PHILOSOPHER'S COMPASS

THE WEDO JOURNAL OF INTERDISCIPLINARY PHILOSOPHY

Editor-in-Chief
Ying Fangtian

Vol. 1 No. 1 April 2025

Philosopher's Compass

The WEDO Journal of Interdisciplinary Philosophy

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Publisher: *Philosopher's Compass* is published by the World Eco-Design Organization (WEDO).

ISSN: 3078-4697 (Online), 3078-4700 (Print)

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On a Certain Inconsistency in Lacan's Work

Slavoj Žižek[1]

[1]University of Ljubljana, Ljubljana, Slovenia, slavoj.zizekkrecic@ff.uni-lj.si

EDITOR'S NOTE

This Special Contribution essay by world-renowned philosopher Slavoj Žižek reflects our commitment to broadening access to interdisciplinary philosophy and diversifying the views and approaches of philosophical research. Professor Žižek is a long-time champion of innovative and autonomous philosophical scholarship. We extend our gratitude to him for supporting this endeavor. —Kan Zhang

KEYWORDS: Lacan, Kant with Sade, Kant, Death Drive, Georges Bataille

As Lacanians, we should be especially attentive to shifts and inconsistencies in Lacan's own teaching. Perhaps the greatest shift occurs in the course of his seminar on the ethics of psychoanalysis: there is a subtle but radical change in how he reads the motif of "Kant with Sade."[1] At the beginning, he refers to Saint Paul, to Paul's notion of a law which enables (calls for) its sinful transgression, while towards the end, law itself becomes the law of desire. To clarify this shift, let's begin with the famous passage from Paul's Romans 7:

> So, my brothers and sisters, you also died to the law through the body of Christ, that you might belong to another,to him who was raised from the dead, in order that we might bear fruit for God. For when we were in the realm of the flesh, the sinful passions aroused by the law were at work in us, so that we bore fruit for death. But now, by dying to what once bound us, we have been released from the law so that we serve in the new way of the Spirit, and not in the old way of the written code. What shall we say, then? Is the law sinful? Certainly not! Nevertheless, I would not have known what sin was had it not been for the law For I would not have known what coveting really was if the law had not said, "You shall not covet." But sin, seizing the opportunity afforded by the commandment, produced in me every kind of coveting. For apart from the law, sin was dead. Once I was alive apart from the law; but when the commandment came, sin sprang to life and I died.[2]

One of the last echoes of this stance is found in the work of Georges Bataille who for this reason remains strictly *premodern*, stuck in this dialectic of the law and its transgression, of the prohibitive law as generating the transgressive desire, which forces him to the debilitating perverse conclusion that one has

[1]See Lacan (2015).

[2]*New International Version Bible* (2011, Romans 7:4–10)

to install prohibitions in order to be able to enjoy their violation—a clearly unworkable pragmatic paradox. What Bataille is unable to perceive are simply the consequences of the Kantian philosophical revolution: the fact that *the absolute excess is that of the Law itself*—the Law intervenes in the homogeneous stability of our pleasure-oriented life as the shattering force of the absolute destabilizing heterogeneity. In Buddhism, you are taught to sacrifice desire in order to attain the inner peace of Enlightenment in which sacrifice cancels itself. For Lacan, the true sacrifice is desire itself: desire is an intrusion which throws off the rails the rhythm of our life; it compels us to forfeit everyday pleasures and comforts for discipline and hard work in the pursuit of the object of our desire, be it love, a political Cause, science... In short, Lacan's reading of Kant's ethics is not fully consistent. The basic line of Lacan's reading of Kant is adequately rendered in Russell Sbriglia's summation of Joan Copjec's elaboration of her notion of the "sartorial superego":

> Whereas utilitarianism blithely assumes that "man can be counted as zero," psychoanalysis insists that, if counted man can indeed be, he can only be counted as "minus one" (87).[3] Confident that the goal of man is the maximization of pleasure and that pleasure can therefore be used to regulate and manipulate man, utilitarianism presumes that "man is basically and infinitely manageable," that he is, in short, "fundamentally ruly" (85). The psychoanalytic objection to this supposition, Copjec clarifies, rests not on the protest that man is more than "rationalist engineers" like Bentham allow, but rather that "man is, in a manner, less" than utilitarians realize insofar as "he is radically separated from, and cannot know, what he wants" (87)—a separation and an unknowing that renders man fundamentally unruly. Hence Copjec's conclusion that "the difference between the utilitarian and the Lacanian subject is the difference between zero and minus one, between a subject who is driven to seek the maximization of his pleasure in his own greater good, and a subject for whom pleasure cannot function as an index of the good, since the latter is lost to him"—lost because the subject is ultimately "subject to a principle beyond pleasure" (87), that principle being, of course, what psychoanalysis dubs the death drive.[4]

Up to this point I cannot but fully agree: for Kant, freedom effectively is not the freedom to pursue one's pleasures without constraints, it is on the contrary "the freedom to resist the lure of the pleasure principle and to submit oneself to the law of the death drive" (96). Freedom does not reside in spontaneously following one's cravings; it is a form of *resistance* to these cravings, a form of self-control. But now we come to the problematic point: Lacan sees the limit of Kant's notion of categorical imperative in Kant's ignorance of how the distinction between the subject of the enunciated and the subject of enunciation works in the case of categorical imperative—a failure that makes it seem as though it "come[s] from nowhere," which, in turn, allows the addressee to "presume to occupy the vacant enunciative position" and "take itself as the source of the statement": "the ethical subject hears the voice of conscience as its own" (96–98). With his autonomous ethics, Kant thus "sealed up again the gap he so dramatically opened" (96): it appears that subject itself issues the moral imperative he obeys in acting ethically.

[3] Numbers in parentheses refer to pages in Copjec (1994).

[4] See Sbriglia (n.d.).

Again, in Lacanese, what Kant failed to do was to distinguish between the subject of the *enunciated* (the subject of the *statement* that Kant correctly understood the categorical imperative to be) and the subject of its *enunciation* which is decentered with regard to the moral subject—this agency that pushes the subject to act ethically is, of course, what psychoanalysis identifies as the *superego*. And here Sade enters as the "truth" of Kantian ethics: the categorical imperative is not libidinally neutral since the pain we, its subjects, experience when doing our duty brings enjoyment to the decentered superego agency. From this standpoint, we can claim that "acting ethically, paradoxically, entails not *identifying* with the moral law (as in Kant), but *dis-identifying* with it, it entails not heeding this 'impulse,' but '*recoil[ing]*' in 'moral revulsion' (88) from this 'incomprehensible part of our being' (92)."

However, the actual "incomprehensible part of our being" is not superego but *desire itself*, which is constitutively decentered with regard to subject, desire which makes subject barred, a void. And, as it was formulated with brilliant simplicity by Lacan, the reason Sade was not able to think the barred subject resides in his misconception of the difference between the two deaths, the biological death of the common mortal body and the death of the other "undead" body: it is clear that what Sade aims at in his notion of a radical Crime is the murder of this second body. Sade deploys this distinction in the long philosophical dissertation delivered to Juliette by Pope Pius VI in the book 5 of *Juliette*:

> There is nothing wrong with rape, torture, murder, and so on, since these conform to the violence that is the way of the universe. To act in accordance with nature means to actively take part in its orgy of destruction. The trouble is that man's capacity for crime is highly limited, and his atrocities no matter how debauched ultimately outrage nothing. This is a depressing thought for the libertine. The human being, along with all organic life and even inorganic matter, is caught in an endless cycle of death and rebirth, generation and corruption, so that "there is indeed no real death," only a permanent transformation and recycling of matter according to the immanent laws of "the three kingdoms," animal, vegetable, and mineral. Destruction may accelerate this process, but it cannot stop it. The true crime would be the one that no longer operates within the three kingdoms but annihilates them altogether, that puts a stop to the eternal cycle of generation and corruption and by doing so returns to Nature her absolute privilege of contingent creation, of casting the dice anew.

What, then, at a strict theoretical level, is wrong with this dream of the "second death" as a radical pure negation which puts a stop to the life-cycle itself? In a superb display of his genius, Lacan (2006) provides a simple answer: "It is just that, being a psychoanalyst, I can see that the second death is prior to the first, and not after, as de Sade dreams it" (p. 667). (The only problematic part of this statement is the qualification "being a psychoanalyst"—a Hegelian philosopher can also see this quite clearly.) In what precise sense are we to understand this priority of the second death—the radical annihilation of the entire life-cycle of generation and corruption—over the first death which remains a moment of this cycle? Aaron Schuster points the way:

> Sade believes that there exists a well-established second nature that operates according to immanent laws. Against this ontologically consistent realm he can only dream of an absolute

Crime that would abolish the three kingdoms and attain the pure disorder of primary nature.[5]

In short, what Sade doesn't see is that there is no big Other, no Nature as an ontologically consistent realm—nature is already in itself inconsistent, unbalanced, destabilized by antagonisms. The total negation imagined by Sade thus doesn't come at the end, as a threat or prospect of radical destruction; it comes at the beginning, it always-already happened, it stands for the zero-level starting point out of which the fragile/inconsistent reality emerges. In other words, what is missing in the notion of Nature as a body regulated by fixed laws is simply *subject itself*: in Hegelese, the Sadean Nature remains a Substance, Sade continues to grasp reality only as Substance and not also as Subject, where "subject" does not stand for another ontological level different from Substance but for the immanent incompleteness-inconsistency-antagonism of Substance itself. And, insofar as the Freudian name for this radical negativity is death drive, Schuster is right to point out how, paradoxically, what Sade misses in his celebration of the ultimate Crime of radical destruction of all life is precisely the death drive.

