:2). Indeed, a musical octave is a doubling of frequency—a middle C note on a piano has a fundamental frequency of 440 Hz and the C note one octave higher has a fundamental frequency of 880 Hz.[58] Similarly, a musical fifth involves the mathematical ratio of 3:2 and the fourth, the ratio of 4:3. All small integer ratios generate consonance when played upon two musical strings, as illustrated in Figure 6. These consonant ratios mathematically "fit well" together in the sense that the numbers involved overlap often: for instance, the multiples of 3 are often divisible by 2 (6, 12, 18, etc.). In contrast, the dissonant minor second involves ratios of 50:53, and these numbers only very rarely overlap.

To test the generalizability of this mathematical model, Aristotle's student Aristoxenus writes that the Pythagoreans cast bronze chimes with integer proportions and found that a chime that is double in thickness produces a tone that is an octave lower (half the frequency).[59] In later work, Theon of Symrna (100 AD) wrote that the Pythagoreans also tested their theory using cups that were filled with integer proportions of water.[60] For the Pythagoreans, this empirical evidence proved more than a theory of music—it served as evidence that harmonies in nature (i.e., "the harmony of the spheres")

52 Richard S. Westfall, *The Construction of Modern Science: Mechanisms and Mechanics* (Cambridge: Cambridge University Press, 2002).
53 Leonid Ja. Zhmud, "'All Is Number'? 'Basic Doctrine' of Pythagoreanism Reconsidered," *Phronesis* 34, no. 3 (1989): 270–92, https://doi.org/10.1163/156852889x00189.
54 Zhmud, *Pythagoras and the Early Pythagoreans*.
55 Miranda Lundy et al., *Quadrivium: The Four Classical Liberal Arts of Number, Geometry, Music & Cosmology*, ed. John Martineau (New York: Bloomsbury USA, 2010).
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56 Andrew Barker, *The Science of Harmonics in Classical Greece* (Cambridge: Cambridge University Press, 2007), 25.
57 Tyler Mayo, "Research and Experiment in Early Greek Thought" (PhD dissertation, University of Michigan, 2019), available at https://hdl.handle.net/2027.42/150050.
58 One Hertz or Hz is equivalent to one cycle of oscillation per second.
59 Leonid Zhmud, "Aristoxenus and the Pythagoreans," in *Aristoxenus of Tarentum: Texts and Discussion, Rutgers University Studies in Classical Humanities, Volume XVII*, ed. Carl A. Huffman (New Brunswick, NJ: Transaction Publishers, 2017), 223–49.

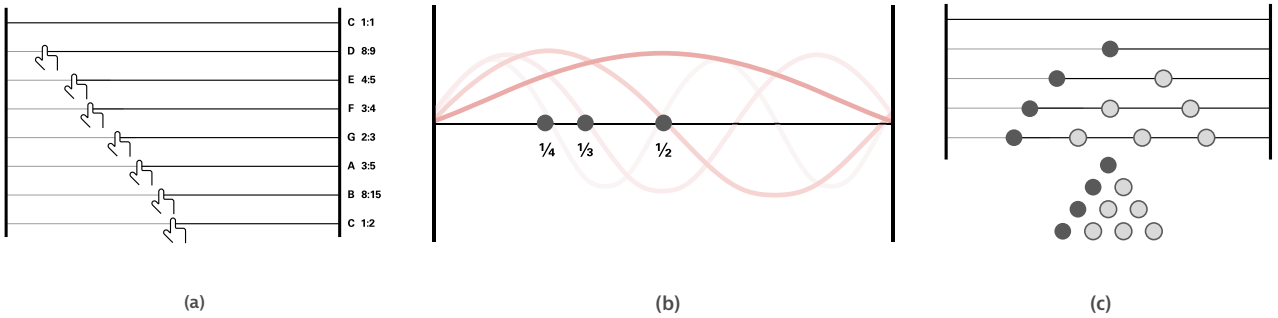

Figure 6
(a) The Pythagorean musical scale on stringed instruments is due to the small-integer relationship in the lengths of strings. (b) The length of the string is directly correlated with the frequency of sounds produced; the nodes of the harmonics or overtones of the fundamental frequency also indicate where a proportion of the string can produce a consonant note. (c) The Pythagorean Tetractys, explained in Figure 5, is revealed in the tuning of instruments. This reveals a hidden zeroth element of the Tetractys, representing the open string.

were manifestations of fundamental harmonies in mathematics. Empirical research can link harmonies in number to harmonies in the physical world to harmonies in our mental experience. [**RP.14**]

Pythagorean Harmony as an Enduring, Imperfect Theory

A challenge to this Pythagorean theory of harmony, however, comes from everyday experience. Modern musical tuning is not Pythagorean but rather uses equal temperament. With the exception of the 1:2 octave, equal temperament ratios are only approximations of the perfect integer ratios of Pythagoras. Not only do we tolerate a little mistuning, but we also even seem to find consonance that is slightly dissonant more pleasurable than pure consonance itself.[61] What can account for the pleasure of musical harmony, then? This question, which was the first question posed to empirical science, is still an open question 2,500 years later.

Music has a strange and nearly universal capacity for the non-verbal communication of emotions and experience. While there are enormous cultural differences in musical practice, taste, and perception,[62] harmonic similarities are striking: for instance, prehistoric bone flutes found in China,[63] Europe, and America[64] all produce octaves. What can account for this common qualitative experience of harmony?

One hypothesis is that the small number of ratios found in consonant notes produces *perceptual fusion*. An early articulation can be found in the writing of the mathematician Euclid (c. 325 BCE), who used a harmonic measurement device (known as a *Canon* or monochord) to provide a mathematical exposition of harmony. His conclusion focuses on the ability of consonant sounds to blend together into a whole: "Now some sounds we know are consonant and others dissonant, the consonant uniting to produce a single blend, the dissonant failing to do so."[65] This suggests that the pleasure of musical harmony comes from the unification of the various parts of the sound into a singular whole [**RP.15**].

An Interlude: Harmony, Consonance, and Contemporary Science

The notion of fusing consonant notes into "one sound" is an ancient idea of harmony. This might be explained due to the *periodic alignment* of multiple waves. That is, notes might fuse into one harmonious chord when the

60 Richard D. McKirahan Jr., "Theon of Smyrna. *Mathematics Useful for Understanding Plato*: Translated from the 1892 Greek/French edition of J. Dupuis by Robert and Deborah Lawlor and edited and annotated by Christos Toulis and others. Secret Doctrine Reference Series. San Diego, CA (Wizards Bookshelf). 1970. ISBN 0-913510-24-6. xvi + 174 pp. $11.95," *Historia Mathematica* 9, no. 1 (1982): 100–104, https://doi.org/10.1016/0315-0860(82)90147-1.
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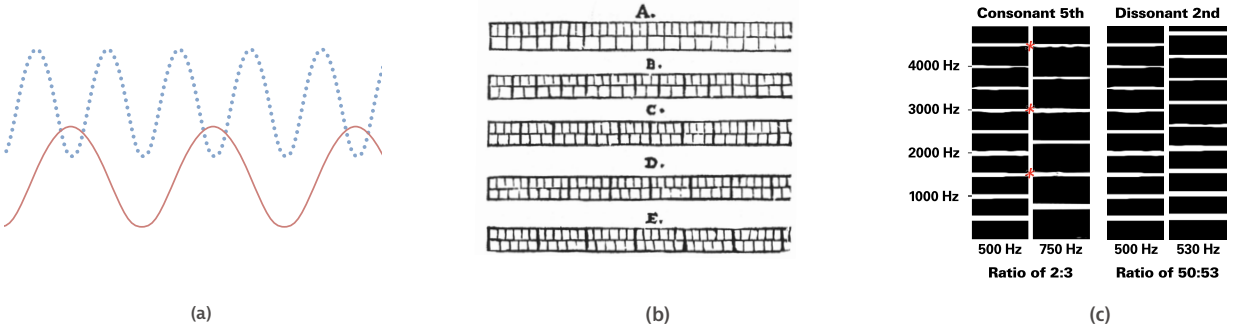
61 Imre Lahdelma and Tuomas Eerola, "Mild Dissonance Preferred over Consonance in Single Chord Perception," *i-Perception* 7, no. 3 (2016): 1–21, https://doi.org/10.1177/2041669516655812.
62 Josh H. McDermott et al., "Indifference to Dissonance in Native Amazonians Reveals Cultural Variation in Music Perception," *Nature* 535 (July 2016): 547–50, https://doi.org/10.1038/nature18635.



(a) (b) (c)

Figure 7
(a) A simple 2:1 diagram shows how periodic alignment might enable the fusing of frequencies into greater wholes. (b) Keller (1636) illustrates the aligning ratios of the 1:2 octave (A), the 2:3 fifth (B), the 3:4 fourth (C), the 4:5 major third (D) and the 5:6 minor third (E). (c) A spectrogram of plucked strings reveals consonant intervals (such as the 2:3 ratio of a musical fifth) share common harmonics, while dissonant intervals (such as the 50:53 ratio of a minor second) do not share harmonics. Shared harmonics, or harmonic alignment, will lead to increased resonances between notes and may also help support perceptual fusion. 7a, 7c © 2022 J. Derek Lomas; 7b source: Barbieri, "Galileo's' Coincidence Theory of Consonances," 210, Figure 1.

peaks and the troughs of their sounds often line up or "kiss" (Figure 7). This so-called periodicity model is highly predictive of consonance, but it has a key flaw: a slightly different start time of one note (a phase difference) would mean that a consonant musical combination would never generate periodic alignment.[66] A phase difference (which is inevitable when plucking strings) would mean that the peaks of the waves would *never* line up. Nevertheless, a phase misalignment of two consonant notes does not produce intolerable dissonance. In one modern neurological theory of consonance and dissonance, the author proposes that the brain might automatically align the phases of the auditory neurons that mirror the frequency of external sounds.[67]

Thus, periodic alignment might allow sound combinations to be heard fluently as a single entity rather than as two conflicting entities. This aesthetic theory suggests that *perceptual fusion* facilitates cognitive processing fluency, which is generally pleasing.[68] Alternatively, modern analysis techniques can reveal the shared harmonics that exist between consonant musical tones (Figure 7a). These shared harmonics or harmonic alignments would enable mutual resonances (resonance occurs when frequencies match), in musical instruments as well as in the brain. [**RP.16**]

Whether through periodic alignment, harmonic alignment, or other features, the mind is able to integrate diverse auditory elements into a well-fitted wholeness (perceptual fusion). [**RP.17**] Recent work has shown that the perceptual fusion of consonant notes is effectively universal across people—even among distant tribes in the Amazon rainforest—but also that the experience of pleasure from these notes is deeply affected by cultural experience.[69] [**RP.18**] As humans generally enjoy success and dislike failure,[70] there may be an enjoyment in grasping the orderly basis of sounds and a sort of discomfort when we fail to perceive an integrated order. Harmony may be pleasurable because it reduces the challenge of perceiving complexity into a comprehensible wholeness. [**RP.19**] Some of this processing may be based on basic informational properties of the musical notes (consonant chords reduce information entropy[71] due to the redundancy of overlapping frequencies) but other aspects of the processing are surely based on cultural experience. Rather than being a settled matter, the scientific understanding of consonance, dissonance, and harmony is far from complete. The first scientific research question continues to hold mysteries. And, scientific breakthroughs continue to occur, such as

63 Juzhong Zhang, Xinghua Xiao, and Yun Kuen Lee, "The Early Development of Music. Analysis of the Jiahu Bone Flutes," *Antiquity* 78, no. 302 (2004): 769–78, https://doi.org/10.1017/S0003598X00113432.

64 Jelle Atema, "Old Bone Flutes," *Pan* 23, no. 4 (2004): 18–23, available at http://www.bio.umass.edu/biology/kunkel/pub/lobster/Atema/Atema_Old_Bone_flutes-Pan2004.pdf.

65 Patrizio Barbieri, "'Galileo's' Coincidence Theory of Consonances, from Nicomachus to Sauveur," *Recercare* 13 (2001): 202, available at https://www.jstor.org/stable/41701361.

66 Ibid., 210, Figure 1.

67 Frieder Stolzenburg, "Harmony Perception by Periodicity Detection," *Journal of Mathematics and Music* 9, no. 3 (2015): 215–38, https://doi.org/10.1080/17459737.2015.1033024.

a recent model explaining the relationship between horizontal and vertical harmony.[72]

To be clear, consonance is not the same as harmony. Consonance and dissonance are opposites, but dissonant intervals are musically essential—and consonance without dissonance is … dull. Consonance and dissonance can fit well together—dissonance can be harmonized—because dissonant notes introduce tensions that consonant notes are able to resolve. This tension and resolution give musical compositions a wholeness and aliveness. Dissonance is, therefore, a part of the harmony (which is the fitting-togetherness of the whole composition). In contrast to consonance and dissonance, the opposite of harmony is disharmony (*anarmostoi*). A disharmonious note is more than a dissonant note —it is a note that does not fit—specifically in the sense that it detracts from the whole composition. [**RP.20**]

The concept of fusion and fluency can be extended beyond music. Consider the challenge of a theater play: how can hours of different design elements be unified together into a coherent "whole" experience? Harmony may be pleasurable because it supports "pleasure from parsimony": when one can understand a complex situation in terms of a simple function, it feels good. [**RP.21**] A complex model of the world is not as valuable or pleasing as a simple model. When the mind can transform complexity into new and simple "wholes" that can be comprehended fluently, it feels good. In this manner, harmony can explain how or why certain designs "hold together" while others don't.

Plato's Harmony: Virtue, Justice, Pleasure, and Happiness

Plato's importance can hardly be overstated. He founded the Academy over 2,350 years ago— this organizational concept continues to play a major role in modern society. Furthermore, while very little Pythagorean literature has survived, all of Plato's known works have survived. In the sciences, progress seems to follow the linear trend of technological development. However, modern philosophy is not merely an evolved state of ancient philosophy. Instead, the so-called Lindy effect[73] applies, where the oldest material can be some of the most important.

Plato was deeply influenced by the Pythagorean viewpoint. He seemed to view harmony as the basis of individual virtue and the justice of the governing state. He even incorporated principles of harmony and the golden mean into his writing structure.[74] Yet, Plato never states his own beliefs outright; instead, he presents dialogues between characters that allow the reader to construct their own understanding. As a result, what Plato *specifically* believed about harmony is rather unclear.

In the *Philebus*, Socrates engages in a dialogue where harmony is presented as the basis of pleasure and pain. "When the harmony in living creatures is disrupted, there will at the same time be a disintegration of their nature and a rise of pain … but if the reverse happens, and harmony is regained and the former nature restored, we have to say that pleasure arises."[75] [**RP.22**] Plato also represents harmony as the basis of health and disease, as in *The Sophist*: "Perhaps you have never reflected that disease and discord are the same."[76] [**RP.23**] And, in *The Republic*, he positions harmony as akin to moral virtue: "ugliness and discord and inharmonious motion are nearly allied to ill words

68 Rolf Reber, Norbert Schwarz, and Piotr Winkielman, "Processing Fluency and Aesthetic Pleasure: Is Beauty in the Perceiver's Processing Experience?," *Personality and Social Psychology Review* 8, no. 4 (2004): 364–82, https://doi.org/10.1207/s15327957pspr0804_3.

69 Malinda J. McPherson et al., "Perceptual Fusion of Musical Notes by Native Amazonians Suggests Universal Representations of Musical Intervals," *Nature Communications* 11 (June 2020): 1–14, https://doi.org/10.1038/s41467-020-16448-6.

70 Derek Lomas et al., "Optimizing Challenge in an Educational Game Using Large-Scale Design Experiments," in *CHI '13: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York: ACM, 2013), 89–98, https://doi.org/10.1145/2470654.2470668.

71 William A. Sethares, "Consonance and Dissonance of Harmonic Sounds," in *Tuning, Timbre, Spectrum, Scale*, 2nd ed. (London: Spring, 2005), 77–95, https://doi.org/10.1007/1-84628-113-X_5.

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72 Chan et al., "The Science of Harmony."

73 Iddo Eliazar, "Lindy's Law," *Physica A: Statistical Mechanics and Its Applications* 486 (November 2017): 797–805, https://doi.org/10.1016/j.physa.2017.05.077.

74 John Bernard Kennedy, *The Musical Structure of Plato's Dialogues* (Abingdon: Routledge, 2014).

75 Plato, *Plato: Complete Works*, ed. John M. Cooper (Cambridge: Hackett Publishing, 1997), 419.

76 Plato, *Sophist*, vol. 3 of *The Dialogues of Plato*, translated into English with analyses and introductions by Benjamin Jowett, 3rd edition revised and corrected (Cambridge: Oxford University Press, 1892).

and ill nature, as grace and harmony are the twin sisters of goodness and virtue and bear their likeness."[77] [**RP.24**]

In Plato's *Philebus*, it is introduced that some Pythagoreans believe that the human soul[78] (Greek: *Psuche* or *Psyche*) is a harmony—yet, Socrates denies this, claiming that if the soul was a harmony, it would be proof that a man's soul was mortal: the harmony of an instrument is destroyed when the instrument is broken. Nevertheless, in *The Republic*, the soul is described as having different parts (appetite, reason, and spirit[79]) that can harmonize with each other (producing virtue and happiness) or conflict with each other (producing vice and unhappiness). Plato associates harmony in the soul with ethical goodness and happiness and makes a parallel to the role of justice in a well-governed state. [**RP.25**] In his introduction to *The Republic*, translator Benjamin Jowett summarizes: "Virtues are based on justice … and justice is based on the idea of good, which is the harmony of the world, and is reflected both in the institutions of States and in motions of the heavenly bodies."[80] Thus, Plato presents a diversity of ideas about the nature of harmony: pleasure, pain, health, disease, virtue, vice, justice, injustice…. How can harmony and discord account for so much??