This brings us back to Kant, to Kant's preeminence over Sade: Kant characterized free autonomous act as an act which cannot be accounted for in the terms of natural causality, of the texture of causes and effects: a free act occurs as its own cause, it opens up a new causal chain from its zero-point. So insofar as "second death" is the interruption of the natural life-cycle of generation and corruption, no radical annihilation of the entire natural order is needed for this—an autonomous free act already suspends natural causality, and subject as already is this cut in the natural circuit, the self-sabotage of natural goals. The mystical name for this end of the world is "night of the world," and the philosophical name, radical negativity as the core of subjectivity. And, to quote Mallarmé, a throw of the dice will never abolish the hazard, i.e., the abyss of negativity remains forever the unsublatable background of subjective creativity. We may even risk here an ironic version of Gandhi's famous motto "be yourself the change you want to see in the world": the subject is itself the catastrophe it fears and tries to avoid. And is the lesson of Hegel's analysis of the French revolutionary terror not exactly the same (which is why the parallel between Sade's absolute crime and revolutionary terror is well grounded)? Individuals threatened by the Terror have to grasp that this external threat of annihilation is nothing but the externalized/fetishized image of the radical negativity of self-consciousness—once they grasp this, they pass from revolutionary Terror to the inner force of the moral Law.

So I think Lacan ultimately doesn't claim that the Kantian categorical imperative is sustained by a Sadean superego injunction to enjoy: what happens in an authentic ethical act is another dis-identification, a dis-identification between the moral law and the superego. If my desire is sustained by a superego imperative (as is the case in every form of transgressive desire, a desire that thrives on violating what the law prohibits), then this desire is by definition compromised—in acting in this way, I betray my desire.

And to dispel the impression that we are dealing here with distinctions of no practical or political interest, think about Ukraine today, in 2024. The country is confronting a forced choice: life or freedom? However, this choice has an additional twist: both choices imply death. If, in the present situation, you choose life (surrender), you choose death (disappearance as a nation, as Russia repeatedly made it clear). If you choose freedom (i.e., continued armed resistance, but with the prospect of less Western support),

[5] Schuster (2016). From this point, all unattributed quotations refer to the pages of this work.

you choose (for many Ukrainians and their habitat) actual death and destruction. In Lacanian terms, the difference is none other than the one between the two deaths: symbolic death (loss of symbolic identity) and actual biological death. Perhaps, this is the best definition of our global predicament today.

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Philosopher's Compass 1/1 (2025): 6–21.

Jury Nullification, Verdictal Asymmetry, and the Ultimate Logic of Anarchy

Travis Hreno[1]

[1]University of Akron, Akron, Ohio, USA, th34@uakron.edu

ABSTRACT

Jury Nullification, Verdictal Asymmetry, and the Ultimate Logic of Anarchy" is a critical examination and analysis of the 'anarchy objection' to jury nullification, a common argument against informing juries of their nullification power. The anarchy objection asserts that jury nullification leads to inconsistent verdicts (verdictal asymmetry) and, as a result, social anarchy and chaos. Through careful analysis, I argue that the anarchy objection is predicated on two flawed premises: first, that jury nullification promotes verdictal asymmetry, and second, that such asymmetry leads to anarchy. Such commitments are, I argue, empirically unsupported and conceptually misguided. Verdictal asymmetry is an intrinsic feature of the common law system, present at nearly every adjudicative stage, and not uniquely linked to jury nullification; yet we certainly do not live in an environment of jural/social anarchy. Finally, I discuss how the principle of treating like cases alike is primarily a procedural constraint, not a mandate for verdictal symmetry. By dismantling the anarchy objection, this paper contributes to a deeper understanding of the jurisprudence surrounding the jury nullification debate and its role within the legal system.

KEYWORDS: Jury Nullification, Verdictal Asymmetry, Anarchy Objection

> Jury nullification is put forward in the name of liberty and democracy, but its explicit avowal risks the ultimate logic of anarchy.[1]

1 | INTRODUCTION

Jury nullification, whereby a jury returns a not guilty verdict for a defendant believed to be guilty by law and fact, has provoked a great deal of criticism and condemnation from the courts. One of the more popular arguments appealed to by the bench when framing their opprobrium of jury nullification is the so-called *anarchy objection*: jury nullification leads to inconsistent verdicts for similar cases (*verdictal asymmetry*, as I shall refer to it in this paper), which in turn, "would lead to chaos and an absence of justice."[2] The factual and conceptual errors engendered by a commitment to the *anarchy objection*, are, I

[1] *United States v. Dougherty*, 473 F.2d 1113, 1133 (D.C. Cir. 1972).
[2] *State v. Kelly*, 727 S.E.2d 912, 915 (N.C. Ct. App. 2012).

intend to prove, substantial. To begin with, there is significant empirical evidence to suggest that there is, in reality, no robust correlation between jury nullification and verdictal asymmetry – quite the opposite, in fact. Moreover, whatever verdictal asymmetry does fall out of the jury system is a feature of the jury system itself – jury nullification is therefore not implicated in its existence within the justice system. Beyond the functioning of juries, verdictal asymmetry is an endemic feature of the justice system at nearly all adjudicative stages, particularly at the level of the judiciary – eliminating or minimizing instances of jury nullification will therefore not eliminate verdictal asymmetry from the justice system. Additionally, and importantly, we do not currently live in a jural/social environment of chaos, anarchy, and disorder. If the *anarchy objection* were to be believed, we should expect to see some evidence of such, given the extant nature of verdictal asymmetry within the justice system. We do not. Finally, the *anarchy objection*, I show, is ultimately predicated on a naïve and unreflective commitment to, and preference for, the concept of verdictal symmetry – that ideal that, when like cases are treated alike, the verdicts too ought to mirror one another, in the name of justice and fairness. This account of the principle simply gets the issue wrong. Treating like cases alike is a *procedural* constraint on fairness – it addresses the idea that similar defendants who are accused of similar crimes ought to have access to the same jural procedures and processes, and be tried according to the same standards and laws. This principle is, I argue, therefore best understood as being agnostic regarding verdicts – it is process-driven, not content-oriented.

Taking these perspectives together, it will become clear that, to the degree that the *anarchy objection* is predicated on a rejection of verdictal asymmetry, it must be dismissed as naïve, specious, and ultimately based on a misunderstanding of the adjudicate role in the common law and the demands of fairness.

2 | JURY NULLIFICATION

Jury nullification refers to a jury's deliberate choice to return a not guilty verdict for a defendant whom it believes, on the facts and law, to be guilty of the offense charged. Specifically, nullification occurs when a jury, despite believing both (a) that the defendant has committed the act or omission in question beyond a reasonable doubt and (b) that such conduct is prohibited by law, nevertheless chooses to acquit the defendant.[3] In nullifying, the jury refuses to be bound by the facts of the case or by the judge's instructions on the law. Such behaviour, it is important to note, is a perfectly legal exercise of the jury's discretionary powers. Nullified verdicts cannot be reviewed, overruled, dismissed, or impeached – nor are jurors subject to any form of redress or punishment for engaging in nullification. The court is bound by law to accept such verdicts, and case law is replete with judgments affirming this.[4] Jury nullification

[3]Travis Hreno, *Jury Nullification: The Jurisprudence of Jurors' Privilege* (Cambridge: Ethics International Press, 2024), 7.

[4]See, for example, *Horning v. District of Columbia*, 254 U.S. 135, 138 (1920), where Holmes, J. stated, "[T]he jury has the power to bring in a verdict in the teeth of both law and facts"; *Morissette v. United States*, 342 U.S. 246, 275 (1952), "But juries are not bound by what seems inescapable logic to judges"; *United States v. Moylan*, 417 F.2d 1002, 1006 (4th Cir. 1969) (emphasis added), "If the jury feels the law is unjust, we recognize the undisputed power of the jury to acquit, even if its verdict is contrary to the law as given by a judge, and contrary to the evidence... If the jury feels that the law under which the defendant is accused is unjust, or that exigent circumstances justified the actions of the accused, or for any reason which appeals to their logic or passion, the jury has the power to acquit, and the courts must abide by that decision"; *United States v. Dougherty*, 473 F.2d 1113, 1130 (D.C. Cir. 1972), "The jury has an 'unreviewable and irreversible power... to acquit in disregard of the instructions on the law given by the trial judge...'"

thus grants the jury a nearly unreviewable power to return a verdict of not guilty for defendants who are, according to the law, guilty of the crime charged. As the Court in State v. Hooks[5] described it:

> Jury nullification, also called jury lenity, is the extraordinary power of the jury to issue a not-guilty verdict even if the law as applied to the proven facts establishes that the defendant is guilty. Jury nullification is a curious paradox: it is the jury's prerogative to disregard the law without actually committing an unlawful offense in doing so; its exercise is literally illegitimate (contrary to law) but practically legitimate (allowed by law). It is the physical power to disregard the law that has been laid down to [the jury] by the court. In that sense, the most accurate description of the jury's paradoxical authority to act on its own in disregard of the law even while it is charged with following the law is *the raw power to bring in a verdict of acquittal in the teeth of the law and the facts*.[6]

By definition, jury nullification can only result in an acquittal, not a conviction. Guilty verdicts unsupported by the evidence or rendered despite the jury's belief in the defendant's innocence already have a name: they are known as "unjust convictions," and there exist remedies in place for such cases; guilty verdicts, at least in principle, always remain open to appellate review. On the other hand, when the jury returns a not guilty verdict – regardless of the reason – the verdict must stand and is immune to review or appeal.[7] This is in great part because the Fifth Amendment of the *U.S. Constitution*, through the operation of the *Double Jeopardy Clause*, forbids the State from pursuing multiple prosecutions against an individual for the same crime – even when confronting nullified verdicts.[8] Thus, whenever a jury engages in nullification, the power and operation of that specific law(s) has been, for that specific case, and that specific defendant, *nullified* – rendered null and void. Hence the term jury *nullification*. This power to nullify, affirmed repeatedly by case law and precedent, has been defended on the grounds that it functions as a "safety valve"[9] in the legal system, giving jurors the authority to reject those laws they perceive to be objectionable, unjust, or contrary to the democratic will of the people.

Jury nullification introduces a tension into the administration of the law. Since verdicts of not guilty are binding and unreviewable, it appears that built into the justice system itself is a means by which that system can be subverted; that is, although jurors are directed to follow the law, jury nullification allows jurors the power to disregard the law. It is not surprising, therefore, that it elicits much controversy and condemnation from courts and scholars alike. Given its nature as an intrinsic and necessary feature of the criminal jury system,[10] however, the real debate regarding jury nullification is, and always has been: ought juries be instructed or informed of their ability to nullify the law?[11] As the law currently stands, a

[5] *State v. Hooks*, 752 N.W.2d 79 (Minn. Ct. App. 2008).

[6] *Id.* at 86.

[7] See, *United States v. Ball*, 163 U.S. 662 (1896); *U.S. v. Siegelman*, 640 F.3d 1159, 1185 n. 36 (11th Cir. 2011) (emphasis added), "we permit logically inconsistent jury verdicts as to different counts, and even as to different co-defendants. *We permit jury nullification*. We do not inquire whether a verdict is the result of compromise, mistake or even carelessness."

[8] U.S. v. Siegelman, *id.*

[9] *U.S. v. Dougherty*, 473 F.2d 1113, 1134.

[10] See, Travis Hreno, "Necessity and Jury Nullification," *Canadian Journal of Law and Jurisprudence* 20, no. 2 (2007): 351.

[11] See, for instance, Irwin A. Horowitz, "The Effects of Jury Nullification Instructions on Verdicts and Jury Functioning in

trial judge's instructions to the jury are to make no reference to the jury's ability to nullify.[12] Nevertheless, the issue of a nullification instruction to the jury continues to be raised, particularly at the appellate level, and the courts, in response, continue to offer reasons to justify their rejection of such explicit candor.

3 | THE ANARCHY OBJECTION

Perhaps the most common objection to a nullification instruction is the anarchy objection – a position predicated on the view that jury nullification promotes or leads to a state of jural anarchy, and that any endorsement of jury nullification is thereby "an invitation to anarchy"[13] in the administration of the criminal law and society in general. For that reason, proponents of the anarchy objection conclude, any and all efforts must be made to discourage its use.[14] The Court in *United States v. Dougherty*,[15] for instance, voiced emphatic support for the anarchy objection to a nullification instruction, stating that "[t]his so-called right of jury nullification is put forward in the name of democracy, but its explicit avowal risks *the ultimate logic of anarchy*."[16] The Dougherty Court went on to cite with approval *United States v. Moylan*[17] where Sobeloff, J. made the following claim: "To encourage individuals to make their own determinations as to which laws they will obey and which they will permit themselves as a matter of conscience to disobey is to invite chaos… *Toleration of such conduct would not be democratic, as appellants claim, but inevitably anarchic*."[18] This perspective was reinforced by the Kansas Supreme Court, which, in commenting on the advisability of a nullification instruction, stated that the practice and encouragement of jury nullification "creates anarchy and destroys the very protections which the law affords."[19] This line of reasoning has, as mentioned, found widespread endorsement, both by the courts and by legal scholars.[20]

Criminal Trials," *Law and Human Behavior* 9, no. 1 (March 1985): 25; *U.S. v. Navarro-Vargas*, 05 C.D.O.S. 4311; Steven E. Barkan, "Jury Nullification in Political Trials," *Social Problems* 31, no. 1 (October 1983): 38; Alan Scheflin and Jon Van Dyke, "Jury Nullification: The Contours of a Controversy," *Law and Contemporary Problems* 43, no. 4 (Autumn 1980): 51; *State v. Hokanson*, 140 N.H. 719, 721 (1996); *United States v. Krzyske*, 836 F.2d 1013 (6th Cir. 1988).

[12] See, for instance, *Sparf v. United States*, 15 S.Ct. 273 (1895); *United States v. Avery*, 717 F.2d 1020 (6th Cir. 1983), cert. denied, 466 U.S. 905 (1984); *Horning v. District of Columbia*, 41 S.Ct. (1920); *United States v. Burkhart*, 501 F. 2d 993 (6th Cir. 1974).

[13] James Joseph Duane, "Jury Nullification: The Top Secret Constitutional Right," *Litigation* 22 (1996): 6.

[14] See, *U.S. v. Powell*, 955 F.2d 1206 (9th Cir. 1992); *State v. Nicholas*, 185 Wash. App. 298 (Wash. Ct. App. 2014).

[15] *United States v. Dougherty*, 473 F.2d 1113 (D.C. Cir. 1972).

[16] *Id.* at 1133 (emphasis added).

[17] *United States v. Moylan*, 417 F.2d 1002 (4th Cir. 1969).

[18] *Id.* at 1009 (emphasis added).

[19] *State v. McClanahan*, 212 Kan. 208, 216, 510 P.2d 153, 159 (1973).

[20] See, for instance, *United States v. Dougherty*, 473 F.2d 1113, 1137 (D.C. Cir. 1972): "An explicit instruction to a jury conveys an implied approval that runs the risk of degrading the legal structure requisite for true freedom, for an ordered liberty that protects against anarchy as well as tyranny;" *United States v. Ogle*, 613 F.2d 233, 241 (10th Cir. 1980): "To empower each individual to decide whether the particular law is worthy or runs against the individual's private beliefs would necessarily produce a lawless society and chaos. Quite apart from the fact of invalidity of such a system, it has no practical social value. Such a government would fail in a very short time, for carried to its logical conclusion it is anarchy and revolution;" *United States v. Decoster*, 624 F.2d 196, 325 n.9 (D.C. Cir. 1979): "My colleague's proposal for jury nullification is that juries should be instructed by the judge that they need not return verdicts on the law or the evidence — thus denying any semblance of due process or equal protection of the law by a form of jury anarchy;" *People v. Sanchez*, 58 Cal.App.4th 1435, 1446 n.2 (Cal. Ct. App. 1997): "the path of nullification leads to anarchy;" *People v. Dillon*, 34 Cal.3d 441, 488 n.39 (Cal. 1983): "Whatever the result of that exercise, it cannot seriously be urged that, when asked by the jurors, a trial judge must advise them: 'I have instructed you on the law applicable to this case. Follow it or ignore it, as you choose.' Such advice may achieve