A Classical Critique of Harmony

Aristotle levied an important rhetorical critique of harmony: he claimed that harmony was just a metaphor that obscured understanding. After all, musical "harmony does not contain virtue, nor virtue harmony."[81] [**RP.26**] This is a fair point: do we really expect to find musical intervals in a virtuous person's brain? On the other hand, harmonization in music and harmonization in virtue might both be manifestations of a more general principle of harmony. [**RP.27**] This principle might be formulated as the inherent *goodness* of integrating differences together into a greater whole.[82]

Aristotle also shows the necessity of harmony when he critiques "the error of Socrates": "The error of Socrates must be attributed to the false notion of unity from which he starts. …[T]here is a point at which a state may attain such a degree of unity [that] it will become an inferior state, like harmony passing into unison, or rhythm which has been reduced to a single foot."[83] Aristotle is pointing out that harmony is more valuable than unity—no one wants a song reduced to a single note, rhythms to a single beat, or a picture to a single point. [**RP.28**] Unlike unity, harmony flourishes from diversity and resolving conflicts. A song might end dissonances by resolving them, but the presence of those conflicts is precisely what makes the harmony rich.

Music as an Enduring Model of Harmony

As musicians know, the best songs are not just a series of consonant notes, but rather involve a narrative integration of musical dissonances. We value the resolution of dissonance, not just the "having" of consonance. Purely consonant songs are boring. All good songs—and all good stories—involve the introduction of tension and dissonance as this motivates the harmonization. Conflict and its resolution give songs and stories more meaning and a greater sense of wholeness. And, just as harmony is more magnificent when there are discords to harmonize, our biggest challenges, when overcome, can become our biggest achievements.

77 Plato, *The Republic of Plato*, translated into English with introduction, analysis, marginal analysis, and index by Benjamin Jowett, 3rd edition revised and corrected throughout (Oxford: Clarendon Press, 1888), [401a].

78 While a modern reader might consider "the soul" or psyche to refer to conscious experience, Plato instead clarifies that "the union or communion of soul and body in one feeling and motion would be properly called consciousness." In other words, the harmony of the soul and the body together produces consciousness or sensation. Plato, *Philebus*, vol. 5 of *The Dialogues of Plato*, translated into English with analyses and introductions by Benjamin Jowett, 3rd edition revised and corrected (Cambridge: Oxford University Press, 1892).

79 John M. Cooper, "Plato's Theory of Human Motivation," *History of Philosophy Quarterly* 1, no. 1 (1984): 3–21, available at https://philpapers.org/rec/COOPTO-2.

80 Plato, *The Republic of Plato*, vii.

81 Aristotle, *The Complete Works of Aristotle*, vol. 1, ed. Jonathan Barnes (Princeton: Princeton University Press, 1995), 236.

82 This still leaves open the question: to what extent can a general principle of harmony be explained mathematically? In theory, a deeper mathematical understanding of musical harmony should help explain more general principles of harmony, such that they could be related to other domains—like harmony between people.

83 Aristotle, *The Politics of Aristotle: Introduction and Translation*, vol. 1, translated into English with Introduction, Marginal Analysis Essays, Notes and Indices by Benjamin Jowett (Oxford: Clarendon Press, 1885), 35.

Summary from the Classical Period

The Pythagorean-Platonic view of harmony, in summary, refers to the integration of the many into the one; that is, harmonization is the process of bringing different elements together into a well-fitting whole. Like the word "harmony" is used today, in classical Greece, harmony was understood as a conscious phenomenon present in everyday experience—one can feel discord within a social interaction like one can feel a mistuned musical instrument. [**RP.29**] That is, one regularly experiences a feeling of harmony. At the same time, harmony is also a phenomenon that occurs in material systems (e.g., in music) and within incorporeal ideas (e.g., in mathematics). As such, harmony might serve as a bridge between these three worlds (consciousness, materiality, and incorporeality). [**RP.30**] The Pythagorean-Platonic notion of harmony is not a musical metaphor, but rather treats musical harmony and other harmonies in the cosmos as manifestations of harmonies derived from pure mathematics. This notion of harmony can serve as a generative source of hypotheses to guide empirical, scientific investigations, as it did at the very outset of the history of science.

Summary of Reflective Propositions from Classical Western Philosophy

[**RP.9**] Dissonance can enrich harmony; the resolution of dissonance is more valuable than "having" consonance.

[**RP.10**] Harmony comes from the resolution of conflict; unity amidst variety. Conflict and its resolution give designs (e.g., songs and stories) more meaning and a greater sense of wholeness.

[**RP.11**] The contemporary idea of "diversity and inclusion" has classical parallels in the theory of harmony.

[**RP.12**] Harmonies in mathematics manifest as harmonies in the cosmos.

[**RP.13**] The earliest attested scientific experiment sought to test a mathematical model of harmony.

[**RP.14**] Empirical research can link harmonies in number to harmonies in the physical world to harmonies in our mental experience.

[**RP.15**] The pleasure of musical harmony comes from the unification of the various parts of the sound into a singular whole.

[**RP.16**] Harmonic alignment and mutual resonance may support perceptual fusion: shared harmonics in musical tones allow for mutual resonances (in the instruments or in the brain), as resonance occurs when frequencies align.

[**RP.17**] Musical consonance is associated with mathematical alignments which may enable perceptual fusion and cognitive fluency.

[**RP.18**] The perceptual fusion of consonant tones appears to be universal but the experience of the pleasure of consonance is dependent upon cultural experience.

[**RP.19**] Harmony is pleasurable because it reduces the challenge of perceiving complexity by transforming the complexity into a simpler and more comprehensible wholeness.

[**RP.20**] While dissonance can be resolved into harmony in order to strengthen the whole, *disharmony* is a mis-fitting that detracts from the whole.

[**RP.21**] Beyond musical consonance, harmony explains the aesthetic pleasure of integrating different design elements into a coherent and whole experience. There is a "pleasure from parsimony" when one can understand a complex situation in terms of a simple function.

[**RP.22**] Pleasure is associated with harmony and pain associated with disintegration.

[**RP.23**] Health is associated with harmony and disease associated with discord.

[**RP.24**] Virtue and ethical goodness is harmonious and "ill will" is inharmonious.

[**RP.25**] A just and well-governed state is harmonious.

[**RP.26**] Harmony may be only a metaphor and an obscuring one.

[**RP.27**] Musical harmony may be a manifestation of a deeper universal principle of harmony, which also manifests in other domains.

[**RP.28**] Harmony is more valuable than excessive unity.

[**RP.29**] Harmony is a conscious phenomenon present in everyday experience — one can feel discord within a social interaction like one can feel a mistuned musical instrument.

[**RP.30**] Harmony is a "common currency" that bridges our understanding of the mathematical world, the physical world, and the conscious world.

The History of Harmony from the Renaissance to the Early Modern Period

The Pythagorean notion of harmony played an explicit role during the Renaissance, the European Enlightenment, and during the Scientific Revolution. After the destruction of the Athenian Academy around 550 AD, the Latin-speaking West lost Plato for nearly 900 years. However, in 1438, Plethon brought Plato's Greek writings from Constantinople to Florence. The wealthy banker Cosimo Medici hired Marsilio Ficino to translate Plato's works into Latin — along with many other works, including two biographies of Pythagoras. Ficino himself was a brilliant philosopher and he led the founding of a new Academy in Florence. The availability of "the classics" helped cultivate a flourishing of ideas that would transform Europe: it was the beginning of the Renaissance and the European Enlightenment.

Leonardo Da Vinci (1452–1519), the prototypical Renaissance man, wrote: "Do you not know that our soul is composed of harmony?"[84] His iconic Vitruvian Man is actually a visual representation of the harmony of the different parts of figure of the human being. The image, Figure 8, is based on a quote from Vitruvius' Ten Books on Architecture: "In a temple there ought to be harmony in the symmetrical relations of the different parts to the whole. In the human body, the central point is the navel. If a man is placed flat on his back, with his hands and feet extended, and a compass centered at his navel, his fingers and toes will touch the circumference of a circle thereby described. And just as the human body yields a circular outline, so too a square may be

84 Leonardo da Vinci, "A Treatise on Painting," in *Trattato della Pittura: Libro A [Leonardo da Vinci on Painting: A Lost Book], ed. Carlo Pedretti* (Los Angeles: University of California Press, 1965), available at http://www.treatiseonpainting.org/cocoon/leonardo/printEd/all.

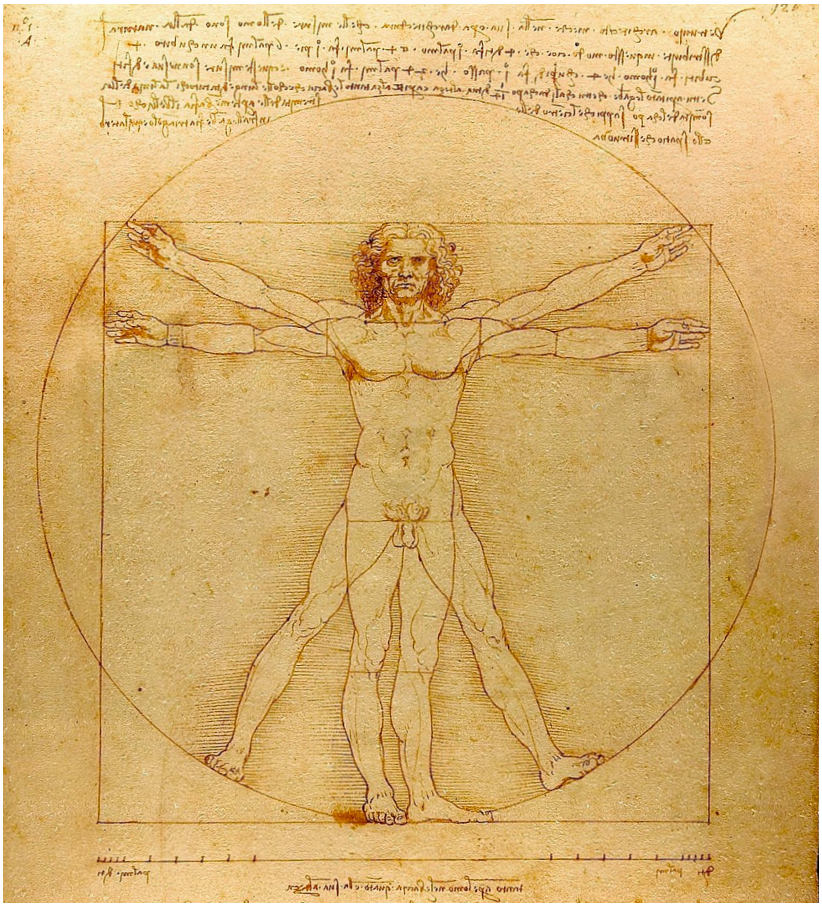


Figure 8
Leonardo Da Vinci's Vitruvian Man is a representation of the mathematical harmonies of the human form. Photo credit: Luc Viatour.

found from it. For if we measure the distance from the soles of the feet to the top of the head, and then apply that measure to the outstretched arms, the breadth will be found to be the same as the height, as in the case of a perfect square."[85] This quote implies that there are mathematical harmonies in physical forms, from architecture to the human body. [**RP.31**]

Leon Battista Alberti (1404–1472) was another famous designer known for his architecture, painting, poetry, cryptography, and philosophy. Benefiting from the newly translated Plato, he claimed that the best art had a foundation in mathematics. His definition of beauty has remained popular for centuries: "Beauty is the reasoned harmony of all the parts within a body, so that nothing may be added, taken away or altered but for the worse."[86] This is a beautiful phrase, but with Aristotle's critique in mind: is Alberti referring to harmony as a metaphor or a mechanism? His quote would still be beautiful and instructive, even if it just referred to harmony as a metaphor from music, but it can also be understood to operate as a scientific principle. As it turned out, the empirical question of harmony as a physical mechanism apparent in the structure of the cosmos was a driving motivation during the Scientific Revolution.

85 Vitruvius Pollio, *Vitruvius: The Ten Books on Architecture*, trans. Morris Hicky Morgan; with illustrations and original designs prepared under the direction of Herbert Langford Warren (1919; Berlin: DeGruyter, 1986), Book III, Chapters 1 and 3.

86 Leon Battista Alberti, *On the Art of Building in Ten Books*, trans. Joseph Rykwert, Neil Leach, and Robert Tavernor (Cambridge, MA: MIT Press, 1992), 156.

Copernicus (1473–1543) is often credited with sparking the scientific revolution because his heliocentrism broke with the doctrine of the Christian Church. However, Copernicus himself didn't consider heliocentrism to be an innovation; instead, he viewed it merely as the restoration of Pythagorean knowledge.[87] He was not alone: when Galilei Galileo (1564–1642) was put under permanent house arrest by the Church, he remarked that this had imposed "a seasonable silence upon the Pythagorean opinion."[88] Galileo was deeply familiar with harmony and as he had conducted empirical investigations on the nature of its mysteries. As a young boy, he helped his father Vincenzo Galileo (1520–1591) conduct a series of quantitative experiments on harmony. For instance, they used room-length vibrating strings in their effort to define the modern equations that describe how the pitch of a plucked string relates to its length, tension, and mass.[89]

While Galileo's trouble came from conflicts with the Church, Johannes Kepler's (1571–1630) trouble also came from conflicts with empirical data. Kepler's story is shared here to show the challenge of conducting empirical investigations into harmony. Kepler was enamored by his own vision of harmony—it seemed so perfect—but the data told a different story.

Kepler believed in a harmonious cosmos and wanted to use newly available astronomical data to illustrate the Pythagorean "Harmony of the Spheres." Kepler believed that the speed of the planets should form natural musical intervals, according to planetary size or distance.[90] Yet, despite his best efforts, Kepler's original formulation of planetary harmony (which was based on the nesting of all five Platonic forms) simply did not conform to the data (Figure 9a). It was *close*, but no closer than other geocentric models. This was a period of great personal distress for Kepler, as his mother had been imprisoned (and eventually died) on the charges of witchcraft. He felt personally responsible because of a book he wrote: his seminal science fiction novel *Somnium* (The Dream).[91] In this book, he described a fictious voyage to visit people living on the moon. However, in the story, the voyage was made possible by demons summoned by a herb doctor—and his mother was a well-known herb doctor. During this extremely stressful period, Kepler wrestled with his own beliefs

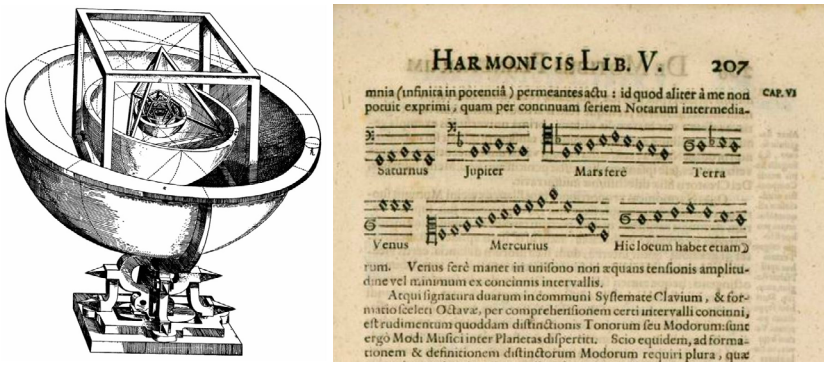
87 Thomas W. Africa, "Copernicus' Relation to Aristarchus and Pythagoras," *Isis* 52, no. 3 (1961): 403, available at https://www.jstor.org/stable/228080.

88 Ibid.

89 Barbieri, "'Galileo's' Coincidence Theory of Consonances."

90 Bruno Gingras, "Johannes Kepler's Harmonice Mundi: A 'Scientific' Version of the Harmony of the Spheres," *Journal of the Royal Astronomical Society of Canada* 97, no. 5 (2003): 228, available at https://adsabs.harvard.edu/pdf/2003JRASC..97..228G.

91 Maria Popova, *Figuring* (New York: Vintage, 2019), available at https://www.themarginalian.org/2019/12/26/katharina-kepler-witchcraft-dream/.



(a) (b)

Figure 9
(a) Kepler's original notion of the harmony of the spheres involved proportions corresponding to a nesting of the simplest three-dimensional shapes (the Platonic solids). However, he eventually discovered a different harmony that fit the data better. (b) Kepler published his laws of gravitation in a book entitled *The Harmony of the World*. It contained musical intervals traversed by the planets. 9a by Kepler, *Mysterium Cosmographicum*, Tübingen, 1596; 9b by Kepler, *Harmonices Mundi Libri V*, Linz, 1619.

in the inherent harmonies of the cosmos. Eventually, dedicated to the data, Kepler was forced to change his conceptualization of harmony.