Before we proceed further in this analysis, I think it is important to clarify and disambiguate what, exactly, is meant by 'anarchy' in this context. Decidedly, the term is not being used formally, in reference to any particular academic theory of the state and/or political authority – the courts are not expressing concern about Kropotkinian influences in the administration of the law, for instance. Rather, 'anarchy' in this context is being used in a somewhat informal and vernacular sense, similar to the idea of chaotic disorder, and the foundational commitment of the *anarchy objection* is that jury nullification will lead to some form of *jural* disorder or chaos: a widespread, inconsistent, and unstable approach to the application and administration of the criminal law – a state of total legal/jural anarchy, in other words. Giving a *nullification instruction* will, according to this view, thereby lead to "anarchy in the courtroom, and that might in the end harmfully infect organized society."[21] Such jural anarchy, the argument continues, would corrupt the administration of the law to the degree that the legal system could no longer be relied upon to function as a reliable "legal structure requisite for true freedom, for an ordered liberty that protects against anarchy as well as tyranny."[22] Put explicitly, in a state of jural anarchy our fundamental and essential legal rights would, for all intents and purposes, cease to exist. The *anarchy objection*, therefore, is predicated on the claim that jury nullification is, on the whole, inconsistent with the sound, stable, and consistent administration of the criminal law; that it will, essentially, promote and engender widespread jural anarchy, chaos, and the breakdown of the very "protections afforded by the rule of law."[23]

One final thing needs to be understood about the *anarchy objection*: its scope and context. It would be a misrepresentation, and unduly uncharitable, to attribute to the *anarchy objection* the claim that any one individual instance of jury nullification would thereby be the thin edge of the wedge towards total legal

pragmatic justice in isolated instances, but we suggest the more likely result is anarchy;" *Arshack v. United States*, 321 A.2d 845, 851 (D.C. 1974): "No doubt juries sometimes act out of compassion and in disregard of the law. But we will not place upon such conduct by juries the stamp of judicial approval through an instruction from the court. To do so would actually encourage anarchy in the courtroom, and that might in the end harmfully infect organized society;" *United States v. Simpson*, 460 F.2d 515, 520 n.12 (9th Cir. 1972): where the court referred to jury nullification as "a kind of anarchy; that is, a system in which the ultimate test of socially permissible conduct is, to a significant degree, the random reaction of a group of twelve people selected at random. Acceptance of this as the principle governing individual conduct which collides with the rules adopted by governmental processes would, of course, amount to rejection of law as the controlling principle of society;" *State v. McClanahan*, 212 Kan. 208, 216, 510 P.2d 153, 159 (1973), where the court stated, in regard to jury nullification that "[d]isregard for the principles of established law creates anarchy and destroys the very protections which the law affords;" Lawrence W. Crispo, Jill M. Slansky, and Geanene M. Yriarte, "Jury Nullification: Law Versus Anarchy," *Loyola of Los Angeles Law Review* 31 (1997): 60–61: "Jury nullification does and will continue to occur, but courts should never encourage it… If individuals were allowed to decide that certain laws apply to some and not to others, true anarchy would reign;" Caisa E. Royer, "The Disobedient Jury: Why Lawmakers Should Codify Jury Nullification," *Cornell Law Review* 102 (2017): 1406: "Without any consequences, jury nullification may involve less integrity than other acts of conscientious lawbreaking wherein the lawbreakers willingly suffer penalties for their actions. Juries can, in theory, mercurially acquit defendants which would create a system of anarchy instead of a system of democracy;" Jeffery Abramson, "Two Ideals of Jury Deliberations," *University of Chicago Legal Forum* (1998): 147, stating that if courts allow jurors to "deliberate whether they happened to agree with the law, then there effectively would be no law at all, only an anarchy of conscience, an unpredictable series of ad hoc judgments by isolated groups of twelve;" Susan Yorke, "Jury Nullification Instructions as Structural Error," *Washington Law Review* 95 (2020): 1148–49: "Nullification thus simultaneously occupies dissonant roles in our jurisprudential universe. It is anarchy, subverting the most basic tenets of our adjudicative process. And it is itself a fundamental tenet of that process, instilling in the people the power to resist government tyranny and prevent injustice. Law values order; nullification is mayhem." See also, Alan Scheflin and Jon Van Dyke, "Jury Nullification: The Contours of a Controversy," *Law and Contemporary Problems* 43, no. 4 (1980): 85–90, for an in-depth discussion of this objection.

[21] *Arshack v. United States*, 321 A.2d 845, 851 (D.C. 1974).

[22] *United States v. Dougherty*, 473 F.2d 1113, 1137 (D.C. Cir. 1972).

[23] *State v. McClanahan*, 212 Kan. 208, 216, 510 P.2d 153, 159 (1973).

collapse and anarchy – no one reasonably endorses such a view. Rather, the *anarchy objection* ought best be understood as the claim that a legal system that allows for, licenses, endorses, or otherwise approves of jury nullification is a legal system that is thereby incompatible with the necessary consistency to prevent jural anarchy. In other words, the *anarchy objection* is not concerned so much with specific cases of jury nullification, as it is with the institutional/systemic approval of the practice. It is, in this sense, a holistic or systemic, as opposed to atomistic, objection to jury nullification. Mike Reck, in *A Community with No Conscience: The Further Reduction of a Jury's Right to Nullify in People v. Sanchez*,[24] provides a formalized account of the structure of this argument:

The Anarchy Objection formalized

(i) "If jury nullification is allowed, the law will be applied inconsistently and the outcomes of similar cases would turn on how those particular jurors felt on that particular day,"[25] or, more simply, *jury nullification promotes verdictal asymmetry* (*JNVA*).

(ii) "If laws are not applied consistently then, in effect, the law is different for each person. If the law can change daily, then all people do not have to live by the same standards, and society drifts from order to anarchy,"[26] or, more simply, *verdictal asymmetry promotes social anarchy* (*VAA*).

(iii) Therefore, "Jury nullification carries with it the inherent danger of anarchy,"[27] or, more simply, *jury nullification promotes social anarchy* (*JNA*).

Reck concludes from this that "[i]t is difficult to advocate nullification on the basis of fairness when the doctrine allows one defendant to unfairly walk away while another defendant under similar circumstances may be severely punished."[28] As Reck defines and describes it, the *anarchy objection* is thus motivated by an assertion of the inherent unfairness of inconsistent, or asymmetric verdicts, or, as I call it here, *verdictal asymmetry*. A legal system committed to justice, fairness, and most importantly, the prevention of social chaos, the advocates of the *anarchy objection* assert, would not license such *verdictal asymmetry* and would therefore not promote or in any other way sanction jury nullification. Thus, at its most basic conceptual level, the *anarchy objection* is predicated on a rejection of *verdictal asymmetry* as being contrary to jural stability, coherence, consistency, and, ultimately, the most fundamental principles of justice instantiated in the rule of law.

Admittedly, this might appear, prima facie, to be a somewhat persuasive and reasonable view. It is, after all, based on that rather commonsense principle that justice demands that like cases be treated alike (for the sake of brevity, I shall abbreviate this principle as LCA (like cases alike)). This is hardly a con-

[24] Mike Reck, "A Community with No Conscience: The Further Reduction of a Jury's Right to Nullify in People v. Sanchez," *Whittier Law Review* 21 (1999): 285.
[25] *Id.* at 307.
[26] *Id.*
[27] *Id.* at 296.
[28] *Id.* at 308.

troversial view, and dates back to at least Aristotle, if not earlier.[29] However, as I shall demonstrate in the following pages, the *anarchy objection* fails on two very important and fundamental grounds: the first premise greatly exaggerates, to the point of misrepresentation, the relationship between jury nullification and verdictal asymmetry. *JNVA*, in other words, is empirically false – jury nullification does not promote inconsistent verdicts for similar cases. And the second premise fails on two related points: first, since verdictal asymmetry is, in fact, an intrinsic and necessary part of the law at nearly every stage of the adjudicative process, any attempt to eliminate or actively discourage verdictal asymmetry would ultimately entail the near total dismantling of the entirety of the common law system; second, given the extant and robust presence of verdictal asymmetry within the criminal law, we would expect to see some sign of anarchy by now if there was, indeed, a causal relationship between verdictal asymmetry and anarchy – we have not! Both premises of the *anarchy objection* must therefore be rejected, I conclude. Finally, I raise a small point at the end about the *LCA* principle and its relation to verdictal asymmetry. These two are not in conflict, I suggest, as the *LCA* principle is best understood as a procedural constraint, and is agnostic *vis-à-vis* verdicts.

4 | THE FIRST PREMISE (JNVA)

JNVA, while initially a somewhat plausible claim, ultimately does not bear up to close scrutiny. To begin with, it is not at all obvious or clear that inconsistent verdicts would necessarily follow by giving a nullification instruction. Jurors informed of their privilege to nullify would simply have a wider array of things to consider, judge, weigh, and debate while engaged in their deliberations. Perhaps the addition of these extra considerations will result in less consistency between verdicts, as the advocates of the *anarchy objection* suggest, but there is no reason to suppose that this is so. Indeed, we have every reason to expect the opposite – that different juries, appealing to a wide bank of common and shared extra-legal notions of community values, mores, and justice, might very well converge upon the same or similar conclusions about the appropriate verdict in similar cases.[30] While a nullification instruction will most likely increase the number of not guilty verdicts returned *overall*, the claim that such verdicts would thereby be returned in ways that are radically inconsistent with other similarly instructed juries simply does not follow as a necessary or even likely implication. And, in fact, there is empirical evidence to suggest that different juries receiving similar instructions – regardless of whether such instructions include information about jury nullification – tend to return similar verdicts in similar cases, in direct contradiction to *JNVA*. Irwin Horowitz, in *The Effect of Jury Nullification Instruction on Verdicts and Jury Functioning in Criminal*

[29] Aristotle, *Nicomachean Ethics*, 5.1131a10–b15, trans. W. D. Ross (Oxford: Oxford University Press, 1925) (c. 350 BCE); Aristotle, *Magna Moralia*, 1.1193b–1194b, trans. W. D. Ross (Oxford: Oxford University Press, 1925) (n.d.); Aristotle, *Politics*, 3.1280a8–16, 1282b18–23, ed. and trans. Ernest Barker (Oxford: Oxford University Press, 1946) (c. 350 BCE). See, also, H.L.A. Hart, "Positivism and the Separation of Law and Morals," *Harvard Law Review* 71 (1958): 623–24: "If we attach to a legal system the minimum meaning that it must consist of general rules – general both in the sense that they refer to courses of action, not single actions, and to multiplicities of men, not single individuals – this meaning connotes the principle of treating like cases alike, though the criteria of when cases are alike will be, so far, only the general elements specified in the rules. *It is, however, true that one essential element of the concept of justice is the principle of treating like cases alike.*"

[30] For a related discussion, see, for instance, Cynthia Lee, "Cultural Convergence: Interest Convergence Theory Meets the Cultural Defense," *Arizona Law Review* 49 (2007): 911.

Trials,[31] conducted a study designed to measure the effects of nullification instructions on how jurors reason. Horowitz found that those juries who were informed of their nullificatory powers tended to, in general, behave more mercifully than those receiving standard-pattern jury instructions.[32] This is not surprising, for obvious reasons, and is certainly in keeping with what both proponents and opponents of the *nullification instruction* assume will occur in such cases. What is particularly important to note, however, is that in an experiment involving 45 mock juries, 270 jurors, and 3 different criminal cases, Horowitz recorded no significant differences in verdicts returned by mock juries *within* groups receiving identical instructions. Specifically, and importantly, the juries that received the nullification instruction all returned consistent verdicts with one another.[33] Horowitz has since expanded on this work, and has confirmed his initial findings,[34] noting that "the good news is that nullification instructions did not produce an amplification of juror biases [or inconsistencies]."[35] While nullification instructions can yield more merciful verdicts in some cases, the empirical evidence that exists suggests that such mercy is applied in a wholly consistent and consonant manner, and not in the anarchic, chaotic, inconsistent, and capricious ways assumed by the proponents of the *anarchy objection*:

> Research on jury nullification instructions suggest that, contrary to concerns expressed by some legal scholars, providing nullification instructions would not lead to anarchy. Rather, while juries might rely on their values and beliefs to [render a verdict]… deliberation provides further stability to the process of jury decision-making even when nullification instructions are presented.[36]

A nullification instruction, therefore, would seem to promote (or at least preserve) verdictal *symmetry*, and not, as proponents of the *anarchy objection* assert, its contrary. It is true, perhaps, that if only some juries are informed of the doctrine of jury nullification while others are not then we might expect an increase in verdictal asymmetry. But it should hardly be surprising that different juries receiving inconsistent instructions might thereby return inconsistent verdicts. And the solution – if we wish to avoid this – is simply to make such instructions uniform. As Horowitz's research has demonstrated, we can expect more or less stable and symmetrical verdicts from similarly instructed juries. The weight of reason and evidence suggests, therefore, that *JNVA* is false, and must be rejected.

5 | THE SECOND PREMISE (VAA)

There is, moreover, a more fundamental problem with the anarchy objection beyond its empirical paucity: the existence of verdictal asymmetry in the criminal law is, I argue, an irrelevant and otiose point *vis-à-*

[31] Irwin Horowitz, "The Effect of Jury Nullification Instruction on Verdicts and Jury Functioning in Criminal Trials," *Law and Human Behavior* 9, no. 1 (1985): 25.

[32] *Id.* at 31

[33] *Id.*

[34] Irwin Horowitz, "Jury Nullification: An Empirical Perspective," *North Illinois University Law Review* 28 (2008): 425.

[35] *Id.* at 447.

[36] Mauricio J. Alvarez, Monica K. Miller, and Brian H. Bornstein, "'It Will Be Your Duty…': The Psychology of Criminal Jury Instructions," in *Advances in Psychology and Law*, ed. Brian H. Bornstein and Monica K. Miller (Springer, 2016), 147–48.

vis jury nullification or a nullification instruction. The criminal law is, in principle and in fact, already susceptible at all adjudicative levels to application and outcomes in ways that are inconsistent and asymmetric between different defendants facing similar cases, and in ways that cannot be attributed simply or primarily to jury nullification. Yet such asymmetry is rarely identified as problematic when not attributed to jury nullification:

> The justice system is rife with both unpredictability and subjective judgment, quite apart from jury nullification… When suspects are prosecuted, different juries may make different judgments about the factual evidence, rendering jury trial outcomes unpredictable even without nullification…The point here is that unpredictability is rarely regarded as a great problem, certainly not as rendering the system "lawless" or "anarchic". Hardly anyone thinks, for example, that prosecutorial discretion should be eliminated in order to make the system more predictable.[37]

Verdictal asymmetry is, according to Huemer, a fact of the law at nearly all adjudicative stages. Moreover, even if juries were to be singled out for some arbitrary reason for their contributions to the justice system's extant verdictal asymmetry, their inconsistent verdicts are most reasonably explained as, not nullification, but rather the inevitable consequence of using jurors – imperfect reasoning machines, operating under incomplete and imperfect epistemic conditions – to freely deliberate upon and return verdicts. Indeed, the courts have repeatedly affirmed the expected reality that "[d]ifferent jurors [will] draw different conclusions about the right verdict on the basis of exactly the same evidence."[38] Such is a basic truth of the jury trial and, frankly, of human nature in general. This position was stated clearly and succinctly in *Roth v. United States*,[39] where the court claimed that "it is common experience that different juries may reach different results under any criminal statute. That is one of the consequences we accept under our jury system."[40] Other courts have expanded on this reasoning and have explained why such verdictal asymmetry is an inevitable consequence of the jury system itself: "Many reasons may explain apparently inconsistent verdicts…, possibly, that two juries simply viewed similar evidence differently."[41] Or: "In a world populated by human beings, verdicts delivered by different juries are unlikely to be perfectly consistent."[42] Obviously, such observations are not meant to stand as profound challenges to our common-sense understanding as to how human reasoning operates. Quite the contrary. What is important however, at least from the perspective of a legal analysis of the issue, is the courts' acknowledgment of, and seeming tacit approval of, the possibility of such inconsistencies in jury verdicts *simpliciter*. To single out jury nullification for its role in promoting verdictal asymmetry seems, therefore, to be entirely

[37] Michael Huemer, "The Duty to Disregard the Law," *Criminal Law and Philosophy* 12 (2018): 8.

[38] Phoebe C. Ellsworth, "Some Steps between Attitudes and Verdicts," in *The Jury Trial in Criminal Justice*, ed. D. D. Koski (Carolina Academic Press, 2003): 301.

[39] *Roth v. United States*, 354 U.S. 476 (1957).

[40] *Id.* at 492 n.30.

[41] *People v. Palmer*, 24 Cal.4th 856, 858 (Cal. 2001).

[42] *State v. Peeler*, 2007 Ct. Sup. 11903, 11908 (Conn. Super. Ct. 2007). See, also, *Williams v. Curry*, No. 2:05-cv-01313-JWS, at *11 (E.D. Cal. Feb. 3, 2009): "Even when they have similar evidence, different juries may reach different conclusions as to guilt;" *State v. Taylor*, 664 P.2d 439, 450 (Utah 1983): "Conflicting votes among the members of the jury may reflect different ideas of what the 'beyond a reasonable doubt' standard means. We accept this as part of the jury process."

arbitrary and rhetorically unmotivated – indeed, even in a world of perfectly behaving jurors, obediently respecting the adjudicative division of labor, we would still expect inconsistent verdicts for similar cases from different juries.