This change in mindset enabled Kepler to discover what became known as Kepler's Laws of Gravitation. He did not, however, abandon his belief in harmony—he merely updated it. Kepler's laws were presented in a book entitled *Harmonices Mundi* (The Harmony of the World)[92] which printed accurate musical intervals describing the data of orbiting planets (Figure 9b). The key takeaway from Kepler's work is that a belief in rational harmony may inspire scientific discovery, but that we must be willing to change our conceptions of harmony in response to empirical data. [**RP.32**]

Kepler was far from the last scientist to show the mathematical harmonies of the world. In fact, scientists have now discovered planetary systems that appear to be far more harmonious than our own, such as TRAPPIST-1. Here, seven exoplanets are in near-perfect orbital resonance—for instance, for every three cycles of one planet there are exactly two cycles of another planet: this is the musical ratio of a fifth (3:2).[93] Harmony, in a way, has also been central to proving a key theory of the big bang—namely, that in the moment when matter was first formed, acoustic vibrations rang throughout the entire universe, like a bell. These vibrational waves of compression and expansion, known as Baryonic Acoustic Oscillations, helped create contrast in the density of early matter, such that gravitational forces could aggregate the denser regions into galaxies. The first reverberating cosmic harmonies can still be seen in the Cosmic Microwave Background radiation. The discovery of the presence of harmonics in the ringing frequencies served as proof.[94] The takeaway here is that harmony in the cosmos is much more than metaphor—it is, in fact, a pervasive mechanism for the operation of natural forces. [**RP.33**] Furthermore, a common mathematical theory of harmony and resonance can generate specific hypotheses for empirical testing. [**RP.34**]

Robert Hooke (1635–1703) was one of the founders of the English Royal Society, the oldest scientific organization in the world. He was elected as "Chief Curator," a role that required him to technically engineer experiments suitable for demonstration to the Royal Society. In his first years, he conducted multiple experiments regarding the nature of harmony.[95] In one experiment, he investigated how different musical tones produce different spatial geometries [**RP.35**]; using a violin bow, he vibrated a plate of glass with flour sprinkled on it and this resulted in the creation of different geometric forms (this phenomenon is now known as "Cymatics"[96]). Hooke also gave the first conclusive evidence for the periodic nature of sound waves. Using a spinning toothed gear, he produced musical tones; he found that spinning the gear at double the speed produces a tone one octave higher (double the frequency). Most importantly, Hooke's work integrated an understanding of vibrations, large and small, from cathedral-sized pendulums to the oscillations of matter under a microscope. From Hooke we gain the modern perspective that all the atoms in the universe can be modeled as harmonic oscillators. They oscillate back and forth, like springs, where the restoring force is equal to the displacement force. If atoms operate as harmonic oscillators, then the physical cosmos is quite literally composed of harmony (Figure 10). [**RP.36**]

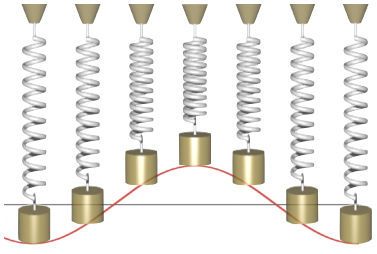


Figure 10
All atoms are harmonic oscillators. They oscillate back and forth, like springs, where the restoring force is equal to the displacement force. Image copyright. Developed based on an animated image created by Svjo at Wikimedia Commons, 2013; licensed under CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0/).

92 Ibid.
93 Kenneth Chang, "The Harmony that Keeps Trappist-1's 7 Earth-size Worlds from Colliding," *New York Times*, May 10, 2017, https://www.nytimes.com/2017/05/10/science/trappist-earth-size-planets-orbits-music.html; Luca Maltagliati, "Harmonious Resonances," *Nature Astronomy* 5, no. 3 (March 2021): 228, https://doi.org/10.1038/s41550-021-01330-2.
94 Amedeo Balbi, *The Music of the Big Bang: The Cosmic Microwave Background and the New Cosmology* (Berlin: Springer, 2008).
95 Penelope Gouk, *Music, Science and Natural Magic in Seventeenth-Century England* (New Haven: Yale University Press, 1999).
96 You Jin Oh and Sojin Kim, "Experimental Study of Cymatics," *International Journal of Engineering and Technology* 4, no. 4 (2012): 434, available at http://www.ijetch.org/papers/404-E3006.pdf.

Newton (1643–1727) took the idea of cosmic harmony to the next level in his *Principia Mathematica* (1687), one of the most important books in the history of science. He showed that the entirety of physical and celestial mechanics could be reduced to a few simple mathematical equations. It may have felt like the world was actually made of math, or as Aristotle described the Pythagorean opinion: "All is Number."[97] Further, with all earnestness, Newton credited Pythagoras for discovering the "inverse-square law of gravitation."[98]

Perhaps the most incredible claim about harmony comes from Christiaan Huygens (1629–1695), also of the Royal Society. In his final book, published posthumously, Huygens speculates about aliens living on other planets. He first explains why it is likely that intelligent aliens will have discovered geometry: "Nature itself invites us to be Geometricians: it presents us with Geometrical Figures, with Circles and Squares, with Triangles, Polygons, and Spheres."[99] These geometrical figures are universal and thus, he claimed, aliens will have developed principles of musical harmony—such as the musical fifth (ratio of 2:3).[100] This is a profound argument: that harmony may be a universal principle, even on alien worlds. [**RP.37**]

Summary of Reflective Propositions from the Renaissance to the Scientific Revolution

[**RP.31**] There are mathematical harmonies in physical forms, from architecture to the human body.

[**RP.32**] Conceptions of harmony can be proved wrong; empirical evidence is important.

[**RP.33**] Harmony in the cosmos is a more than a metaphor—it is an observable physical phenomenon.

[**RP.34**] Mathematical theories of harmony and resonance can generate specific hypotheses for empirical testing.

[**RP.35**] Harmony can manifest as a spatial phenomenon as well as a temporal phenomenon.

[**RP.36**] Atoms (and other physical matter) are based on harmonic oscillation, another example of the harmonic composition of the cosmos.

[**RP.37**] Harmony may be a universal principle; even aliens worlds may have musical 5ths.

Early Modern History of Harmony in Ethics, Aesthetics, Politics, and Economics

Empirical investigations of harmony by leading scientists of the European Enlightenment were also accompanied by philosophical inquiries into the best ways to structure society. This next section now reviews how leading philosophers adopted the notion of harmony for the purpose of designing an ethical society. Their work contributed directly to the development of national and international policies that explicitly aimed for a more harmonious world.

Leibniz (1646–1716) defined harmony in a multitude of ways that were all similar and are presented in Table 2 below.[101] That harmony was primarily

97 Zhmud, "'All Is Number.'"

98 His rationale was that the inverse square law also governs the relationship between pitch and the tension on a string. James E. McGuire and Plyo M. Rattansi, "Newton and the 'Pipes of Pan,'" *Notes and Records: The Royal Society Journal of the History of Science* 21, no. 2 (1966): 108–43, https://doi.org/10.1098/rsnr.1966.0014.

99 Christiaan Huygens, *Cosmotheoros: Or Conjectures Concerning the Planetary Worlds, and Their Inhabitants* (London: Timothy Childe, 1689), Book 1, 88.

100 Ibid.

101 Laurence Carlin, "On the Very Concept of Harmony in Leibniz," *The Review of Metaphysics* 54, no. 1 (2000): 99–125, available at https://www.jstor.org/stable/20131488.

Table 2 **Definitions of harmony found in Leibniz**

Harmony is ... [a]	*Harmonia est ...* [b]
Unity in variety	*unitas in varietate*
A similarity in dissimilar things	*similitudo in dissimilibus*
Uniformly different	*uniformiter difforme*
Diversity identified	*diversitate identitate*
Unity of pluralities	*unitate plurimorum*

"Harmony is when many things are reduced to some unity. For where there is no variety, there is no harmony. Conversely, where variety is without order, without proportion, there is no harmony. Hence, it is evident that the greater the variety and the unity in variety, this variety is harmonious to a higher degree. Hence, dissonances themselves increase pleasantness, if suddenly they are reduced to agreement with other dissonances."[c] [**RP.38**]

[a] Cited in Carlin, "On the Very Concept of Harmony in Leibniz," 100–101.
[b] Ibid.
[c] Ibid., 106.

understood as "unity in variety." This demonstrates that the key role of diversity in harmony was acknowledged early and directly in the European Enlightenment.

Immanuel Kant (1724–1804) is famous for his theories of beauty, reason, and metaphysics. One of Kant's most enduring ideas is the notion of "free play" in the mind. He says: "Poetic art is an artificial play of thoughts. We play with thoughts if we do not labor with them, that is, [they] are [not] necessitated by an end. One merely seeks to entertain oneself with thoughts. For this it is necessary that all the powers of mind are set into an harmonious play."[102] Kant claims that this undirected "free play" of the mind allows for the discovery of harmony, because harmonies are where the brain finds rest. [**RP.39**] In notes taken at a harpsichord concert, Kant wrote, "Harmony arises from the concordance of the manifold, as in music so in poetry and painting. Those are resting points for some nerves."[103] In musical terms, this might be understood as the recognition that harmony offers attractive stability (a resting point) whereas unresolved dissonance produces an unstable but motivating tension. [**RP.40**]

Kant describes beauty using the terms of harmony. For instance: "What sets [the power of the mind] into a harmonious play is beautiful,"[104] or, "Beauty is the property of an object or cognition through which the cognitive faculties are set into a harmonious concord,"[105] or more simply "Beauty is the harmony of sensations."[106] [**RP.41**] This approach avoids the classic debate about whether beauty is inherent to an object or whether it is based on subjective properties; in any case, the sensation of beauty is the result of harmonies in the mind. But, for Kant, harmony was not only relevant to aesthetic experiences. Logic and reason were also based on inner harmonies: "Logic concerns itself only with the harmony of cognition with itself."[107] [**RP.42**] Judgment, too, was a faculty that served the purpose of harmonizing sensations: "The power of judgment seeks to make sensations harmonious among themselves."[108] If judgment aims to harmonize the objects of thought, perhaps greater harmony is associated with more favorable judgements. [**RP.43**]

102 Immanuel Kant, *Notes and Fragments,* ed. Paul Guyer, trans. Curtis Bowman, Paul Guyer, and Frederick Rauscher (Cambridge: Cambridge University Press, 2005), 481.
103 Ibid., 15.
104 Ibid., 536.
105 Ibid., 537.
106 Ibid., 535.
107 Ibid., 36.
108 Ibid., 517.

Harmony in Society: Politics and Economics

The link between harmony, politics, and economic policy began to flourish with Francis Hutcheson (1694–1746). Hutcheson was a Scottish moral philosopher with an enormous impact on the modern world through his influence on the American Founding Fathers. His textbook on moral philosophy was used at Harvard and Yale as early as the 1730s. A specialist of American colonial history describes Hutcheson as "probably the most influential and respected moral philosopher in America in the eighteenth century."[109] It was Hutcheson who introduced the idea of "unalienable rights," such as the collective right to resist oppressive government. Hutcheson was also the originator of utilitarianism (nearly a hundred years before its more famous proponent, Jeremy Bentham), saying, "That action is best, which procures the greatest happiness for the greatest numbers."[110]

One of Hutcheson's key ideas was that humans have *internal senses* that were clearly distinguishable from external senses like seeing and hearing. One of these senses was an internal sense of beauty and harmony. Hutcheson proposes that an inner sense of harmony underpins aesthetic experiences of music, architecture, art, and even mathematics.[111] Hutcheson defined the nature of beauty as "uniformity amidst variety."[112]

What is unique is that Hutcheson linked the study of aesthetics to the study of ethics with a claim that the inner sense also governs *moral* sensibilities. Just as we can perceive pleasure or pain from the harmonious form of a song, Hutcheson explained that we also sense harmony and discord in the emotions, actions, and characters of other people. Thus, an inner sense of harmony could be mutually sensitive to both beauty and virtue. [**RP.44**] Yet, he recognized the danger of relying on this inner sense alone and therefore promoted the idea of "moral computation"—a set of mathematical equations that rationally and scientifically formulates the "course of action [that] does most effectually promote the universal Good."[113] [**RP.45**]

Adam Smith (1723–1790) was the PhD student of Francis Hutcheson. While Smith is best known for his impact in economics, his first book was about empathy (although empathy was only coined in 1909; before then, the concept of "feeling what others feel" was known as sympathy[114]). In *A Theory of Moral Sentiments* (1759), Smith aimed to describe the motivation for people to act virtuously and do good to one another. Smith proposes that *sympathy* is a central motivator for moral behavior and explains that emotions spread between people through this mechanism.[115] Smith claims that our morality operates through a type of sympathetic resonance of emotion: we feel bad when others feel bad and feel good when others feel good. Human sympathy motivates human morality because it feels good to help others feel good. This leads to a harmony of interests: helping others to feel good will make oneself feel good. [**RP.46**]

> "It is only through this that men can have the harmony of sentiments and passions that constitutes their whole grace and propriety."[116]

Smith's most influential work, *An Inquiry into the Causes of the Wealth of Nations* (1776), also investigated the motivations for people to do good to one another. Smith describes how the rational pursuit of self-interest in commerce

109 Norman Fiering, *Moral Philosophy at Seventeenth-Century Harvard: A Discipline in Transition* (Chapel Hill, NC: University of North Carolina Press, 1981), 199.

110 Francis Hutcheson, *An Inquiry into the Original of Our Ideas of Beauty and Virtue: In Two Treatises*, ed. Wolfgang Leidhold (Indianapolis, IN: Liberty Fund, 2004), 125.

111 His example of mathematical beauty: the volume of a cone, a hemisphere and a cylinder have a ratio of 1:2:3.

112 Hutcheson, *An Inquiry into the Original of Our Ideas*, 28.

113 Ibid., 179. This "moral computation" surely has implications for the design of future ethical systems in Artificial Intelligence.

114 Eric Schliesser, ed., *Sympathy: A History* (Cambridge: Oxford University Press, 2015).

115 Seth Lobis, *The Virtue of Sympathy: Magic, Philosophy, and Literature in Seventeenth-Century England* (New Haven: Yale University Press, 2015).

116 Adam Smith, *The Whole Works of Adam Smith: Volume 1* (London: Richardson and Co., 1822), 21.

and trade can result in a mutual, moral benefit to society as a whole. [**RP.47**] Smith's idea implicates a natural harmony between individual interests and the common interest. If the idea that rational commerce and competitive exchange could generate so much moral behavior seems radical now, imagine the reaction in the 1770s, when the majority of people believed that morality was fully dependent upon the threat of law and the fear of divine wrath in the afterlife. That said, Smith was well aware that the collusion of moneyed interests was often directly opposed to the public interest: "People of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in a conspiracy against the public or in some contrivance to raise prices."[117] Nevertheless, Smith provided an enduring philosophical explanation for the *moral* basis of market economies.

Inspired by Smith, Frédéric Bastiat (1801–1850) sought to show why markets benefited humanity through the emergence of complex natural harmonies. Bastiat died just before the publication of his magnum opus, *Harmonies économiques* (1851). His book is a poetic account of how and why market economies tend to form into harmonious systems (that is, organized wholes that effectively integrate diversity)—which Bastiat relates to the harmonious orbits of the planets. [**RP.48**] He was a strong advocate for serving social needs through markets rather than direct government intervention: "It is as if the socialists were to accuse us of not wanting persons to eat because we do not want the state to raise grain."[118]

In his day, Bastiat was viewed as a kind of arch-conservative by Karl Marx, who considered him a "vulgar" defender of capitalism. However, they had a surprising alignment of values, and Marx felt compelled to write a small tract defending himself from accusations that he had plagiarized Bastiat's theory of value, namely, that monetary value derives from the amount of time that a good or service can replace. "The work of others only serves to save us time, and this time-saving is all that constitutes its value, and its price."[119]

Despite Bastiat's unabashed love of free markets, he did not argue for them based on the principle of liberty. Bastiat argues *against* liberty as the underlying moral basis of markets; instead, he puts liberty in the service of harmony as a moral principle.

> "The conclusion of the Economists is for Liberty. But in order that this conclusion should take hold of men's minds and hearts, it must be solidly based on this fundamental principle, that interests, left to themselves, tend to harmonious combinations, and to the progressive preponderance of the general good."[120]

In other words, harmony is the moral basis for markets, not liberty. [**RP.49**] Bastiat asserted that liberty naturally produces harmony as human interests, left alone, naturally and rationally align. This view celebrates the role of liberty in market economies even as it subjects liberty to a greater purpose: creating societal harmony. Bastiat's natural harmonies offer a philosophical explanation for the unexpected morality of market economies.

Other leading economists agreed with the harmonizing power of markets but also advocated for the moderating role of government. The chief economic advisor to US President Abraham Lincoln was Henry Charles Carey

117 Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations* (1776; Chicago: University of Chicago Press, 1976), 144.

118 Norman Barry, "Bastiat's 'the Law,'" *IEA Occasional Paper* No. 123 (2005): 46, https://doi.org/10.2139/ssrn.677441.

119 Karl Marx, "My Plagiarism of F. Bastiat," in *Karl Marx, Frederick Engels: Collected Works, Volume 20* (New York: International Publishers, 1986), 261.

120 Frédéric Bastiat, *Harmonies of Political Economy*, trans. Patrick James Stirling (London: John Murray, 1860), 6.

(1793–1879). Carey published *The Harmony of Interests: Agricultural, Manufacturing, and Commercial* in 1851. Carey writes in direct opposition to the British system of *laissez faire*, which he claimed was prone to corruption and unhealthy centralization. Carey aimed to deliver a philosophically and scientifically sound alternative to the zero-sum pessimism of Malthusian economics (which claims that poverty will necessarily worsen as populations grow). Carey claimed, instead, that there existed "a unity of law leading to perfect harmony of all real and permanent human interests, and directly opposed to the discords taught by Mr. Malthus."[121]

Carey advocated for state interventions that would create the conditions for natural economic harmony. He fought for government acts that fostered the natural harmony between the interests of labor and of capital. He noted that, when wages rise in a growing economy, then "the proportion of the capitalist falls, yet now … [he] accumulates fortune more rapidly than ever, and thus his interest and that of the labourer are in perfect harmony with each other."[122] Carey's policy of moderated government intervention in a relatively free market became known as "the American School" or the "American System," which lasted roughly from 1870–1970.[123]

In 1872, Carey published an extensively researched book describing the unity of all sciences. Entitled *Unity of Law: As Exhibited in the Relations of Physical, Social, Mental and Moral Science*, the book describes a universal harmony in physics, psychology, and economic governance. The book emphasizes respect for diversity, free exchange, and interdependence. The following quote epitomizes Carey's view on harmony and how it connects physics to society:

> "As among individuals, the power of association grows with the development of individuality.… So, too, is it with nations, the tendency toward general peace and harmony being in the ratio of their interdependence; that, in its turn, being in the direct ratio of their independence.…"[124]

This is an important and unintuitive idea: that human diversity is necessary for interdependence, connection, and exchange. [**RP.50**] What is the need to connect, if everyone is the same? That diversity should naturally increase the power of social unity is a powerful notion. Carey carefully describes how this harmony naturally arises:

> "The more thorough the development of differences among men, and the more perfect the power of self-direction, the more complete becomes their interdependence; the greater the harmony in the societary relations; the larger the production; the more rapid the circulation; the more equitable the distribution.… The reverse of this, however, is what we are told in English books.… Under that system [unconstrained laissez faire capitalism], interdependence in the bosom of the society dies away.…"[125]

Carey's idea was that when people are diverse, self-directed, and independent, they have a natural tendency to develop associations of interdependence. A division of labor, for instance, produces greater organizational complexity and greater unity. Similarly, a diverse society of many different people enhances the capacity for trade and exchange — forces that bind society together. Abraham Lincoln's economic advisor is little known today, but he had a major influence on global economic development. And, while

121 Henry Charles Carey, *The Unity of Law: As Exhibited in the Relations of Physical, Social, Mental, and Moral Science* (Philadelphia: HC Baird, 1872), ix.

122 Henry Charles Carey, *The Harmony of Interests, Agricultural, Manufacturing, and Commercial* (Philadelphia: HC Baird, 1868), 152.

123 Rodney J. Morrison, "Henry C. Carey and American Economic Development," *Transactions of the American Philosophical Society* 76, no. 3 (1986): i–ix+1–91, https://doi.org/10.2307/1006463.

124 Carey, *The Unity of Law*, 145.

125 Ibid., 145–46.

Western readers may find it strange to consider the key role of harmony in contemporary communist China, harmony played a leading role in the moral philosophy of market economies.

Summary of the History of Harmony

The concept of harmony has helped shape the modern world through a well-known cast of characters: Confucius, Laozi, Plato, Copernicus, Galileo, Newton, Adam Smith, and others. To each, harmony offered a rational framework for understanding complex scientific, ethical, and aesthetic phenomena. It connected the qualitative to the quantitative and gave a pathway for understanding how observable, complex experiences might have a common, mathematical root. The concept of harmony offers a useful narrative frame for making sense of how and why a complex world holds together.

Summary of Reflective Propositions from the Early Modern Period

[**RP.38**] Harmony is unity in variety. No variety, no harmony. The greater the variety and the greater the unity, the greater the harmony.

[**RP.39]** The undirected "free play" of the mind allows for the discovery of harmony.

[**RP.40**] Harmony is a resting point or attractor for the brain; dissonance motivates change.

[**RP.41**] The perception of beauty is the result of harmony in the mind.

[**RP.42**] Logical coherence is based on the harmony of cognition with itself.

[**RP.43**] If judgment aims to harmonize the objects of thought, perhaps greater harmony is associated with more favorable judgements.

[**RP.44**] Humans have an internal sense of harmony used for aesthetic and moral judgements—the inner sense of harmony is sensitive to virtue and beauty.

[**RP.45**] The sense of harmony is not infallible. An alternative is rational "moral computation."

[**RP.46**] People have sympathetic resonance with one another; as a result, they feel good when others feel good and feel bad when others feel bad. This leads to a harmony of interests (helping others to feel good makes oneself feel good).

[**RP.47**] There is a harmony of interest between individual self-interest and society. The rational pursuit of self-interest in commerce and trade can result in a mutual, moral benefit to society.

[**RP.48**] A market economy, in producing harmonies of interest, can generate new wholes (organizations, systems, etc.) due to richly differentiated labor.

[**RP.49**] Harmony can serve as the moral basis for market economies.

[**RP.50]** Human diversity is necessary for interdependence, connection, and exchange.

Part Two: Harmony in the Modern Era

The concept of harmony may sound, at times, unscientific. Yet, Albert Einstein once wrote that, "without the belief in the inner harmony of our world, there could be no science."[126] His colleague at Princeton, David Bohm (1917–1992), wrote that all scientists wish "to find in the reality in which he lives a certain oneness and totality, or wholeness, constituting a kind of harmony that is felt to be beautiful." Bohm did not claim that this motivation was unique to scientists. Rather, "the artist, the musical composer, the architect, the scientist — all feel a fundamental need to discover and create something new that is whole and total, harmonious and beautiful."[127] [**RP.51**] This next section reviews the role of harmony in psychology, neuroscience, computer science, and the humanities.

Harmony in Psychology

Harmony and Cognitive Dissonance

The human psyche is composed of a vast hierarchy of competing motivations — to eat, to sleep, to play, etc. However, we are limited by the fact that we can only do one thing at a time. When we desire two things that we cannot have simultaneously, we experience internal conflict as a sort of pain. In 1957, Leon Festinger (b. 1919) described this phenomenon using the idea of "Cognitive Dissonance,"[128] which he asserted as a basic motivating drive, energizing and directing human behavior. "Just as hunger is motivating, cognitive dissonance is motivating. Cognitive Dissonance will give rise to activity oriented toward reducing or eliminating the dissonance. Successful reduction of dissonance is rewarding in the same sense that eating is rewarding."[129]

This suggests the brain must always be *harmonizing* competing motivations into coherent intentions and actions. Motivational theorist Bernard Weiner (b. 1935) articulates this idea: "When cognitions are not in harmony, processes are instigated to help bring cognitive structures into consonance."[130] In short, "cognitive dissonance" motivates people to do mental work that enables conflicting desires to be resolved into harmony. The brain seems to have the special ability to balance a multitude of competing motivations (internal motivations as well as the motivations of other people) to minimize dissonance and maximize harmony. [**RP.52**] Indeed, this suggests that much of everyday mental experience can be understood as a process of harmonization. [**RP.53**]

Harmony and Flow

The field of Positive Psychology focuses on positive aspects of the human experience like human happiness and well-being. One of the most influential theories in the field is the theory of "flow" by Mihály Csíkszentmihályi (b. 1934). Flow or flow states are a sort of trance state that involve the complete absorption of a person in their task. Flow is produced by a pleasurable interplay between a person and their environment, as they concentrate and couple their abilities to the demands of the activity.[131] Flow generally occurs when the demands of a task fully engage a person's abilities but does not overwhelm them. [**RP.54**]

Csíkszentmihályi defines "Flow States" in terms of harmony: "Flow is the way people describe their state of mind when consciousness is harmoniously ordered…."[132] He seems to use the term "harmoniously" specifically in the

126 Albert Einstein and Leopold Infeld, *The Evolution of Physics* (Cambridge: Cambridge University Press, 1938), 296.
127 David Bohm, *On Creativity*, 2nd ed., ed. Lee Nichol (London: Routledge, 2004), 3.
128 Leon Festinger, *A Theory of Cognitive Dissonance* (Stanford, CA: Stanford University Press, 1957).
129 Ibid.
130 Bernard Weiner, *Human Motivation: Metaphors, Theories, and Research*, 2nd ed. (Thousand Oaks: Sage, 1992), 305.
131 Mihaly Csikszentmihalyi, *Flow: The Psychology of Optimal Experience* (London: Ebury Publishing, 2013).
132 Ibid., 6.

classical sense of unity in variety: "When an important goal is pursued with resolution, and all one's *varied* activities fit together into a *unified* flow experience, the result is that harmony is brought to consciousness."[133]

Unified flow experiences bring harmony to consciousness because they produce what might be called "whole-mindedness": a complete integration of the varied parts of the self. When people are split in their motivation or thoughts, there is cognitive dissonance; when the parts of their consciousness are unified into a whole, there is flow. [**RP.55**]

Harmony, Happiness, and Mental Health

Recent empirical research shows that harmony is globally ubiquitous as an everyday "lay-person" conception of happiness. A cross-cultural study was undertaken to collect open-ended definitions of happiness from 2799 adults from Argentina, Brazil, Croatia, Hungary, India, Italy, Mexico, New Zealand, Norway, Portugal, South Africa, and the United States. The researchers found that, "across countries and with little variation by age and gender, inner harmony predominated among psychological definitions, and family and social relationships among contextual definitions."[134] In other words, human happiness is commonly understood as inner harmony and harmony in one's relationships. [**RP.56**]

During the Covid-19 pandemic, a study of 12,203 participants from 30 countries revealed that a harmony-based measure of happiness (known as mature happiness) was a separate and complimentary factor of happiness alongside a more well-known model of happiness PERMA ("Positive Emotions, Engagement, Relationships, Meaning, and Achievement"). The researchers found that the measure of inner harmony was a better predictor of anxiety and distress than PERMA.[135] This suggests that the lack of harmony is associated with mental distress. [**RP.57**] Much more can be said about the role of harmony in psychology, but this brief review suggests, to some degree, the *obviousness* of harmony as a primary goal for humans—and, by extension, for human-centered designers. [**RP.58**]

Summary of Reflective Propositions from Psychology

[**RP.51**] There is a widespread motivation to discover and design new things that are whole, harmonious, and beautiful.

[**RP.52**] Conflicting cognitions lead to dissonance, which motivates people to take actions to create harmony.

[**RP.53**] Much of everyday mental experience can be understood as a harmonizing process.

[**RP.54**] A balance or harmony between the mind and the world produces a state of flow.

[**RP.55**] Harmony emerges in experience when one's varied activities fit together into a unified flow. Divided minds experience dissonance while minds that are singularly focused (i.e., whole-mindedness) experience flow.

[**RP.56**] Human happiness is commonly understood as inner harmony and harmony in one's relationships.

133 Ibid., 217, italics added.

134 Antonella Delle Fave et al., "Lay Definitions of Happiness across Nations: The Primacy of Inner Harmony and Relational Connectedness," *Frontiers in Psychology* 7, no. 30 (2016): 1, https://doi.org/10.3389/fpsyg.2016.00030.

135 David F. Carreno et al., "Inner Harmony as an Essential Facet of Well-Being: A Multinational Study During the COVID-19 Pandemic," *Frontiers in Psychology* 12 (March 2021): 911, https://doi.org/10.3389/fpsyg.2021.648280.

[**RP.57**] The lack of harmony is associated with mental distress and anxiety.

[**RP.58**] Harmony is a primary psychological goal for humans—and by extension, for designers.

Harmony in Neuroscience

Harmony need not be viewed with wide-eyed wonder but can also be the basis for reasoned mathematical interpretation. For instance, rhythmic oscillations are pervasive in living systems, from the cycles of sleep, breath, or of a beating heart. Each of the billions of neurons in the brain are, technically speaking, a rhythmic oscillator[136]—meaning that neurons naturally synchronize with one another and demonstrate resonance effects. Individual neurons aren't just on/off switches but can be attuned to respond to different frequencies of input, like "strings on a violin."[137] The brain is a symphony of interlocking rhythms—rhythms that are somehow used to accomplish computational processes.[138] And, the many different oscillations of the brain are coupled with the rhythms of the human body (breathing, heartbeats, locomotion, etc.) in a nested, hierarchical architecture.[139] This architecture can be easily described in terms of actual musical harmony. [**RP.59**]

The harmonic structure of brainwaves is well-established. In a paper cited over 1,800 times, EEG researcher Wolfgang Klimesch describes the "frequency architecture" of brainwaves as resting upon harmonic and resonant relationships.[140] He provides three main points to consider:

1. "Alpha-band activity [~10 Hz] is the dominant—and most resonant—frequency in the awake, conscious brain and the main factor in the coalescence of oscillations."
2. "Harmonic frequencies allow optimal between-frequency communication with the alpha band and they define the center frequencies of traditional frequency bands."
3. "Golden mean frequencies (relative to alpha) allow one to define the frequency separation between frequency domains, as well as the width of each band."[141]

Brainwaves have a clear harmonic relationship—and we are not speaking metaphorically here. Brainwaves are structured around *octaves* (i.e., brainwave bands are frequency doublings with a 1:2 ratio). [**RP.60**] That is, the Alpha-band is a range of electrical fluctuation that occurs roughly 10 times a second (10 Hz)—and Beta-band activity (~20 Hz) is roughly double the frequency of Alpha. In turn, Gamma-band activity (~40 Hz) is roughly double Beta. The "subharmonics" of Alpha waves are Theta waves (~5 Hz, half of Alpha) and Delta waves (~2.5 Hz, half of Theta). Plato claimed that "harmony has motions akin to the revolutions of our soul"[142] and indeed, the oscillations of the human psyche are strongly akin to the oscillations of music. [**RP.61**]

In music, the alignment between notes is called consonance; in brain waves an apparently identical numerical relationship between high and low frequencies is known as "cross frequency coupling." This coupling is computationally essential because it helps explain how information can be transacted between fast, local oscillations and slower, global oscillations.

136 Klaus M. Stiefel and G. Bard Ermentrout, "Neurons as Oscillators," *Journal of Neurophysiology* 116, no. 6 (2016): 2950–60, https://doi.org/10.1152/jn.00525.2015.

137 Anindita Das, Rahul K. Rathour, and Rishikesh Narayanan, "Strings on a Violin: Location Dependence of Frequency Tuning in Active Dendrites," *Frontiers in Cellular Neuroscience* 11 (March 2017): 72, https://doi.org/10.3389/fncel.2017.00072.

138 György Buzáki, *Rhythms of the Brain* (Oxford: Oxford University Press, 2006).

139 Wolfgang Klimesch, "The Frequency Architecture of Brain and Brain Body Oscillations: An Analysis," *European Journal of Neuroscience* 48, no. 7 (2018): 2431–53, https://doi.org/10.1111/ejn.14192.

140 Wolfgang Klimesch, "Alpha-Band Oscillations, Attention, and Controlled Access to Sored Information," *Trends in Cognitive Sciences* 16, no. 12 (2012): 612, https://doi.org/10.1016/j.tics.2012.10.007.

141 Ibid., 613.

142 Plato, *Plato in Twelve Volumes*, trans. W. R. M. Lamb (Cambridge: Harvard University Press, 1925), 9:47.

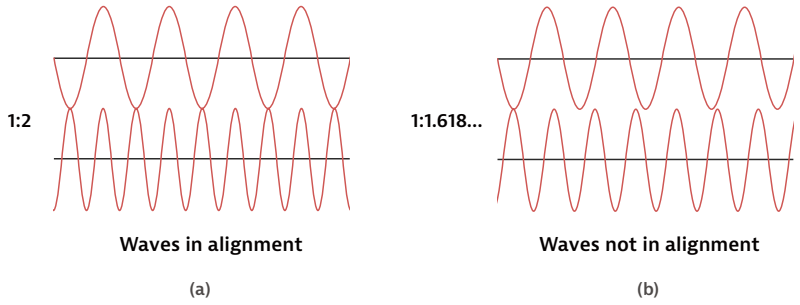


Figure 11
(a) Harmonic proportions (doublings of frequency) maximize interaction between two waves whereas; (b) the golden mean ("the most irrational number") proportions result in non-interaction. Irrational frequency ratios never line up, whereas harmonic frequency ratios produce regular synchrony. Harmonic integration occurs when faster frequencies are aligned fused into a pattern of slower frequencies, such that a nested whole is created. © 2022 J. Derek Lomas.

Harmonic relationships maximize interactions between oscillations; for example: "During states of active processing, harmonic relationships (such as theta/upper alpha, 6:12 Hz) predominate."[143] This is because harmonic proportions result in a greater amount of periodic synchrony (see Figure 11 and Figure 7). In contrast to these harmonics, the so-called golden ratio is "the most irrational number";[144] brain oscillations meeting with the ratio of the golden ratio (also called the Greek letter phi, Φ, and approximated by the decimal 1:1.168…) will essentially eliminate periodic interactions. While the importance of the golden mean is often overstated in design and architecture,[145] the ratio does have important properties as an irrational number. Two frequencies at the golden ratio will never align—thus, when brain frequencies have an irrational ratio, their simultaneous activity will not couple or interact. [**RP.62**] This enables neural multiplexing, where two brainwaves can operate near each other without interfering (like a high theta and a low theta). All told, the classical theory of harmony provides a simple but powerful model for explaining the complex dynamics of neural oscillations. [**RP.63**]

A Hierarchy of Harmony

The harmonic structure of the brain involves a nested hierarchy of frequency couplings that connect the local to the global.[146] For instance, local ~40 Hz gamma cycles can fit into the brain-wide rhythm of ~4 Hz Theta oscillations. Similarly, rhythmic synchronization seems to bind together smaller nested elements into whole units. For instance, oscillatory chunks of language are merged together through rhythmic nested synchrony[147]—phonemes nested in syllables nested in words nested in phrases, and so on (Figure 12).

Harmony and Perceptual Binding in Vision

Perceiving an object as a "whole" requires a process of harmonization, where diverse visual elements can be perceived as a unity or whole object. Consider the picture of the fish in Figure 13. As a gestalt[148] or "wholeness," there is a definite hierarchy: the dots compose triangles; the three triangles together (the head, the body and the tail) then compose the fish. "The binding problem" of perception refers to how the brain is able to unify

143 Belinda Pletzer, Hubert Kerschbaum, and Wolfgang Klimesch, "When Frequencies Never Synchronize: The Golden Mean and the Resting EEG," *Brain Research* 1335 (June 2010): 93, https://doi.org/10.1016/j.brainres.2010.03.074.

144 Nikos Salingaros, "Applications of the Golden Mean to Architecture," *Meandering Through Mathematics* 21 (2012): online, available at https://patterns.architexturez.net/doc/az-cf-172604.

145 Ibid., 95.

146 Peter J. Uhlhaas et al., "Neural Synchrony in Cortical Networks: History, Concept and Current Status," *Frontiers in Integrative Neuroscience* 3 (July 2009): 17, https://doi.org/10.3389/neuro.07.017.2009.

147 György Buzsáki, *The Brain from Inside Out* (New York: Oxford University Press, 2019).

148 Steven Lehar, "Gestalt Isomorphism and the Primacy of Subjective Conscious Experience: A Gestalt Bubble Model," *Behavioral and Brain Sciences* 26, no. 4 (2003): 375–408, https://doi.org/10.1017/s0140525x03000098.

diverse elements into a singular object[149] — to turn variety into a unity. The brain is able to "chunk" elements into a whole in a hierarchical fashion, with chunks made of sub-chunks made of sub-chunks and so on.

This process of visual harmonization (bringing diversity into unity) is rhythmic and even musical. According to the theory of perceptual "binding through synchrony," the brain represents elements in an object with a common rhythm. That is, the brain uses rhythmic synchronization to bind together the different elements in an object.[150] Different objects in the visual field will have different binding rhythms; for instance, a whole teapot would have one common synchronization rhythm, but if the handle were broken off, the brain would assign a different rhythm to the handle. In Figure 13, this would imply that the visual unity of the fish is achieved through rhythmic synchronization.