Indeed, the courts have gone even further than mere tacit approval or begrudging acknowledgment of jury verdictal asymmetry, and have, upon occasion, asserted that such behavior on the part of the jury is not only to be expected, but is decidedly not, in and of itself, unconstitutional, evidence of a fundamental miscarriage of justice, nor of a violation of the rule of law. In *Standefer v. United States*,[43] for instance, the court commented on the "reality that different juries may reach different results under any criminal statute. That is one of the consequences we accept under our jury system… *While symmetry of results may be intellectually satisfying, it is not required*."[44] Commenting on this issue, the Court in *Miller v. California*[45] asserted: "The mere fact juries may reach different conclusions as to the same material does not mean that constitutional rights are abridged."[46] Inconsistent jury verdicts are not, in the eyes of the courts, a symptom of early-stage jural anarchy or systemic unfairness; they are simply the result of a jury system whose adjudicative function depends on the vagaries of human nature and reason, and they are this way by design. As the Court in *La Morte v. Town of Darien*[47] put it: "Reasonable people may disagree concerning facts… *That is what trials are about*."[48] Verdictal asymmetry, under this view, is built into the very structure and operation of the jury system. Thus, if we wish to eliminate verdictal asymmetry, withholding a *nullification instruction* does not seem to be an efficacious response; such inconsistencies are the result and reality of the jury system itself. Seen in this light, whatever rhetorical force the *anarchy objection* has seems directed more towards the dismantling of the entirety of the jury system itself rather than at the withholding of a *nullification instruction* or a mere condemnation of jury nullification – this is, after all, one of the logical implications of the *anarchy objection*: if we wish to eliminate verdictal asymmetry from the criminal law, we must remove any independent adjudicative role from the jury.

However, the problems with the *anarchy objection* run even deeper than this. Verdictal asymmetry is not some rare, radical departure from the rule of law, indulged in only by the occasional few misbehaving jurors. To the contrary, the possibility of such is purpose-built into nearly every stage of the adjudicate process, including and particularly at the level of the bench. Consider the doctrine of judicial discretion – the authority given to judges to make decisions based on their understanding, judgment, and interpretation of the law in cases where the law does not mandate a specific outcome. While such discretion is guided by statutory frameworks, precedents, and rules of fairness, it inherently introduces variability into

[43] *Standefer v. United States*, 447 U.S. 10 (1980) (citation omitted). See, also, *Bartmess v. State*, 708 S.W.2d 905 (Tex. App. 1986).

[44] *Standefer, id.* (emphasis added), at 25.

[45] *Miller v. California*, 413 U.S. 15 (1973).

[46] *Id.* at 26 n.9. See, also, *Hamling v. United States*, 418 U.S. 87, 101 (1974): "It has, of course, long been the rule that consistency in verdicts or judgments of conviction is not required;" *State v. Embassy Corp.*, 215 Neb. 631, 634 (Neb. 1983): "The fact that juries may reach different results on similar facts does not render obscenity statutes unconstitutional." *People v. Boyer*, 31 A.D.3d 1136, 1137-38 (N.Y. App. Div. 2006): "Also lacking in merit is the further contention of defendant that he was deprived of his right to due process as well as his right to equal protection based on the fact that the respective juries reached different verdicts with respect to defendant and his codefendant."

[47] *La Morte v. Town of Darien*, FSTCV155014649S (Conn. Super. Ct. July 18, 2016).

[48] *Id.* at *1 (emphasis added). See, also, *Turner v. Rush Medical College* 182 Ill. App. 3d 448, 455 (Ill. App. Ct. 1989): "Questions on which reasonable men may arrive at different results should not be determined as a matter of law, but, rather, should remain within the jury's province for determination."

the judicial process, which can occasionally manifest in verdictal asymmetry. Moreover, the courts have time and time again ruled that such verdictal asymmetry from the bench is perfectly consistent with the proper exercise of judicial discretion within the rule of law. As the Court in *Bracey v. Grondin*[49] asserted: "That other trial courts have reached different conclusions on similar facts, however, does not amount to an abuse of discretion by the district court in this case. *Indeed, discretion by its very nature permits different judges to reach different—but reasonable—conclusions on the same set of facts.*"[50] This principle – that judicial discretion sanctions inconsistent verdicts for similar cases – is embedded deep in the common law and precedent.[51] It is a well-established, accepted, and seemingly necessary consequence of judicial discretion, and hence, follows from the ideal of an independent judiciary itself.[52] Indeed, "the very nature of judicial discretion precludes rigid standards for its exercise."[53] Moreover, beyond the doctrine of judicial discretion is the plain fact that judges – like jurors – are imperfect reasoning machines operating under incomplete and imperfect epistemic conditions. As far back as the 17th century, Lord Vaughan, in *Bushel's Case*,[54] noted as much, arguing that persons faced with the same facts often draw conflicting conclusions, and that even two judges frequently drew different conclusions regarding the same case: "I would know whether anything be more common, than for two men students, barristers or judges, to deduce contrary and opposite conclusions out of the same case in law?… A man cannot see by another's eye, nor hear by another's ear, nor can a man conclude or infer the thing to be resolved by another's understanding or reasoning."[55] Contemporary courts have echoed this view. The Court in *Zimmermann v. Netemeyer*,[56] for example, stated that "different judges, different courts, can justifiably reach different conclusions… from a consideration of the same set of facts."[57] Once again, this is not some complex legal doctrine, or the result of particularized policy considerations – it is entirely consistent with the basic commonsense understanding as to how human reasoning operates and functions. This commonsense understanding is embodied in that fundamental adjudicative maxim of rational investigation and discourse central to any search for the truth, be it epistemic or legal: "Reasonable men may disagree whether in common experi-

[49] *Bracey v. Grondin*, 712 F.3d 1012 (7th Cir. 2013).

[50] *Id.* at 1020 (emphasis added).

[51] See, for instance, *United States v. Bell*, 819 F.3d 310, 322 (7th Cir. 2016): "But as to matters entrusted to a trial judge's discretion, it is often true that judges presented with the same record may reach different conclusions;" *Sabin v. Bur. of Motor Vehicles*, 26 Ohio Misc. 2d 8, 13 (Ohio Com. Pleas 1986): "No doubt different judges will reach different conclusions in exercising discretion authorized by law;" *The People v. Ledon*, No. D080234, at *2 (Cal. Ct. App. May 15, 2023): "While we understand that different judges could have reached different conclusions on the same facts, [the defendant's] complaints do not establish an abuse of discretion;" *In re M.P.B.*, No. 05-22-00399-CV, at *5 (Tex. App. Sep. 12, 2022): "different judges may reach different conclusions in different trials on substantially similar facts without abusing their discretion;" *Ortiz v. Secretary of Defense*, 842 F. Supp. 7, 13 (D.D.C. 1993): " two different judges may sometimes view the same facts and, in their discretion, come to different conclusions without violating the Equal Protection Clause;" *Winegarner v. State*, 235 S.W.3d 787, 791 (Tex. Crim. App. 2007): "different trial judges [may] reach different conclusions in different trials on substantially similar facts without abuse of discretion."

[52] See, for example, *U.S. v. Andrews*, CRIMINAL No. SA-02-CR-258(2)-FB, at *2 (W.D. Tex. Jan. 28, 2004): "If the United States is to continue its tradition of an independent judiciary unfettered by the political branches, federal trial judges familiar with the facts and humanity involved in a particular case must have some modicum of discretion."

[53] *Gordon v. United States*, 383 F.2d 936, 941 (D.C. Cir. 1967).

[54] *Bushel's Case*, 124 Eng. Rep. 1006 (1670).

[55] *Id.* at 1008.

[56] *Zimmermann v. Netemeyer*, 122 Ill. App. 3d 1042 (Ill. App. Ct. 1984).

[57] *Id.* at 1051. See, also, *Durr v. Stille*, 139 Ill. App. 3d 226 (Ill. App. Ct. 1985); *Duncan v. Rzonca*, 133 Ill. App. 3d 184 (Ill. App. Ct. 1985).

ence a particular inference is available."[58] Again, inconsistent judicial verdicts are not, in the eyes of the courts, a symptom of early-stage jural anarchy, nor of systemic and unconstitutional unfairness; they are the result of individual judges properly exercising their judicial discretion and independence against the backdrop of the vagaries of human nature, reason, and circumstance. As jurist and retired judge Gerald Seniuk describes it:

> Systemic incoherence [verdictal asymmetry] – that individual judges could decide the same case differently – is a by-product and consequence of an independent and impartial tribunal's power to make fair decisions in an adversarial process. Such systemic incoherence is tolerable because of the need for independent judges to have sufficient discretion to decide cases fairly. The inevitable consequence of that discretion is that judges may reasonably disagree about the verdict.[59]

As such, even if we completely eliminated the possibility of jury nullification through such radical approaches as removing any adjudicative role whatsoever from the jury, and placing all adjudicative powers solely within the purview of the trial judge, we would still expect inconsistent and asymmetric verdicts for similar cases. Again, therefore, if we are seeking to eliminate verdictal asymmetry, withholding a nullification instruction would not be an efficacious approach, as such asymmetries would still exist even in trials without juries; they are often the result of individual judges exercising their legally sanctioned judicial discretion in individual cases. In order to eliminate such inconsistent verdicts then – or at least not license an adjudicative procedure that has the possibility of such built in – it seems we must therefore eliminate any and all discretionary adjudicative roles whatsoever, not just for juries, but also for judges. In other words, if we want to remove the possibility of verdictal asymmetry from the criminal law, we must remove any independent adjudicative role from the judiciary.

This, then, is the logical consequence of embracing the *anarchy objection*'s rejection of verdictal asymmetry: if we wish to eliminate the possibility of, or refuse to endorse, a legal procedure that yields inconsistent verdicts for similar cases, we must (i) eliminate any and all adjudicative functions from the jury; and, (ii) eliminate any and all adjudicative functions from the judiciary. I take (i) or (ii) on its own to provide motive enough to reject the *anarchy objection*; the conjunction of these two statements, however, is an obvious reductio for anyone who conceives of a legal system as necessarily requiring a sophisti-

[58] *Montgomery v. State*, 810 S.W.2d 372, 391 (Tex. Crim. App. 1991). See, also, *Commonwealth v. NC Fin. Sols. of Utah, LLC*, No. CL-2018-6258, at *9 (Va. Cir. Ct. Oct. 28, 2018): "This Court is cognizant that reasonable judges may disagree in resolution of particularly vexing legal questions;" *State v. Brown*, 392 Wis. 2d 454, 479 (Wis. 2020): "Reasonable judges may disagree about the meaning or application of the law;" *Van Poyck v. Florida Dept. of Corrections*, 290 F.3d 1318, 1330 n.13 (11th Cir. 2002): "Reasonable judges can disagree on the proper interpretation of the United States Supreme Court's precedents;" *San Diego Police Dep't v. Geoffrey S.*, 86 Cal.App.5th 550, 581 (Cal. Ct. App. 2022): "The Legislature's intent with respect to the meaning of a statute is not always crystal clear, and in this instance it might be better characterized as opaque. It is therefore hardly surprising that reasonable judges might disagree;" *Bridgestone/Firestone North American Tire, LLC v. Garcia*, 991 So. 2d 912, 917 (Fla. Dist. Ct. App. 2008): "Would I have reached the same result the trial court reached in this case? Probably not. But… if for no other reason than that reasonable judges could disagree on the trial court's ruling, I agree we must affirm;" *Renfroe v. Kirkpatrick*, 549 F. Supp. 1368, 1374 (N.D. Ala. 1982): "This court realizes that reasonable judges, like reasonable jurors, can disagree."

[59] Gerald Seniuk, "Systemic Incoherence in Criminal Justice: Failing to Treat Like Cases Alike," *The Canadian Bar Review* 93 (2015): 768.

cated adjudicative procedure and process.[60] To the degree that one remains skeptical of the possibility of a purely mechanical, empirically exhaustive, consistent, and reliable form of legal adjudication of facts to law, divorced entirely from the vagaries of human nature and reason (a possibility one ought to be robustly skeptical of), one ought likewise to be skeptical of the rhetorical force and strength of the *anarchy objection*. Even if we eliminated jury nullification altogether, or even the jury system itself, verdictal asymmetry would still exist as part of the legally sanctioned principles and doctrines of judicial discretion and independence – these too would also need be eliminated in the quixotic quest for verdictal symmetry.

Verdictal asymmetry is, therefore and for all intents and purposes, an intrinsic and necessary element of the criminal justice system, and any efforts to achieve verdictal symmetry would ultimately entail the dismantling of the common law legal system along with its associated doctrines, principles, and traditions:

> Systemic incoherence [verdictal asymmetry] arises from the traditions of common law jurisprudence. The common law trial is based on advocacy, with each adversarial side trying to convince the judge to accept its story – or, to restate that in legal terms for a criminal case, to persuade the judge that the prosecution failed or succeeded in proving its case beyond a reasonable doubt. With the presence of reasonable competing stories and a fair opportunity for the adversaries to argue their cases, judges must be open to actual choice in rendering a verdict such that different judges could arrive at different verdicts. If these conditions are not present, the verdicts would be predictably uniform and there would be no need for a trial.[61]

According to this perspective, then, rather than viewing the legal system as inherently unfair or unjust, we ought instead to see its endorsement of verdictal asymmetry as a consequence of "*fairness* in that it reflects a 'fair' opportunity in the adversarial process for the parties to show the judge why their evidence should be accepted and relied upon. Hence, systemic incoherence is a necessary and unavoidable consequence of the way the criminal justice system is organized in principles and practices."[62] To equate uniformity of verdictal outcome to justice and equality under the law is therefore to fundamentally misunderstand the very nature of the common law adversarial system and history of the criminal trial. To put my point as strongly as I can: eliminating the structural possibility of verdictal asymmetry within the criminal law would require us to bring down the entire temple of justice upon our heads in an attempt to eliminate the adjudicative discretion present at nearly every point in the justice system. I see this as an obvious reason to reject the anarchy objection.

There is, finally, a somewhat trivial, but nevertheless, telling reply to the anarchy objection. We begin by noting that jury nullification is a phenomenon that currently takes place within the criminal justice system[63] without any jural anarchy thereby resulting. To put this plainly, we are not currently living in an anarchic legal environment that "harmfully infect(s) organized society,"[64] despite the continued

[60] See, for instance, H. L. A. Hart's discussion of primitive legal systems and their shortcomings in H.L.A. Hart, *The Concept of Law*, 3rd ed. (Oxford: Oxford University Press, 2012), 92–93.

[61] Gerald Seniuk, "Systemic Incoherence in Criminal Justice: Failing to Treat Like Cases Alike," *The Canadian Bar Review* 93 (2015): 754.

[62] *Id.*

[63] According to one researcher, roughly 4% of all acquittals are the result of jury nullification. Robert C. Black, "FIJA: Monkey-wrenching the Justice System," *UMKC Law Review* 66 (1997): 16.

[64] *Arshack v. United States*, 321 A.2d 845, 851 (D.C. 1974).

existence of jury nullification within the legal system. Not only does jury nullification currently occur (albeit, despite the absence of a nullification instruction), but even if it didn't, verdictal asymmetry is, in fact, an extant and robust feature of the legal system at nearly all procedural levels – we live in a jural environment whose adjudicative functions are predicated on the possibility of verdictal asymmetry. Yet, again, it is clear that we do not live in a state of jural or social anarchy (or, more moderately, whatever strains our jural and social structures are currently facing cannot be attributed to verdictal asymmetry, nor, ultimately, to jury nullification). If verdictal asymmetry can indeed be implicated in the breakdown of jural and social order, regardless of whether jury nullification is the cause, presumably we would have seen some evidence of this relationship within the last two hundred plus years of American common law jurisprudence. We have not, and hence, the *anarchy objection* must be rejected as specious reasoning.

6 | VERDICTAL ASYMMETRY AND LCA

The entirety of the *anarchy objection* is predicated on a desire to eliminate or minimize verdictal asymmetry within the criminal law. But the question needs to be asked: why should we want to eliminate verdictal asymmetry in the first place? After all, if we have no reason to share in the *anarchy objection*'s vicious assessment of phenomenon, much – if not the entirety – of the rhetorical force of the *anarchy objection* is eliminated. Presumably, and according to the advocates of the *anarchy objection*, we should reject verdictal asymmetry on the grounds that it violates the *LCA* principle. If similar defendants, facing similar charges, under similar laws, for similar acts, do not also receive similar verdicts, such reasoning goes, then clearly these like cases were not being treated alike, and justice was thereby subverted. Fairness demands similar verdicts for similar cases, such reasoning continues, and verdictal asymmetry is, in this respect, the conceptual antithesis of fairness under the law. However, this analysis is predicated on a fundamental misunderstanding of what it means for like cases to be treated alike under the law. The principle of *LCA* ought best be understood as a formal, or procedural constraint: one addressed to the processes, procedures, and relevant doctrines surrounding how adjudicative investigations are to be conducted. It addresses the idea that similar defendants who are accused of similar crimes ought to have access to the same jural procedures and processes, and be tried according to the same standards and laws. It is not, however, meant to constrain the specific outcomes of specific trials; as a procedural mechanism, it is, as such, agnostic regarding verdicts. *LCA* demands fairness in process, and not equality of outcome.

Therefore, instances of asymmetric verdicts do not necessarily violate the *LCA* principle. As Huemer puts the point: "The function of a criminal trial is to do justice by that defendant – that is, to punish the defendant in the case at hand if and only if he has done something that deserves punishment. The function of a trial is not to mete out punishment that will be convenient to some larger social policy objective irrespective of the defendant's own desert."[65] We treat like cases alike with parity of procedure, not uniformity of verdict – that is what fairness and justice under the law demands. To think otherwise is to fundamentally misunderstand the entirety of the adjudicative function of judges and juries within the common law system.

[65] Michael Huemer, "The Duty to Disregard the Law," *Criminal Law and Philosophy* 12 (2018): 9.