How does "binding by synchrony" work? When an object is perceived in the visual cortex, the parts of the cortex spatially corresponding to the parts of the object all receive a phase-locked ~40 Hz signal from inhibitory interneurons. The synchronized inhibition synchronizes the firing from the different parts of the cortex — the diverse neurons will all fire together when the amplitude of the inhibitory neural firing is lowest. Another part of the brain can "tune in" to

149 Andrey Vyshedskiy, "Neuroscience of Imagination and Implications for Human Evolution," *Current Neurobiology* 10 (February 2019): 89–109, https://doi.org/10.31234/osf.io/skxwc.

150 Andreas K. Engel, Pascal Fries, and Wolf Singer, "Dynamic Predictions: Oscillations and Synchrony in Top-Down Processing," *Nature Reviews Neuroscience* 2, no. 10 (2001): 704, https://doi.org/10.1038/35094565; Pascal Fries, "A Mechanism for Cognitive Dynamics: Neuronal Communication through Neuronal Coherence," *Trends in Cognitive Sciences* 9, no. 10 (2005): 474–80, https://doi.org/10.1016/j.tics.2005.08.011.

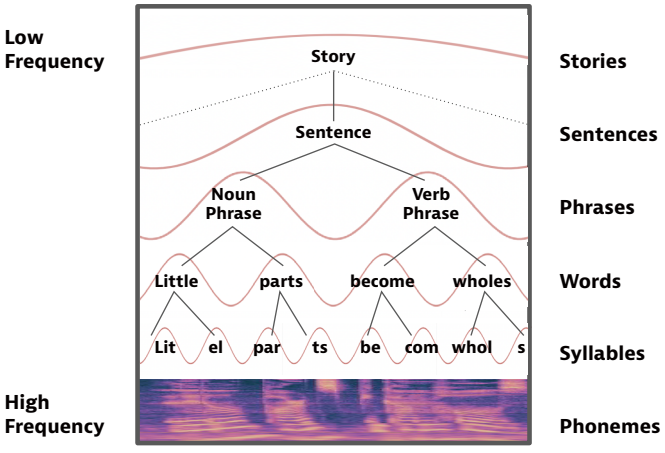


Figure 12
Phonemes nest into syllables which nest into words which nest into phrases which nest into sentences which nest into stories. © 2022 J. Derek Lomas.

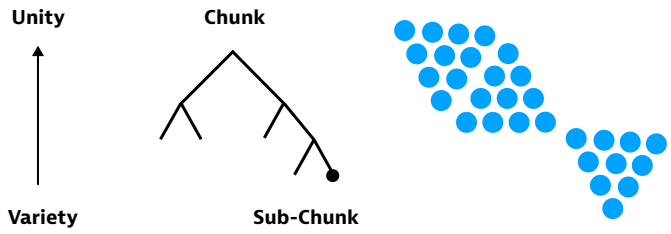


Figure 13
It is a property of the human experience that we can pay attention to only one thing at a time (give or take). The mind can turn perceptual variety into a unitary experience through hierarchical chunking. The perception of objects, language, and music involves nested hierarchies, just as the image of the fish emerges out of the gestalt composition of parts. © 2022 J. Derek Lomas.

those specific elements of the whole object by "patching in" to the frequency and phase of the shared ~40 Hz inhibitory firing. Neural synchronization thus enables communication between different parts of the brain and provides an account for the "chunking" of varied perceptual elements into a whole.[151] The brain harmonizes perceptual input using nested hierarchies of rhythm in order to create a unified perceptual experience. [**RP.64**]

Harmony and Conceptual Binding in Culture

The mechanism of hierarchical rhythmic integration described above applies to the unified perception of objects[152] but also to language[153] and, of course, to music.[154] [**RP.65**] It may also play a key role in the conception of novel objects in the imagination. The ability to imagine things that don't exist—that is, to flexibly combine random conceptual components into new conceptual wholes—is an extremely powerful cognitive ability. A recent theory of human cultural evolution points to the potential role of musical harmony and rhythm in enabling more complex imaginative cognitive possibilities.[155] The evidence comes from the profound discovery that the earliest example of representational art in Europe (the Löwenmensch, which shows an innovative combination of a man with a lion head) was discovered less than a meter away from one of the earliest examples of a bone flute (both dated to about 35,000 BCE). The theory is that the emergence of musical culture enabled new cognitive capabilities, including the ability to flexibly imagine any set of arbitrary concepts in the mind. Why might musical harmony or rhythm help support the imagination?

Recall that the "binding through synchrony" theory describes how diverse elements in the visual field can be unified together into objects using a common, synchronized rhythm. Just as arbitrary visual elements might be synchronized together to create a unitary whole,[156] arbitrary semantic elements might also be capable of being bound together into novel concepts through a similar form of synchronization. [**RP.66**] If so, the emergence of musical rhythms or harmonies in culture may have developed the cognitive proficiency to synchronize, harmonize and MERGE[157] complex concepts together. The ability to appreciate musical harmony may have triggered a cognitive revolution in the imagination.[158]

Harmony as a Selection Force in Consciousness and the Brain

The harmonization described in the sections above is presented as a physical mechanism in the brain that enables the creation of unified conscious experiences. As neuroscientists seek a "common currency"[159] to explain the link between immaterial mental experiences and physical brain activities, the concept of harmony is a strong candidate. [**RP.67**] One of the most popular theories of consciousness is known as the "Global Neuronal Workspace."[160] With the assumption that a person can have only *one* conscious experience at a time, the theory proposes that consciousness emerges as the result of mental elements that temporarily win an ongoing competition to integrate into the single, unified global neuronal workspace.

A guitar string illustrates how harmonization can play a role as a selection pressure in this competition. When a guitar string is plucked, a massive range of frequencies is produced. However, only the frequencies that *fit* will survive.[161] Specifically, only the vibrations with wavelengths that *literally fit the length of*

151 György Buzsáki and Brendon O. Watson, "Brain Rhythms and Neural Syntax: Implications for Efficient Coding of Cognitive Content and Neuropsychiatric Disease," *Dialogues in Clinical Neuroscience* 14, no. 4 (2012): 345, https://doi.org/10.31887/DCNS.2012.14.4/gbuzsaki.

152 Lucia Melloni et al., "Computation and Its Neural Implementation in Human Cognition," in *The Neocortex*, ed. W. Singer, T. J. Sejnowski, and P. Rakic Strüngmann (Cambridge, MA: MIT Press, 2019), 323–46, available at http://hdl.handle.net/21.11116/0000-0005-A3AE-F.

153 David Poeppel and M. Florencia Assaneo, "Speech Rhythms and Their Neural Foundations," *Nature Reviews Neuroscience* 21, no. 6 (June 2020): 322–34, https://doi.org/10.1038/s41583-020-0304-4; Elliot Murphy, *The Oscillatory Nature of Language* (Cambridge: Cambridge University Press, 2020), https://doi.org/10.1017/9781108864466.

154 Fred Lerdahl and Ray S. Jackendoff, *A Generative Theory of Tonal Music* (Cambridge, MA: MIT Press, 1996).

155 Vyshedskiy, "Neuroscience of Imagination and Implications."

156 Andreas K. Engel and Wolf Singer, "Temporal Binding and the Neural Correlates of Sensory Awareness," *Trends in Cognitive Sciences* 5, no. 1 (2001): 16–25, https://doi.org/10.1016/S1364-6613(00)01568-0.

157 Robert C. Berwick and Noam Chomsky, "All or Nothing: No Half-Merge and the Evolution of Syntax," *PLoS Biology* 17, no. 11 (2019): e3000539, https://doi.org/10.1371/journal.pbio.3000539.

158 Albert Lin and J. Derek Lomas, "Enigma of Mind: A Theory of Evolution and Conscious Experience," in *Enigma: Darwin College Lecture Series* (Cambridge: Cambridge University Press, 2022).

159 Georg Northoff, Soren Wainio-Theberge, and Kathinka Evers, "Is Temporo-Spatial Dynamics the 'Common Currency' of Brain and Mind? In Quest of 'Spatiotemporal Neuroscience,'" *Physics of Life Reviews* 33 (July 2020): 34–54, https://doi.org/10.1016/j.plrev.2019.05.002.

160 Stanislas Dehaene, Hakwan Lau, and Sid Kouider, "What Is Consciousness, and Could Machines Have It?," *Science* 358, no. 6362 (2017): 486–92, https://doi.org/10.1126/science.aan8871.

161 David A. Jaffe and Julius O. Smith, "Extensions of the Karplus-Strong Plucked-String Algorithm," *Computer Music Journal* 7, no. 2 (1983): 56–69, available at http://www.jstor.org/stable/3680063.

the guitar string will be amplified—due to constructive interference—and all the other frequencies will be damped. The frequencies that fit and survive include the string's fundamental frequency and harmonics of the fundamental. "Survival of the harmonized" describes the fact that, among a multitude of diverse frequencies, only the frequencies that fit or harmonize will survive. By analogy, rhythmic elements in the brain that do not fit or harmonize with dominant neural rhythms[162] may be unable to enter conscious awareness. In this way, harmony could serve as a "fitness function" in the brain; neural circuits may be tuned through this selection force to maximize harmony.[163] [**RP.68**]

Recently, scientists have discovered that electrical oscillations in the brain can produce so-called "harmonic modes":[164] hierarchical, global electrical patterns that resemble the beautiful patterns of sand that Robert Hooke discovered emerging on a vibrating plate (see Cymatics or Chladni Plates). Science is only beginning to unravel how the brain's massive hierarchy of neural oscillations fits together in a rhythmic, metrical structure. While much remains to be discovered, the mathematical principles of harmony clearly manifest in the brain—just as they do in the rest of the cosmos.

Restoring Harmony in the Brain: Synchronization and Desynchronization

How might this concept of a fundamentally musical mind help inform the design of useful applications for societal benefits? Here we recognize that concept of harmony is perhaps the oldest theory of mental health and disease. In a modern setting, harmony and related notions of coherence and synchrony could provide a simple, intuitive and testable framework for devising interventions for various mental disorders. This is because many psychiatric disorders are associated with either a deficit of coherence and synchrony between different parts of the brain,[165] as is the case with Schizophrenia and Alzheimer's disease, or with an excess of coherence. Major depression, for instance, is associated with excess neural coherence during resting states, which may "reflect depressive biases toward internal thoughts at the cost of engaging with the external world."[166] Parkinson's disease produces motor tremors because the motor system is unable to break out of a repetitive loop—again, an excess of coherence. And, epileptic seizures result from runaway synchronization in the brain.[167] Too much unity and not enough diversity—or vice versa—is unhealthy for the brain and body. Designers (and medical doctors), might then consider both how they could enhance harmony through synchronization strategies but also through a recognition of the value of *desynchronization*. [**RP.69**]

Deep brain stimulation (DBS), which has been proven to be helpful in the treatment of Parkinson's disease, uses tuned rhythmic electrical stimulation that is designed to disrupt and desynchronize overly strong coherent rhythms in the basal ganglia.[168] Similarly, DBS and electroshock therapy are effective for treating major depression—again, through an approach of trying to disrupt pathologically excessive internal brain rhythms and rumination loops. There is now an opportunity to use less invasive stimulation techniques such as transcranial alternating current stimulation (TACS)[169] or design interventions based on flickering lights, pulsing sounds, vibrations, or other techniques.

162 Pascal Fries, "Rhythms for Cognition: Communication through Coherence," *Neuron* 88, no. 1 (2015): 220–35, https://doi.org/10.1016/j.neuron.2015.09.034; Randolph F. Helfrich, Assaf Breska, and Robert T. Knight, "Neural Entrainment and Network Resonance in Support of Top-Down Guided Attention," *Current Opinion in Psychology* 29 (October 2019): 82–89, https://doi.org/10.1016/j.copsyc.2018.12.016.

163 Lin and Lomas, "Enigma of Mind."

164 Selen Atasoy, Isaac Donnelly, and Joel Pearson, "Human Brain Networks Function in Connectome-Specific Harmonic Waves," *Nature Communications* 7, no. 1 (January 2016): 1–10, https://doi.org/10.1038/ncomms10340.

165 Peter J. Uhlhaas and Wolf Singer, "Neural Synchrony in Brain Disorders: Relevance for Cognitive Dysfunctions and Pathophysiology," *Neuron* 52, no. 1 (2006): 155–68, https://doi.org/10.1016/j.neuron.2006.09.020.

166 Roselinde H. Kaiser et al., "Large-Scale Network Dysfunction in Major Depressive Disorder: A Meta-Analysis of Resting-State Functional Connectivity," *JAMA Psychiatry* 72, no. 6 (2015): 603–11, https://doi.org/10.1001/jamapsychiatry.2015.0071.

167 Niranjan Chakravarthy et al., "Controlling Synchronization in a Neuron-Level Population Model," *International Journal of Neural Systems* 17, no. 2 (2007): 123–38, https://doi.org/10.1142/S0129065707000993.

168 Charles J. Wilson, Bryce Beverlin II, and Theoden Netoff, "Chaotic Desynchronization as the Therapeutic Mechanism of Deep Brain Stimulation," *Frontiers in Systems Neuroscience* 5 (June 2011): article no. 50, https://doi.org/10.3389/fnsys.2011.00050.

169 Nir Grossman et al., "Noninvasive Deep Brain Stimulation via Temporally Interfering Electric Fields," *Cell* 169, no. 6 (2017): 1029–41, https://doi.org/10.1016/j.cell.2017.05.024.

Perhaps disorders of excess coherence might be addressed with desynchronization approaches, while disorders of insufficient coherence might be addressed with "pacemaker" approaches? [**RP.70**]

These dynamics also imply that, hypothetically at least, it should be possible to identify some measure of neural harmony, harmonicity, consonance, or dissonance that would predict disorders in mental health or general well-being. [**RP.71**] The question is: how might such measures of brain harmony be operationalized? It is surprisingly difficult, at present, to determine the consonance or dissonance of a complex song, largely due to the challenge of precisely operationalizing what that means. But, perhaps the potential to generalize from music to mental health will inspire advances in signal processing methods for measuring harmony and its many factors in the brain.

Summary of Reflective Propositions from Neuroscience

[**RP.59**] The many different oscillations of the human body and brain are nested together into a hierarchy that can be described in terms of musical harmony (resonance, octaves, harmonics).

[**RP.60**] Brainwaves are structured around *octaves* (frequency doublings).

[**RP.61**] The oscillatory structure of music is akin to the oscillatory structure of the psyche.

[**RP.62**] The golden ratio prevents information interference between nearby frequency bands.

[**RP.63**] The classical theory of harmony provides a simple but powerful model for explaining the complex dynamics of neural oscillations.

[**RP.64**] Harmony, in the form of synchronized rhythmic integration, supports perceptual binding and the chunking of diverse perceptual elements into a unified whole.

[**RP.65]** Hierarchies of nested rhythm supports unified perception in visual perception, music, and language.

[**RP.66**] Harmonization between concepts, through synchronized rhythms, may enable the arbitrary integration of semantic concepts in the imagination.

[**RP.67**] Harmony may be the common currency between mental experience and physical brain activities, as synchronized neural activity is required to bring diverse elements into our unitary conscious experience.

[**RP.68**] Harmony can serve as a selection force or "fitness function" in evolutionary processes in the brain (i.e., survival of the harmonized).

[**RP.69**] Harmony exists in the dynamic balance of synchronization and desynchronization. Too much of either is unhealthy.

[**RP.70**] Disorders of excess coherence might be addressed with desynchronization approaches, while disorders of insufficient coherence might be addressed with "pacemaker" or synchronization approaches.

[**RP.71**] Advances in measuring the harmony of auditory signals could lead to brain measures of harmony that correlate with health or well-being.

Harmony in Computer Science

If harmony plays such a big role in neural processing, should it not also have implications for computer science? Indeed, harmony has already played a fascinating role in the early history of artificial intelligence.

In the 1980s, University of California San Diego was a hotbed of cognitive science and neural network research. Geoff Hinton, David Rumelhart, Paul McClelland, Paul Smolensky, Terry Sejnowski, and Donald Norman all contributed work that underpins contemporary success with Deep Learning Neural Networks.[170]

One early attempt at devising algorithms for artificial intelligence was known as pandemonium:[171] a collection of computational processes (demons) could operate together and the loudest demon would "win." In response, Paul Smolensky introduced the "harmonium," where the most harmonious relationship between elements would "win." Smolensky was motivated to formulate an approach to *pre*symbolic computation.[172] Like James J. Gibson (best known to designers for coining the term "affordance" to describe an action possibility), Smolensky was opposed to reducing all of human cognition to symbolic processing. As an alternative, he designed the harmonium to maximize the "harmony" among a set of computational elements. This concept and metric of harmony was operationalized as a measure of self-consistency between layers in the neural network, for instance, the fitness or harmony between a set of concrete surface features and between a set of abstract features. Smolensky based the harmonium on a notion of a "computational temperature of the cognitive system." As the temperature was raised, a variety of relations could occur between elements. As it was lowered, "the machine will eventually 'freeze' into a completion that maximizes the harmony."[173]

While Smolensky is credited with priority in this approach, the term *harmonium* and *harmony* largely disappeared in AI research. Instead, Geoff Hinton and Terry Sejnowski's concept of a "restricted Boltzmann machine" that minimizes "free energy" became the term of art. However, the two systems are, in fact, *identical*: "Smolensky's harmony is equivalent to our energy (with a sign reversal)."[174] When Hinton, Smolensky, and David Rummelhart all wrote an article together, they struggled to name their outcome measure: harmony maximization or free energy minimization? As a compromise, they renamed the harmony maximization metric and called it "goodness-of-fit."[175] Even to this day, deep learning and neural networks optimize for the metric of harmony by another name. [**RP.72**] This also provides a clear indication that measures of harmony have considerable potential as objective functions for AI optimization. [**RP.73**]

Potential for Harmony in Computational Systems

As AI systems become ever more powerful and ubiquitous, it may become challenging to keep their outcomes in alignment with human values. For that reason, a clear understanding of the nature of human values has been recognized as a critical element in the safety of AI systems.[176] Thus, designers and computer scientists might consider how harmony could be used to inform the objectives of contemporary AI systems. Classical harmony is already well disposed to mathematical quantification. The challenge is that

170 David E. Rumelhart et al., "Schemata and Sequential Thought Processes in PDP Models," in *Psychological and Biological Models*, vol. 2 of *Parallel Distributed Processing: Explorations in the Microstructures of Cognition*, ed. James L. McClelland, David E. Rumelhart, and the PDP Research Group (Cambridge, MA: MIT Press, 1986), 7–57, available at http://www.cs.toronto.edu/~fritz/absps/pdp14.pdf.

171 Oliver G. Selfridge, "Pandemonium: A Paradigm for Learning," in *Neurocomputing: Foundations of Research*, ed. James A. Anderson and Edward Rosenfeld (Cambridge, MA: MIT Press, 1988), 115–22, available at https://dl.acm.org/doi/10.5555/65669.104389.

172 Paul Smolensky, "Information Processing in Dynamical Systems: Foundations of Harmony Theory," in *Psychological and Biological Models*, vol. 2 of *Parallel Distributed Processing: Explorations in the Microstructures of Cognition*, ed. James L. McClelland, David E. Rumelhart, and the PDP Research Group (Cambridge, MA: MIT Press, 1986), 194–281, available at https://stanford.edu/~jlmcc/papers/PDP/Volume%201/Chap6_PDP86.pdf. For which the opening quote is: "Now, what are the mathematic entities to which we attribute this character of beauty and elegance ...? They are those whose elements are harmoniously disposed so that the mind without effort can embrace their totality while realizing the details. This harmony is at once a satisfaction of our esthetic needs and an aid to the mind, sustaining and guiding...." Henri Poincaré, "Mathematical Creation," *The Monist* 20, no. 3 (1910): 321–35, https://doi.org/10.1093/monist/20.3.321.

173 Smolensky, "Information Processing in Dynamical Systems," 212.

174 Geoffrey E. Hinton and Terrence J. Sejnowski, "Learning and Relearning in Boltzmann Machines," in *Foundations*, vol. 1 of *Parallel Distributed Processing: Explorations in the Microstructure of Cognition*, ed. David E. Rumelhart, James L. McClelland, and the PDP Research Group (Cambridge, MA: MIT Press, 1986), 289, available at https://papers.cnl.salk.edu/PDFs/Learning%20and%20Relearning%20in%20Boltzmann%20Machines%201986-3239.pdf.

175 Rumelhart et al., "Schemata and Sequential thought Processes," 13.

176 Gopal P. Sarma, Nick J. Hay, and Adam Safron, "AI Safety and Reproducibility: Establishing Robust Foundations for the Neuropsychology of Human Values," in *International Conference on Computer*

Safety, Reliability, and Security, ed. B. Gallina et al. (Berlin: Springer, 2018), 511, https://doi.org/10.1007/978-3-319-99229-7_45.

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177 Julián Villegas and Michael Cohen, "'Roughometer': Realtime Roughness Calculation and Profiling," *Audio Engineering Society Convention* 125 (October 2008): paper no. 7516, http://www.aes.org/e-lib/browse.cfm?elib=14668; Tuomas Eerola and Imre Lahdelma, "The Anatomy of Consonance/Dissonance: Evaluating Acoustic and Cultural Predictors Across Multiple Datasets with Chords," *Music & Science* 4 (January 2021): 1–19, https://doi.org/10.1177/20592043211030471.

178 Bin Yang and Marko Lugger, "Emotion Recognition from Speech Signals Using New Harmony Features," *Signal Processing* 90, no. 5 (2010): 1415–23, https://doi.org/10.1016/j.sigpro.2009.09.009.

179 Michael Harris and Bill Tayler, "Don't Let Metrics Undermine Your Business," *Harvard Business Review* 97, no. 5 (2019): 63–69, https://hbr.org/2019/09/dont-let-metrics-undermine-your-business.

180 Mehrdad Mahdavi, Mohammad Fesanghary, and Ebrahim Damangir, "An Improved Harmony Search Algorithm for Solving Optimization Problems," *Applied Mathematics and Computation* 188, no. 2 (2007): 1567–79, https://doi.org/10.1016/j.amc.2006.11.033; Zong Woo Geem, Joong Hoon Kim, and Gobichettipalayam V. Loganathan, "A New Heuristic Optimization Algorithm: Harmony Search," *Simulation* 76, no. 2 (2001): 60–68, https://doi.org/10.1177/003754970107600201.

181 Christopher Alexander, "Harmony-Seeking Computations: A Science of Non-Classical Dynamics Based on the Progressive Evolution of the Larger Whole" (paper, revised and expanded from the keynote speech at the international workshop "The Grand Challenge in Non-Classical Computation," University of York, UK, April 2005, online on "Patterns" Digital Library, 2009), available at https://patterns.architexturez.net/system/files/harmony-seeking-computations_1.pdf.

an operationalization of harmony is elusive and its measurement may pose a challenge that exceed our current technological capabilities. For instance, there are very few and very limited real-time measures of consonance and dissonance in music.[177] Advancing the measurement of consonance and dissonance in complex music could aid measures of harmony in human systems. One example, already discussed, is to provide measures of harmony in the human brain. Another example for the application of measures of harmony in computational systems is in the analysis of interpersonal interactions—hypothetically, an agreeable or disagreeable tone of voice might be identified through measures of consonance and dissonance. In fact, researchers have produced evidence in support of this hypothesis: harmony features (e.g., dissonance) significantly contribute to automated recognition of emotion in the human voice.[178]

Might it be possible to empirically measure the sympathetic resonance between individuals on a video call? Or, might harmonization itself be measured as a function of the balance of synchronization and desynchronization? While much work is necessary to properly operationalize harmony, these suggestions point towards concrete computational opportunities that could support enhanced human relations and conflict resolution. The importance of objective optimization functions for AI systems suggests the value of developing better measurements, both of sympathetic resonance and its counterpart, harmony. Developing improved measures of harmony in music may lead to improved measures of harmony in synchronous online communications. [**RP.74**]

We speculate that technological developments will result in more sensitive assessment and analysis techniques that will enable the operationalization and measurement of harmony in a variety of different domains. This may enable the measurement of harmony in the mind (e.g., measures of cognitive dissonance), in interpersonal interactions (e.g., measures of sympathetic resonance), or in biological, social, economic, or ecological systems (e.g., measures of diversity and integration). If artificial intelligence must, by design, rely on the optimization of numerical metrics or "objective functions", then harmony may be a promising metric (or slate of metrics) for cultivating the development of vibrant, diverse, resilient, and sustainable systems with a strong sense of "wholeness." However, we should take caution that we don't mistake the measure of harmony for the concept of harmony, as is so often the danger of data-driven design approaches.[179] [**RP.75**]

We can report on at least two further attempts to incorporate principles of harmony into computational systems. The first example is the "Harmony Search" algorithm, a so-called metaheuristic algorithm inspired by musical improvisation,[180] which aims to optimize agreement in systems. A more subtle approach was recently introduced by the well-known architect Christopher Alexander, the author of *A Pattern Language*. Alexander proposed "harmony-seeking computation" as an approach to optimize "wholeness."[181] [**RP.76**] While still in a nascent stage, he identified 15 elements of "wholeness" in designs that might be measured, like the presence of coherent centers, strong boundaries, local symmetries, or roughness/imperfection. He proposes that "the harmony that is sought in these computations is indeed what we otherwise call 'beauty.' But the results of harmony-seeking computations are not

merely pretty or artistic. In most cases, they are also better functionally and technically."[182] He envisions harmony-seeking computation as creating "new configurations, unknown configurations, and *good* ones, by taking off from a known configuration, but without (necessarily) requiring the input of human creativity."[183]

Summary of Reflective Propositions from Computer Science

[**RP.72**] Deep learning neural networks optimize for harmony, under the name of "goodness-of-fit."

[**RP.73**] Harmony can serve as an objective function or metric for AI optimization.

[**RP.74**] Improved measures of harmony in music may lead to improved measures of harmony in other systems, like human social interactions.

[**RP.75**] There is a danger in mistaking measures of harmony for the concept of harmony, particularly in computational optimization systems.

[**RP.76**] Harmony can be the basis of computer algorithms that seek wholeness.

Harmony in Art, Design, and Architecture

This next section aims to share a selected examples from the fields of art, architecture and design. We begin with John Dewey, the American pragmatist philosopher. In his book *Art as Experience*, Dewey makes a powerful claim regarding the role of dissonance and tension in the arts. Namely, he welcomes dissonance because it invites reflection and supports new ways of realizing harmony. [**RP.77**]

> "… discord is the occasion that induces reflection. Desire for restoration of the union converts mere emotion into interest in objects as conditions of realization of harmony. With the realization, material of reflection is incorporated into objects as their meaning. Since the artist cares in a peculiar way for the phase of experience in which union is achieved, he does not shun moments of resistance and tension. He rather cultivates them, not for their own sake but because of their potentialities, bringing to living consciousness an experience that is unified and total."[184]

Dewey states that artists can cultivate dissonance, not for the sake of dissonance, because it brings new potentials for "unified and total" experiences. That is, there may be greater harmony when a new conflict is introduced and then resolved, rather than avoided altogether.

But, who is to say how much conflict is sufficient? In 1982, the architects Christopher Alexander and Peter Eisenman (a radical modernist) debated the purpose of architecture. Eisenman made the argument that architecture was not just about meeting needs, but that it should make people uncomfortable and provoke them. Alexander had this to say:

> "My only concern is to produce [a] kind of harmony … The thing that strikes me about your friend's building — if I understood you correctly — is that somehow in some intentional way it is not harmonious. That is, Moneo intentionally wants to produce an effect of disharmony. Maybe even of incongruity … I find that incomprehensible. I find it very irresponsible. I find it nutty. I feel sorry for the man. I also feel incredibly angry because he is fucking up the world."[185]

182 Ibid., 1.
183 Ibid., 12.
184 John Dewey, *Art as Experience* (New York: Minton, Balch & Company, 1934), 15.
185 Christopher Alexander and Peter Eisenman, "Contrasting Concepts of Harmony in Architecture: The 1982 Debate between Christopher Alexander and Peter Eisenman — An Early Discussion of the 'New Sciences' of Organised Complexity in Architecture," *Katarxis* Nº 3: New Science, New Urbanism, New Architecture 3, no. 3 (2004): online, http://www.katarxis3.com/Alexander_Eisenman_Debate.htm.

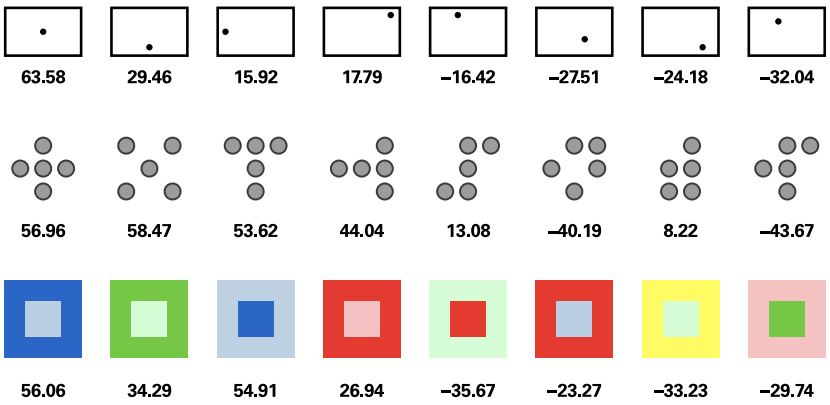

Figure 14
These examples show three types of variation in visual forms: the placement of a single dot, the composition of multiple dots and color combinations. The number below each image shows the figure's average rating of harmony. The figures on the left have high ratings for harmony and the figures on the right have low ratings for harmony. Images courtesy of Stephen Palmer.

One could sympathize with either viewpoint. Following Dewey, architecture can be viewed as a form of art practice that can energize and reveal tensions and dissonances that have the potential to be harmonized in new ways. On the other hand, the sorts of tensions revealed by the egos of architects are not always those that are most productively resolved by public funds or public use. After all, there are many immediate and meaningful tensions that are inherently present in in the nature of design work—we might be cautious about creating dissonance simply for entertainment. [**RP.78**] For instance, how might we support affordable, sustainable, equitable urban growth in a multi-stakeholder society alienated by technology and often lacking meaningful human connection? The question is whether architects feel comfortable leaving these very real tensions unresolved, even as they intentionally introduce other conflicts for intellectual entertainment or artistic exploration. While there should always be a place for art and radical experimentation, Alexander urges us to "build buildings and towns and neighborhoods, in such a way that their action also plays its role in the balanced harmony and life of the earth."[186] There are certainly buildings, towns, and neighborhoods that do not live up to this.

Preference for Harmony

Psychologist Stephen Palmer has investigated the nature of harmony as a factor in aesthetic appreciation. In one beautiful experiment,[187] he systematically varied combinations of colors, dot patterns, and the locations of a single dot in a frame (Figure 14); additionally, he had participants listen to various segments of classical music. On a scale of −100 to 100, participants rated their overall preference for each design and, separately, rated their perception of the harmoniousness of the design. He found that measures of harmony and personal preferences were highly correlated, while participants had more agreement about the harmoniousness of the designs. Further, people generally agreed regarding the designs that were harmonious, yet they had different preferences for this harmony. Palmer then demonstrated that the individual "preference for harmony" could be treated as a separate factor that predicted individual tastes.

186 Christopher Alexander, *The Phenomenon of Life*, book two of *The Nature of Order: An Essay on the Art of Building and the Nature of the Universe* (Berkeley, CA: The Center for Environmental Structure, 2002), 28.

187 Stephen E. Palmer and William S. Griscom, "Accounting for Taste: Individual Differences in Preference for Harmony," *Psychonomic Bulletin & Review* 20 (June 2013): 453–61, https://doi.org/10.3758/s13423-012-0355-2.

Counter intuitively, the more years of education in visual arts or music, the more likely individuals were to prefer compositions that had *lower* rankings of harmony. This might be similar to a person with a more refined palette preferring more exotic foods: musicians are better prepared to appreciate challenging and dissonant compositions and visual artists may come to appreciate more unusual designs. The development of expertise (connoisseurship) seems to enable people to perceive new harmonies that are not apparent to novices. [**RP.79**] Designs that are too harmonious may be too akin to the saccharine sweetness of children's music; more dissonant music may have more "verve." Yet, in the mind of the appreciator, if the dissonance can be successfully resolved, they may experience even greater harmony.

Harmonizing Opposites as the Basis for Aesthetic Pleasure

In 2014, designer and psychologist Paul Hekkert proposed a Unified Model of Aesthetics (UMA).[188] This model proposed that beauty (aesthetic pleasure) arises from the harmonization of opposing forces or motivations — and, the simultaneous maximization of the opposing forces resulted in the highest level of beauty. Hekkert proposed three pairs of opposites, at a perceptual, cognitive and social level, respectively: *unity* and *variety, typicality* and *novelty*, and *connectedness* and *autonomy*. Each pair of opposites comes from an underlying tension between the human need for safety and the need for accomplishment. To say it plainly, an attractive design should have diverse characteristics (variety) and hold together as one (unity); it should be new but also familiar; and, finally, a product should help a person stand out from the crowd (autonomy) but also help them fit in (connectedness). The UMA model states that the harmony of the opposites causes aesthetic pleasure.

To validate the UMA model, Berghman and Hekkert[189] had participants rate dozens of images of product designs to gather measures of each factor. They found that opposing factors (e.g., novelty and typicality) were each *independently* correlated with aesthetic pleasure. This showed that the opposite factors are not merely two different sides of the same scale. In their regression model of aesthetic pleasure, the strongest effect was produced by unity and variety. Expanding his UMA model beyond our appreciation of objects, Hekkert states that this reconciliation or harmonization of opposing forces also explains the beauty of concepts and ideas, and should therefore be an important driver of change. Here is how he summarized it at a university-wide celebration:

> "After all these years of doing research in aesthetics, I have come to the conclusion — a conviction that is empirically established — that beauty arises from simultaneously addressing and harmonizing apparent opposites. If designers manage to resolve the tension between short and long-term concerns, between immediate gratification and sustained well-being, and between conflicting personal and social values, they create a world that is worth living in."[190] [**RP.80**]

What other opposites might be important for designers to consider harmonizing? The following list combines opposites found in Hekkert's work with other opposites relevant to the present article: *short-term* and *long-term*, *immediate gratification* and *sustained well-being*, *personal values* and *social values*, *unity* and *variety*, *novelty* and *familiarity*, *autonomy* and *connectedness*,

188 Paul Hekkert, "Aesthetic Responses to Design: A Battle of Impulses," in *The Cambridge Handbook of the Psychology of Aesthetics and the Arts*, ed. Pablo P. L. Tinio and Jeffrey K. Smith (Cambridge: Cambridge University Press, 2014), 277–99, https://doi.org/10.1017/CBO9781139207058.015.

189 Michaël Berghman and Paul Hekkert, "Towards a Unified Model of Aesthetic Pleasure in Design," *New Ideas in Psychology* 47 (2017): 136–44, https://doi.org/10.1016/j.newideapsych.2017.03.004.

190 "Paul Hekkert Delivers TU Delft's Foundation Day Lecture."

safety and *achievement*, *stability* and *growth*, *diversity* and *inclusion*, *social* and *solitude*, *synchronization* and *desynchronization*, *order* and *chaos*, *scientific* and *spiritual*, *rational* and *emotional*, *ancient* and *modern*, *concrete* and *abstract*, *quantitative* and *qualitative*, *East* and *West*, *global North* and *global South*, *capitalist* and *socialist*, *artificial* and *natural*, *consonance* and *dissonance*. Each of these opposites provoke tensions that might be harmonized through innovations in design.

Reflection on the Implication of Harmony for Designers

Understanding classical theories of harmony can help inform and provoke contemporary design practice. Many designs, despite effort, simply do not hold together: perhaps the overall concept is not clearly communicated or there are parts that stand out harshly. When designers create new designs, they want them to have a quality of wholeness and integrity. Harmony theory offers to describe the fitness of designs, indicating how parts can be integrated together to create new wholes—at both a material and conceptual level. Design itself can be conceptualized as the process of integrating parts—materials, information, systems, etc.—into new functional wholes. [**RP.81**] Design is an integrative discipline and a good design process is essentially integrative; it harmonizes the motivations, needs and values of multiple stakeholders.

Designs require internal or material integrity or they will simply fall apart. Designs also need to *fit well* into the overall system of use. [**RP.82**] Designers, also, need to harmonize with the context they aim to serve—and should seek their own internal harmony. When designers act with authenticity and integrity as individuals, they bring authenticity and integrity to their designs. Further, well-integrated (authentic) teams with well-integrated (authentic) people may be a prerequisite for creating products with integrity.[191] [**RP.83**] When designers and organizations exhibit character and integrity—when they themselves are healthy, harmonious, and whole—they are best prepared to help the systems they work with become more whole. And, yet, a theory of harmony clearly indicates that simple agreement is not harmony. The ability to think differently and to create contrast—this may be necessary to produce the energy that enables the discovery of truly harmonized outcomes.

Through the lens of harmony theory, we might consider a good design to be one that helps a system achieve greater integration between its internal parts and the parts of the larger system that contains it, whereas a bad design results in lowered system integrity. Good designs should help systems maintain harmony or/and regain harmony, whereas a bad design disharmonizes a system. But this is not to say that discord or tension or conflict is inherently disharmonious. As we have explained earlier, harmony presupposes diversity and tension between diverse parts in a system.[192] Designers might aim to deliberately create a space for tension and conflict in their designs so that they can be more easily resolved. [**RP.84**]

Summary of Reflective Propositions from Art, Design, and Architecture

[**RP.77**] Discords are useful in the arts for inviting reflection and supporting new ways of realizing harmony.

191 Kim B. Clark and Takahiro Fujimoto, "The Power of Product Integrity," *Harvard Business Review* 68, no. 6 (1990): 107–18, https://hbr.org/1990/11/the-power-of-product-integrity.

192 Chenyang Li, "Harmony and Ren: A Response to Leung Yat-hung's Critique of *The Confucian Philosophy of Harmony*," in *Confucian Political Philosophy: Dialogues on the State of the Field*, ed. Robert A. Carleo III and Yong Huang (Cham: Springer, 2021), 54, https://doi.org/10.1007/978-3-030-70611-1_2.

193 William James, *The Principles of Psychology*, vol. 1 (New York: Henry Holt and Co, 1890), 675, https://doi.org/10.1037/10538-000.

194 Alexander, *The Phenomenon of Life*, 17.

[**RP.78**] There are many immediate and meaningful tensions that are inherently present in in the nature of design work—we might be cautious about creating dissonance simply for entertainment.

[**RP.79**] Expertise (or connoisseurship) enables people to appreciate new harmonies not apparent to novices.

[**RP.80**] Beauty comes from the harmonization of apparent opposites.

[**RP.81**] Design is the process of integrating parts into new, functional wholes.

[**RP.82**] Designs require internal integrity (internal parts fitting well) and external integrity (fitting well into the overall system). Good designs harmonize well, internally and externally.

[**RP.83**] Authentic, integrated designers (inner harmony) in authentic, integrated teams (interpersonal harmony) can create authentic, integrated products (designs that harmonize).

[**RP.84**] Designers might deliberately create a space for tension and conflict in their designs in order that these tensions and conflicts may be more easily resolved.

Part Three: Applications of Harmony in Design

To guide a discussion of how harmony theory might be used to understand and support contemporary design, we use the Confucian model of hierarchical harmony from Figure 3. This model can organize efforts to design for a more harmonious world by directing us to improve harmony at a personal level, at an interpersonal level, at the level of societal organizations, and at an ecological level. Designers can aim to harmonize within and between each level.

Designing for Harmony at the Personal Level

Harmony is a phenomenon that humans can acutely *feel*—it manifests within our conscious experience and acts like a guidance system for our social behavior and our creative design work, leading us towards the beautiful and the good. This follows from the insights of Francis Hutcheson (who proposed that humans use an inner sense of harmony to support aesthetic and ethical judgment) and from the psychologist William James, who said: "æsthetic and moral judgments … express inner harmonies and discords between objects of thought."[193]

We suggest that the harmonization of conflicting motivations and impulses is critical to our practical intelligence as human beings and as designers. This harmonization process, selecting and shaping action possibilities to support optimal outcomes, is based upon felt, conscious, aesthetic experiences. Out of many potential actions, only some will *intuitively* feel right or good or beautiful. In short, the sense of harmony in the conscious mind supports intuitive decision making in design. [**RP.85**]

Architect Christopher Alexander puts it in the following way: "As architects, builders, and artists, we are called upon constantly—every moment of the working day—to make judgments about relative harmony. We are constantly trying to make decisions about what is better and what is worse…."[194] We argue that designers use their internal sense of felt harmony to make

aesthetic and ethical decisions, whether they know it or not. This is an ability that varies across individuals, and we propose, is an ability that can be developed through design education that focuses on the development of introspective abilities. [**RP.86**]

Harmony theory may identify new possibilities to enhance personal well-being through technology. Plato claimed that harmony in music could restore harmony in the individual psyche. While this might seem far-fetched, a recent meta-analysis of controlled experiments concludes "that music therapy is an effective treatment which helps people with psychotic and non-psychotic severe mental disorders to improve global state, symptoms, and functioning."[195] [**RP.87**] If harmony in auditory music can enhance harmony in the psyche, might harmony be found in tactile or visual music,[196] as well? Or, might harmony in other forms of design (e.g., architecture) also help contribute to harmony in the mind? [**RP.88**]

At an individual level, harmony can also play a role in the conception of happiness and well-being in the fields of design and Human-Computer Interaction (HCI). Recent research explorations on this track include, for example, slow technology for reflection,[197] design for mindfulness,[198] and mood regulation.[199] Designers at the consultancy IDEO have written about how design methods and design thinking can be used to deliberately support harmony between people and technology.[200] All these efforts may be seen as empowering users to regain, maintain, or enhance individual harmony.

How might designers use harmony theory to actively promote well-being? First, they should perhaps understand harmony as a process, and consider a dissonant or conflicting state as a chance for a greater harmonious state to come. In the design field, a possibility-driven design approach has been proposed to encourage designers to not treat seemingly undesirable situations as problems to be avoided, solved, or naturalized, but as potentials to give rise to human flourishing.[201] [**RP.89**] Second, as inner tension and conflicts are prerequisites for harmonization, capturing individual's intrapersonal conflicts or dilemmas has enabled an unique approach to designing for well-being, through which a designer may aim to resolve (serving both concerns), moderate (prioritizing one concern over another) or trigger (creating awareness of the conflicting concerns) a dilemma.[202] Third, harmonizing conflicts at a personal level may benefit from a non-dualistic, mind-body cultivation of the self. For example, soma design is an emerging approach to designing for personal harmony based on this premise.[203] Many soma design cases illustrate how we may help users harmonize their psyches through designing for their somas.[204] [**RP.90**] Its philosophical foundation, somaesthetics, deeply connects to the Confucian tradition of harmonizing through self-cultivation for tranquility, vitality, and body-mind balance.[205]

We propose that harmony theory can serve as a design framework for enhancing happiness and well-being. [**RP.91**] For example, studies of "inner harmony" and "harmony-based happiness" suggest that there may be new ways of conceptualizing personal well-being that focus on "living in balance between positive and negative aspects of one's life."[206] Pursuing harmony can transcend the pursuit of individual happiness by linking the well-being of the individual to the well-being of society and of the natural world. [**RP.92**]

195 Christian Gold et al., "Dose-Response Relationship in Music Therapy for People with Serious Mental Disorders: Systematic Review and Meta-analysis," *Clinical Psychology Review* 29, no. 3 (2009): 193–207, https://doi.org/10.1016/j.cpr.2009.01.001.

196 John Whitney, *Digital Harmony: On the Complementarity of Music and Visual Art* (Peterborough, NH: Byte Books, 1980).

197 e.g., Barbara Grosse-Hering et al., "Slow Design for Meaningful Interactions," in *CHI '13: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York: ACM, 2013), 3431–40, https://doi.org/10.1145/2470654.2466472; Lars Hallnäs and Johan Redström, "Slow Technology — Designing for Reflection," *Personal and Ubiquitous Computing* 5 (August 2001): 201–12, https://doi.org/10.1007/PL00000019.

198 e.g., Alexandra Kitson, Mirjana Prpa, and Bernhard E. Riecke, "Immersive Interactive Technologies for Positive Change: A Scoping Review and Design Considerations," *Frontiers in Psychology* 9 (August 2018): article no. 1354, https://doi.org/10.3389/fpsyg.2018.01354.

199 Pieter M. A. Desmet, "Design for Mood: Twenty Activity-Based Opportunities to Design for Mood Regulation," *International Journal of Design* 9, no. 2 (2015): 1–19, http://www.ijdesign.org/index.php/IJDesign/article/viewFile/2167/685.

200 David J. Gilmore and Velma L. Velázquez, "Design in Harmony with Human Life," in *Proceedings of CHI '00 Extended Abstracts on Human Factors in Computing Systems* (New York: ACM, 2000), 235–36, https://doi.org/10.1145/633292.633429.

201 For a detailed discussion and design examples, see Pieter M. A. Desmet and Marc Hassenzahl, "Towards Happiness: Possibility-Driven Design," in *Human-Computer Interaction: The Agency Perspective*, ed. Marielba Zacarias and José Valente de Oliveira (Berlin: Springer, 2012), 3–28, https://doi.org/10.1007/978-3-642-25691-2_1.

202 Deger Ozkaramanli, Pieter M. A. Desmet, and Elif Özcan, "Beyond Resolving Dilemmas: Three Design Directions for Addressing Intrapersonal Concern Conflicts," *Design Issues* 32, no. 3 (2016): 83, https://doi.org/10.1162/DESI_a_00401.

203 Kristina Höök et al., "Unpacking Non-dualistic Design: The Soma Design Case," *ACM Transactions on Computer-Human Interaction* 28, no. 6 (2021): 1–36, https://doi.org/10.1145/3462448; Kristina Höök, *Designing with the Body: Somaesthetic Interaction Design* (Cambridge, MA: MIT Press, 2018), 29–32.

Designing for Harmony at the Interpersonal Level

Increasing interpersonal harmony could lead to a variety of improved outcomes, including better family relationships, enhanced collaboration in work settings, improved psychiatric therapy, better educational outcomes, etc. Relatedness, belongingness and positive interpersonal relationships has long been recognized as a crucial factor for human well-being. Designers, by shaping interactions, activities, and practices, have the potential to deliberately enhance interpersonal harmony in a given context.[207]

In the context of the workplace, Don Norman describes how harmonious organizations produce good products: "Producing a good product requires a lot more than good technical skills: it requires a harmonious, smoothly functioning, cooperative and respectful organization."[208] While conflicts between people are inevitable, their resolution is important for team performance. While too much or too little diversity impairs team performance,[209] a meta-analysis shows that team conflict negatively affects team performance.[210] [**RP.93**]

Feeling connected with others often involves a sort of mutual attunement. A specific manifestation of interpersonal harmony might be found in the notion of "vibes." Here, we can define a "vibe" as the perception of a *shared* affective response to a person, product, or situation. In German, a word similar to vibe is "Stimmung"; meaning mood, atmosphere, or tone (and when used in music, the term refers to tuning).[211] As an approach to promoting interpersonal harmony, we propose that designers can deliberately seek to create better vibes as a product or service outcome. [**RP.94**]

How might an understanding of harmony help people attune to each other better and resolve their conflicts in a manner that leads to improved human connection? Perhaps supporting interpersonal *synchrony* could hold promise: two recent studies found that the synchrony between the brains of teachers and students predicted improved student engagement[212] and improved learning outcomes.[213] Similarly, children assigned to synchronized movement activities demonstrated more prosocial behaviors during a later play period.[214] Perhaps common rituals that synchronize behavior, like shaking hands or clinking drinks are existing cultural mechanisms for enhancing interpersonal synchrony. Many design session "ice breaker" activities could be good exemplars of synchrony-promoting activities. However, desynchronization is also critically important, too—such that we can recommend that harmony in interpersonal settings could be generally supported by activities that support both synchronization and desynchronization. [**RP.95**]

Designing for Harmony at the Societal Level

Design has been recognized for its unique approach to positive societal changes in recent years, from driving social innovation to supporting better governmental policy making.[215] For social design, Papanek's masterpiece *Design for the Real World* represents one of the earliest examples.[216] Although Papanek might suggest that social designers set themselves against the market model of design, the Margolins present to the field a more balanced view that offers a better foundation for harmonization—not seeing "the 'market model' and the 'social model' as binary opposites, but instead

204 Kristina Höök et al., "Embracing First-Person Perspectives in Soma-Based Design," *Informatics* 5, no. 1 (2018): 9–20, https://doi.org/10.3390/informatics5010008.

205 Richard Shusterman, "Somaesthetics and Self-Cultivation in Chinese Art," in *Transformative Aesthetics*, ed. Erika Fischer-Lichte and Benjamin Wihstutz (London: Routledge, 2017), 83–93, available at https://www.academia.edu/34933797.

206 See, for example, Carreno et al., "Inner Harmony as an Essential Facet of Well-Being," 1.
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207 Chunmao Wu, Huayuan Xu, and Ziyang Liu, "The Approaches of Positive Experience Design on IoT Intelligent Products," *KSII Transactions on Internet and Information Systems (TIIS)* 15, no. 5 (2021): 1798–1813, https://doi.org/10.3837/tiis.2021.05.012.

208 Don Norman, *The Design of Everyday Things*, revised and expanded edition (New York: Basic Books, 2013), 240.

209 Karin Hoisl, Marc Gruber, and Annamaria Conti, "R&D Team Diversity and Performance in Hypercompetitive Environments," *Strategic Management Journal* 38, no. 7 (2017): 1455–77, https://doi.org/10.1002/smj.2577.

210 Frank R. C. De Wit and Lindred L. Greer, "The Black-Box Deciphered: A Meta-analysis of Team Diversity, Conflict, and Team Performance," *Academy of Management Proceedings* 2008, no. 1 (2008): 1–6, https://doi.org/10.5465/ambpp.2008.33716526.

211 Leo Spitzer, "Classical and Christian Ideas of World Harmony: Prolegomena to an Interpretation of the Word 'Stimmung,' Part I," *Traditio* 2 (1944): 409–64, https://doi.org/10.1017/S0362152900017220.

212 Suzanne Dikker et al., "Brain-to-Brain Synchrony Tracks Real-World Dynamic Group Interactions in the Classroom," *Current Biology* 27, no. 9 (2017): 1375–80, https://doi.org/10.1016/j.cub.2017.04.002.

213 Antonio M. Battro et al., "The Cognitive Neuroscience of the Teacher-Student Interaction," *Mind, Brain, and Education* 7, no. 3 (2013): 177–81, https://doi.org/10.1111/mbe.12025.

214 Bahar Tunçgenç and Emma Cohen, "Interpersonal Movement Synchrony Facilitates Pro-social Behavior in Children's Peer-Play," *Developmental Science* 21, no. 1 (2018): 1–10, https://doi.org/10.1111/desc.12505.

215 For example, Lucy Kimbell, *Applying Design Approaches to Policy Making: Discovering Policy Lab* (Brighton, UK:

University of Brighton, 2015); Ezio Manzini, "Making Things Happen: Social Innovation and Design," *Design Issues* 30, no. 1 (2014): 57–66, https://doi.org/10.1162/DESI_a_00248; Nynke Tromp and Paul Hekkert, *Designing for Society: Products and Services for a Better World* (London: Bloomsbury Publishing, 2018).

216 Victor. J. Papanek, *Design for the Real World: Human Ecology and Social Change*, 2nd ed. (New York: Pantheon Books, 1972). For a review of social design, see also Dung-Sheng Chen et al., "Social Design: An Introduction," *International Journal of Design* 10, no. 1 (2016): 1–5, http://www.ijdesign.org/index.php/IJDesign/article/view/2622/723.

217 Victor Margolin and Sylvia Margolin, "A 'Social Model' of Design: Issues of Practice and Research," *Design Issues* 18, no. 4 (2002): 25, https://doi.org/10.1162/074793602320827406.

218 Frans H. Van Eemeren and Bart Garssen, "In Varietate Concordia — United in Diversity European Parliamentary Debate as an Argumentative Activity Type," in *Reasonableness and Effectiveness in Argumentative Discourse*, ed. Frans H. Van Eemeren (Cham: Springer, 2015), 845–60, https://doi.org/10.1007/978-3-319-20955-5_46.

219 Cicero's De Officiis (44 BCE) states: "When each person loves the other as much as himself, it makes one out of many, as Pythagoras wishes things to be in friendship." Marcus Tullius Cicero, *De Officiis*, trans. Walter Miller (Project Gutenberg, 2014), Book 1, Section 56: Project Gutenberg, https://www.gutenberg.org/files/47001/47001-h/47001-h.htm.

220 Diane Butler, "Peace and Harmony in the World Based on Pancasila and Bhinneka Tunggal Ika (Unity in Diversity)," *Harmoni* 15, no. 2 (2016): 33–40, https://jurnalharmoni.kemenag.go.id/index.php/harmoni/article/view/28.

221 Jawaharlal Nehru, *The Discovery of India* (New York: John Day, 1946, 1989), 157.

222 Damien Mahiet, "Rethinking Harmony in International Relations," *Journal of International Political Theory* 17, no. 3 (2021): 257–75, https://doi.org/10.1177/1755088219868825.

223 Tamar Saguy et al., "The Irony of Harmony: Intergroup Contact Can Produce False Expectations for Equality," *Psychological Science* 20, no. 1 (2009): 114–21, https://doi.org/10.1111/j.1467-9280.2008.02261.x.

224 General Assembly, *Resolution Adopted by the General Assembly on 11 September 2015*. A/RES/69/315 (New York: United

viewing them as two poles of a continuum."[217] If we take a non-dualistic view of market and social design, we may be able to find a sweet spot that harmonizes these opposing forces. For instance, how might socialism and capitalism be harmonized to produce healthy markets, healthy people and a healthy planet?

Social harmony has a long history in large-scale societal politics and remains highly relevant today. Beyond the official policy of creating a "harmonious society" in China (population 1.4 billion), many other major powers have echoes of the classical philosophy of harmony embedded directly into their political fabric. For instance, the motto of the European Union (population 447 million) is "*In Varietate Concordia* — United in Diversity."[218] The motto of the United States of America (population 330 million) is "*E Pluribus Unum*" (Out of Many, One) — a phrase that is originally attributed to Pythagoras.[219] The official national motto of Indonesia (population 274 million) is *Bhinneka Tunggal Ika*, translated as "unity in diversity."[220] And, Jawaharlal Nehru, the first Prime Minister of India (population 1.38 billion), wrote about "unity in diversity" as an ideal critical to national consolidation and progress. In his work *The Discovery of India*, he frames harmony as a perennial goal: "The old philosophers were ever seeking this, and even modern scientists are impelled by this urge. All our schemes and planning, our ideas of education and social and political organization, have at their back the search for unity and harmony."[221]

So, at least 3.8 billion people live in countries that are, in some ways, united in their devotion to harmony as a political ideal. Harmony between people is, after all, essential to creating large, prosperous, and peaceful societies. And, because the approach is cross-cultural, further research on harmony may support useful frameworks for international relations[222] and peace studies. [**RP.96**] Nevertheless, harmony does not always mean peace; a just and equitable society often requires conflict to achieve. And, researchers have pointed out that positive relationships and intergroup harmony does not necessarily lead to positive outcomes, like an equitable society.[223] Sometimes, when everyone is getting along, real issues are left unaddressed. This raises the point that harmony is relative: for instance, the American rebellion was disharmonious to the British empire but it was an essential dissonance for the harmony of the American project. [**RP.97**]

Designing for Harmony at the Natural Level

Harmony in Sustainability

Harmony with nature is a widespread theory of sustainability. [**RP.98**] Harmony is specifically used in the UN Sustainable Development goals to describe a desirable objective for the future: "We are determined to ensure that all human beings can enjoy prosperous and fulfilling lives and that economic, social and technological progress occurs in harmony with nature."[224] Additionally, harmony with nature is now an explicit goal of the Chinese government; President Xi Jinping made this pronouncement in 2018: "By the middle of this century, material, political, cultural, social and ecological progress will have been made; a green development mode and way of life will have fully taken shape; harmony will exist between humans and nature."[225]

Nations, 2015), 2, available at https://www.un.org/en/ga/69/resolutions.shtml.

225 Chuanglin Fang, Zhenbo Wang, and Haimeng Liu, "Beautiful China Initiative: Human-Nature Harmony Theory, Evaluation Index System and Application," *Journal of Geographical Sciences* 30, no. 5 (April 2020): 692, https://doi.org/10.1007/s11442-020-1750-7.

226 HRH The Prince of Wales, Tony Juniper, and Ian Skelly, *Harmony: A New Way of Looking at Our World* (New York: Harper Collins, 2010), 3.

227 Ibid., 325.

228 Annamaria Di Fabio and Akira Tsuda, "The Psychology of Harmony and Harmonization: Advancing the Perspectives for the Psychology of Sustainability and Sustainable Development," *Sustainability* 10, no. 12 (2018): article no. 4726, https://doi.org/10.3390/su10124726.

229 HRH The Prince of Wales et al., *Harmony*, 324.

230 David E. Cooper, "Daoism, Nature and Humanity," *Royal Institute of Philosophy Supplement* 74 (2014): 98, https://doi.org/10.1017/S1358246114000034.

231 Alexander, *The Phenomenon of Life*, 29.

232 Casper H. A. van Leeuwen et al., "Enhancing Ecological Integrity While Preserving Ecosystem Services: Constructing Soft-Sediment Islands in a Shallow Lake," *Ecological Solutions and Evidence* 2, no. 3 (2021): e12098, https://doi.org/10.1002/2688-8319.12098.

233 George Rodenburg, "Marker Wadden: natuurliefhebbers welkom, maar vogels zijn de baas," *rtlnieuws*, June 11, 2021, https://www.rtlnieuws.nl/economie/artikel/5235797/marker-wadden-natuur-vogels-natuurmonumenten-boskalis-flevoland.

In 2010, Charles, Prince of Wales (b. 1948), published a book titled *Harmony* to explain his own philosophical outlook. The book begins with a bang: "This is a call to revolution. The Earth is under threat. It cannot cope with all that we demand of it. It is losing its balance and we humans are causing this to happen. 'Revolution' is a strong word and I use it deliberately."[226]

His key message is that we need to see ourselves "as part of the Natural order rather than isolated from it."[227] He argues that there is a great danger resulting from our insistence on "divorcing" the artificial from the natural and the spiritual from the scientific. Instead, he argues for seeing humanity as an integrated part of nature—this is harmony as a psychology of sustainability.[228] He argues that the well-being of the individual and the well-being of nature and the well-being of society are each interconnected and intertwined. "Studying the properties of harmony and understanding more clearly how it works at all levels of creation reveals a crucial, timeless principle: that no one part can grow well and true without it relating to—and being in accordance with—the well-being of the whole"[229] (see **RP.92**). This philosophical view resembles what Daoism advocates: that humans should see themselves as part of nature, seeking harmony or convergence, in order to find their way to a good life.[230]

The artificial and the natural are not in harmony today. The Earth is losing biological diversity, fast. How might the artificial and the natural be better balanced and integrated to create a stronger whole, like the yin and the yang? Christopher Alexander advocates for the active creation of living natural designs, which is "much more than merely preserving nature; it is much harder. Firstly, it has to be invented; it is not a case of merely smiling at nature and saying, 'Let's keep it that way.' … we are after one pattern of life, which includes the so-called living organisms and the so-called dead matter in a single living system. It is a case of understanding the interaction of man and nature, and making a harmony out of that interaction, which has the beauty of nature and the zest of life."[231]

Consider the case of Lake Markermeer in the Netherlands (Figure 15). The lake was cut off from the surrounding Ijsselmeer in 1976 during the completion of Flevoland, the most recent province of the Netherlands (which was lifted up and "reclaimed" from the ocean). However, the lake lacked access to the sea and was surrounded by artificial shorelines. As the lake silted up, the cloudy water resulted in a massive loss of sea life. As the plants died, the fish died and the birds left. In response, about 80 million euros were spent to create an artificial set of islands (Marker Wadden).[232] As of 2022, these islands are now successfully providing dynamic habitats for fish, plants, and birds[233] and serving as a model for the artificial generation of natural habitats. While the ultimate outcomes of this experiment are unknown, at the very least it suggests that an iterative approach to creating harmony between human activities and nature is possible.

What to make of this "Dutch Nature?" There is something a little unnerving about artificial wetlands on artificial islands in an artificial lake in a country that famous for *simply existing* because one third of its land is technically below sea level. On one hand, perhaps the entire project of the Netherlands should be viewed as a crude imposition of humanity on nature. On

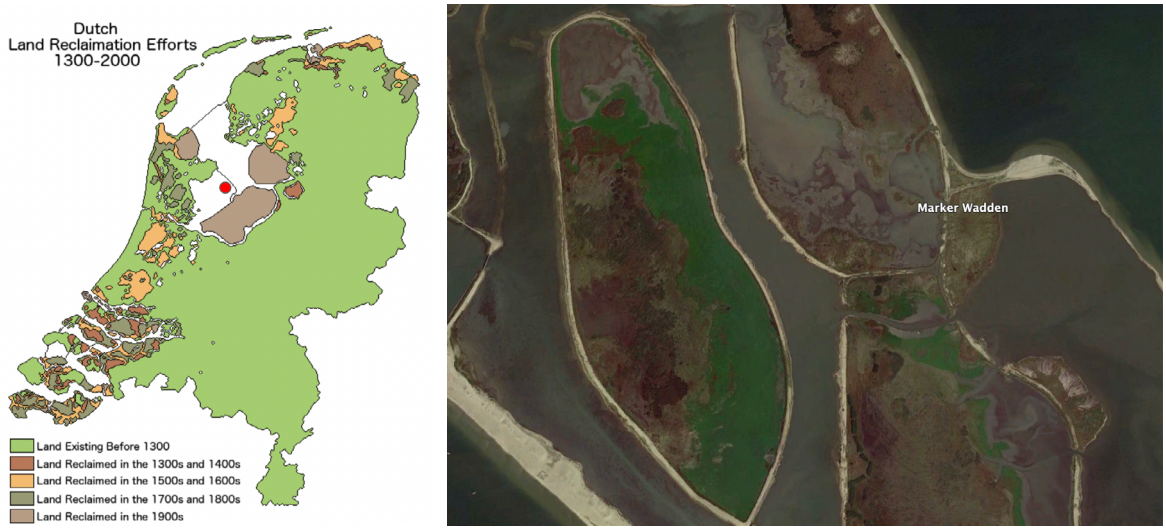

Figure 15
(a) Map of Dutch Land Reclamation Efforts from 1300–2000. The Marker Wadden islands are marked with a red dot. Image courtesy of Theman77777. (b) Marker Wadden. Google Earth Pro 7.3.4.8248. (accessed February 22, 2022). Marker Wadden, Netherlands. 52°34'43"N 5°23'14"E, Eye alt 2.37km.

the other hand, the Netherlands and the Markermeer offer a complex and compelling vision for an integrated harmony between the artificial and the natural.

Much of the Earth has already been deeply affected by human involvement. Separating humans from nature may seem essential to protecting nature, but it may not be possible or sufficient. There is a clear need to protect biodiversity and ecosystem integrity,[234] which can be successfully achieved through the prevention of human interactions with intact natural environments. However, even ecological jewels like the Amazon Rainforest have been profoundly shaped by thousands of years of human intervention[235]—and not just in negative ways.[236] While the destruction of intact, integrated biodiverse ecosystems must be urgently halted, what about the rest of the land and oceans that have already been stripped or dis-integrated? What role is there for design in a process of re-integrating nature? Perhaps harmonizing between the artificial and the natural will be essential for moving from the Anthropocene era to the Symbiocene era.[237] [**RP.99**]

Examples of this harmony include farms that offer external ecological benefits,[238] green cities, rewilding efforts in development,[239] breeding plants for climate adaptation,[240] repopulating oyster reefs,[241] multi-species ecosystem restorations,[242] and many other nature-based solutions. We might even make artificial clouds when necessary[243] or let the Mammoth walk again to maintain the dying tundra.[244] Before long, we may have AI technologies that can give forests or seas a voice, reporting on and advocating for the health and harmony of interconnected ecological systems.[245] The scale is immense and, often, the best action will be non-action (*wu-wei*). Other times, harmony might be found in a spirit of free play or exploration. Regardless of approach, the core challenge is clear: how do we integrate all the levels and harmonize the needs of profit, people, and planet?[246] [**RP.100**]

234 James E. M. Watson et al., "The Exceptional Value of Intact Forest Ecosystems," *Nature Ecology & Evolution* 2, (February 2018): 599–610, https://doi.org/10.1038/s41559-018-0490-x.

235 Carolina Levis et al., "Persistent Effects of Pre-Columbian Plant Domestication on Amazonian Forest Composition," *Science* 355, no. 6328 (2017): 925–31, https://doi.org/10.1126/science.aal0157.

236 Carolina Levis et al., "How People Domesticated Amazonian Forests," *Frontiers in Ecology and Evolution* 5 (January 2018): 171, https://doi.org/10.3389/fevo.2017.00171.

237 Glenn Albrecht, "Enter the Symbiocene," *Next Nature*, accessed Feburary 11, 2022, https://nextnature.net/magazine/visual/2021/symbiocene; Susan L. Prescott and Alan C. Logan, "Down to

Earth: Planetary Health and Biophilosophy in the Symbiocene Epoch," *Challenges* 8, no. 2 (2017): 19, https://doi.org/10.3390/challe8020019.

238 Dana L. Jackson and Laura L. Jackson, eds., *The Farm as Natural Habitat: Reconnecting Food Systems with Ecosystems* (Washington, D.C.: Island Press, 2002).

239 Alison Martin et al., "Taming Rewilding — From the Ecological to the Social: How Rewilding Discourse in Scotland Has Come to Include People," *Land Use Policy* 111 (December 2021): 105677, https://doi.org/10.1016/j.landusepol.2021.105677.

240 E. Charles Brummer et al., "Plant Breeding for Harmony between Agriculture and the Environment," *Frontiers in Ecology and the Environment* 9, no. 10 (2011): 561–68, https://doi.org/10.1890/100225.

241 Victor S. Kennedy et al., "Lessons Learned from Efforts to Restore Oyster Populations in Maryland and Virginia, 1990 to 2007," *Journal of Shellfish Research* 30, no. 3 (2011): 719–31, https://doi.org/10.2983/035.030.0312.

242 Dominic McAfee, Catherine Larkin, and Sean D. Connell, "Multi-species Restoration Accelerates Recovery of Extinguished Oyster Reefs," *Journal of Applied Ecology* 58, no. 2 (2021): 286–94, https://doi.org/10.1111/1365-2664.13719.

243 Jeff Tollefson, "Can Artificially Altered Clouds Save the Great Barrier Reef?," *Nature* 596 (August 2021): 476–78, https://doi.org/10.1038/d41586-021-02290-3.

244 Stewart Brand, "The Case for De-extinction: Why We Should Bring Back the Woolly Mammoth," *Yale Environment* 360, January 13, 2014, https://e360.yale.edu/features/the_case_for_de-extinction_why_we_should_bring_back_the_woolly_mammoth.

245 Nadia Pieretti and Roberto Danovaro, "Acoustic Indexes for Marine Biodiversity Trends and Ecosystem Health," *Philosophical Transactions of the Royal Society B* 375, no. 1814 (2020):1–8, https://doi.org/10.1098/rstb.2019.0447.

246 Hendrik Birkel and Julian M. Müller, "Potentials of Industry 4.0 for Supply Chain Management within the Triple Bottom Line of Sustainability — A Systematic Literature Review," *Journal of Cleaner Production* 289 (March 2021): 125612, https://doi.org/10.1016/j.jclepro.2020.125612.

Summary of Reflective Propositions from Applications of Harmony

[**RP.85**] Harmony and dissonance can be felt in conscious experience; harmony acts like a guidance system for social behavior and for intuitive decision making in design.

[**RP.86**] The sense of harmony can be developed through introspective design education.

[**RP.87**] Musical harmony may support or restore harmony in the individual psyche.

[**RP.88**] Harmony in other media (e.g., visual, tactile; or, product design, architecture) might also contribute to harmony in the mind.

[**RP.89**] Designers can promote well-being by treating problems, undesirable situations, or dilemmas as tensions or dissonance that can to lead to greater harmony.

[**RP.90**] Designers can promote inner harmony by designing for harmony between the mind and the body.

[**RP.91**] Harmony theory can serve as a design framework for enhancing happiness and well-being.

[**RP.92**] Pursuing harmony can transcend the pursuit of individual happiness by linking the well-being of the individual to the well-being of society and of the natural world.

[**RP.93**] Harmonious organizations are important for team performance and for producing good design outcomes.

[**RP.94**] As an approach to promoting interpersonal harmony, we propose that designers can deliberately seek to create better "vibes" as outcomes.

[**RP.95**] Harmony in interpersonal settings might be supported by activities that support a balance of synchronization and desynchronization.

[**RP.96**] Since harmony is a core value for many large governments, research on harmony may support useful frameworks for international relations and peace studies.

[**RP.97**] Harmony is relative: what is disharmonious to one system may enable harmony in another system (e.g., predator and prey).

[**RP.98**] The harmonization of humankind and nature is a concise definition of sustainable design.

[**RP.99**] Harmonizing between the artificial and the natural will be essential for moving from the Anthropocene era to the Symbiocene era.

[**RP.100**] Harmonizing profit, people, and planet is the key design challenge of our time.

Conclusion

Whether as a metaphor or a mechanism, harmony offers a secular source of value that can help designers orient towards a notion of a common good.

Harmony can serve as a theory of sustainable, interconnected well-being. Harmony theory implies a rational and emotional integration of the scientific and the spiritual, the modern and the ancient, the concrete and abstract, the mathematical and the experiential. Harmony serves as a common value across cultures, from east to west, from developed to developing, from capitalist to communist. This harmony is not a result of sameness, but rather of differences integrated together. The pervasive and perennial nature of this theory seems to offer hope and vision for a positive future, but only if we can bring it back into social or philosophical discourse.[247] While a negative future vision of society can be instructive by indicating where we do *not* want to go, we arguably lack constructive positive visions that can illuminate a path forward. In recognizing that theories of harmony are many thousands of years old, we may find encouragement and inspiration for building societies capable of lasting thousands of years longer.

In both Chinese and Greek classical philosophy, harmony links the concepts of beauty, virtue, justice, happiness, health, and pleasure. There is much still to learn and discover, as a recent publication of 40 papers on harmony reveals.[248] While some might dismiss the concept as "dotty mysticism," a better understanding of the concept and its applications could lead to valuable outcomes, from the cultivation of inner harmony to sustainable harmony with nature. For this reason, we hope that the concept of harmonization will receive closer attention by scholars and scientists.

> "[N]ature itself is a harmonic system … if we ignore the principles that sustain that harmony, nature's essential balance and equilibrium become quite literally disordered."[249]

Technology has connected humanity at a global scale. We can travel around the world in a day, video sync with billions of living people, or access thousands of years of history and culture in mere seconds. Even language barriers are falling away with automated translation. But despite all the potential for meaning and integration, many of us face deep disconnection and alienation. Strong and meaningful relationships to people, concepts, or places are difficult to find or cultivate. So, in closing, how might the concept of harmony contribute to a more positive vision for the development of our future world? In particular, how might we design systems that can help humans to better harmonize with each other and with the natural world?

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