7 | CONCLUSION

The *anarchy objection* remains one of the most popular objections expressed by the bench to both the practice of jury nullification and the possibility of a nullification instruction. Despite its popularity, however, it is, ultimately, predicated on a fundamental misunderstanding of the role and value of verdictal asymmetry within the criminal law. I do not wish to be misunderstood in my critique, mind you: I am not accusing the jurists who subscribe to this objection as having a naïve understanding of the law. Rather, it is my belief that such objections have simply not been subjected to critical reflection and analysis, and that doing so will reveal the inherent weakness of the position. *VAA* is a hidden, almost unconscious premise of the *anarchy objection*, and by bringing it forth into the light and subjecting it to scrutiny, its rhetorical paucity is revealed.

The *anarchy objection*, I have demonstrated, is caught on the horns of a dilemma: (i) if the point of the *anarchy objection* is that jury nullification causes verdictal asymmetry, well, first, it does not, and second, such asymmetry already exists as a deeply embedded and intrinsic part of the justice system and the presence or absence of a nullification instruction – regardless of whether (contrary to the evidence) it promotes verdictal asymmetry – will do nothing to eliminate the presence of such asymmetry from the justice system; (ii) if, on the other hand, the point of the *anarchy objection* is that we should eliminate or minimize verdictal asymmetry wherever possible, lest we risk anarchy, then the implication is that the whole of the common law must be dismantled in favor of some mechanical, fully deterministic jurisprudence – a particularly chimerical and unrealistic vision of adjudication within the law.

In framing my objection to and analysis of the *anarchy objection*, I relied on the following five claims:

1. Jury nullification does not lead to verdictal asymmetry. *JNVA* is false.

2. Whatever contributions the jury system does make to verdictal asymmetry are due to the structure and operation of the jury system itself, not nullification. The jury system, by design, allows for verdictal asymmetry.

3. Verdictal asymmetry is present and endemic in other areas of the criminal law as well, particularly in the adjudicative function of judges. The entire adjudicative apparatus of the criminal justice system, outside of the jury, by design, allows for verdictal asymmetry.

4. Our current jural apparatus is riddled with verdictal asymmetry, yet we do not live in a state of jural/social anarchy; there is clearly little connection between verdictal asymmetry and anarchy/chaos.

5. Verdictal asymmetry is not a significant issue and is not contrary to *LCA* principle.

The conjunction of these five claims leads invariably, I contend, to the conclusion that the *anarchy objection* must be rejected.

I will conclude by stating briefly that I do not intend for this paper to be read as a defense of jury nullification or of a nullification instruction. I do, in fact, believe that there are good reasons not to give

such an instruction.[66] The claim that jury nullification, through the operation of verdictal asymmetry, will lead to widespread jural/social anarchy, is, however, simply not one of those reasons. The *anarchy objection* therefore must, for the reasons discussed above, be rejected.

[66] See, for example, Travis Hreno, "Jury Nullification and the Bad Faith Juror," *Law, Ethics and Philosophy* 1 (2013): 53.

Philosopher's Compass 1/1 (2025): 22–41.

Rethinking The Hard Problem, Naturalism, and Idealism

Nathan Wagester[1]

[1]California Polytechnic State University, California, USA, nathanwagesterwork1@gmail.com

ABSTRACT

Contemporary discourse surrounding the hard problem of consciousness is generally considered a conflict between physicalism and dualism. In this paper, I argue for a third option which has largely been ignored by contemporary discourse by claiming that current conditions for a satisfactory answer to the hard problem are flawed. I identify two key informative conditions: the directionality and conceivability conditions. I then show how all current options fail to satisfy these conditions. I claim physicalism cannot satisfy the conceivability condition due to the Knowledge Argument. I consider three plausible objections to the knowledge argument: Lewis' ability analysis, the old fact/new concept view, and Dennett's dissolution of the problem. All of which I contend fail. Second, I claim that dualism will not work either, due to the reasons outlined in Karen Bennett's paper "Why I am Not a Dualist" (Bennett 2021). Finally, I contend that the motivations for the directionality condition are dubious, and thus, we have reason to doubt it. Particularly, I argue that the directionality condition is motivated by a specific interpretation of the causal closure of physics that we need not accept. Since we have reason to doubt the directionality condition, a wide range of largely ignored solutions to the hard problem remain open to us. One of these options is idealism. Finally, I give a rough outline of an idealist theory and explain why it can solve a revised hard problem.

KEYWORDS: Causal Closure, Idealism, Physicalism, Knowledge Argument, Dualism, Hard Problem

1 | INTRODUCTION

As stated by Chalmers in his now infamous paper "Facing Up to the Problem of Consciousness," the hard problem is the question of why it is that conscious experiences of a specific type can arise out of complex neural processing mechanisms and physical processes (Chalmers 2010). This problem appears especially hard because of qualia or the what-it's-like character of conscious states. For instance, the feeling of this particular shade of redness or the feeling of happiness appears to have a qualitative character that mere physical states just don't seem to have. Do atoms or electrons have a what it's like to be them? Intuitively, for most, the answer is no. Hence, the obvious question arises: how in the world could something qualitative arise from something non-qualitative?

Before we can go about answering this question, we should make clear the informative conditions

under which the problem is considered solved. I take it there are the two following conditions:

(A) **The Directionality Condition**: Any satisfactory explanation of consciousness ought to have the qualia of mental states be grounded in non-qualitative physical states.

(B) **The Conceivability Condition**: Any satisfactory explanation of consciousness ought to produce the result that consciousness is inconceivable without its explanans. (Where proposition P is conceivable for S just in case S can imagine a world in which P is true and P is inconceivable for S just in case S cannot imagine a world in which P is true.)

I take it that the hard problem is said to be solved if and only if conditions A and B are satisfied. The existence of the Directionality condition is evidenced in the very formulation of the question and the assumptions of most everyone involved in the current discourse. From Chalmers, David Lewis, Bennett, to Weisberg all frame the question as having the direction of physical-to-mental (Chalmers 2010, Lewis 2005, Bennet 2021, Weisberg). The mental must be grounded in the physical if we are to respect physical science. The existence of the conceivability condition is evidenced by the various conceivability arguments for dualism throughout the discourse. Gertler's phantom pain argument aims to show that qualia are ideally conceivable without physical stuff, whereas p-zombie arguments aim to show that physical stuff is ideally conceivable without inner mental life (Gertler 2013, Kirk 2019). Of course, these arguments rely on the premise that conceivability implies possibility, and hence, so does the conceivability condition. However, we will assume that this relationship between the ideal concept and possibility exists throughout the rest of this paper. Essentially, the conceivability condition posits that consciousness is not possible without its explanans since we are engaged in a reductive explanation that seeks to explain consciousness through some physical feature.

Now that we have stated the conditions under which the hard problem is said to be solved, we are now in a position to evaluate various theories which claim to be capable of overcoming the hard problem. I first turn to physicalism. Before we move forward, I would like to note that this paper will solely focus on what I take to be the most plausible form of physicalism: reductive physicalism. Hence, I will be ignoring both non-reductive physicalism and eliminativism. In regard to non-reductive physicalism, I think that the causal-exclusion problem as stated by Jaegwon Kim is fairly conclusive against the position. I will not rehearse his well-known argument here. However, I agree that such a view, which holds that mental properties are not reducible to physical properties but are explained by them, is bound to slide into reductive physicalism or dualism (Kim 1989, 1992). In regards to eliminativism, the position that denies there are any mental phenomena to be explained, I believe that one needs to only open their eyes to see that such a position is false.

2 | THE INITIAL ARGUMENT AGAINST PHYSICALISM

As we discussed earlier, there are two main opponents in the current discourse which claim to satisfy conditions A and B. These opponents are physicalism and dualism. This section will discuss physicalism and why it fails to satisfy condition B. Since it fails to satisfy condition B, it will not work as a solution to

the hard problem.

There are many conceivability arguments against physicalism. In this paper, I will focus on the Knowledge Argument. This argument shows that facts about consciousness are a genuine addition to the physical facts. Thereby showing that physical concepts in principle cannot satisfactorily account for phenomenal concepts. Condition B is thereby a non-starter. The general form this argument will take is as follows:

1. Facts about consciousness are a genuine addition to the physical facts.
2. If facts about consciousness are a genuine addition to the physical facts, then the physical facts which exhaust the possible physical explanations of consciousness are ideally conceivable without consciousness.
3. If the physical facts which exhaust the possible physical explanations of consciousness are ideally conceivable without consciousness, then physicalism is false.
4. Therefore, the physical facts which exhaust the possible physical explanations of consciousness are ideally conceivable without consciousness.
5. Therefore, physicalism is false.

The obvious point of contention in this argument will be premise one. Premise two trivially follows from premise one. If some type of fact presents a genuine addition to another type of fact, then the concept that represents the former type of fact will be a genuine addition to the latter. Hence, the latter will be conceivable without the former. It follows that if mental facts are genuine additions to physical facts, then physical facts are conceivable without conscious facts. Mental facts are ideally conceivable without its supposed explanans. Premise three trivially follows from physicalism. The general thesis of physicalism is that physical facts exhaust all of the facts. Hence, if it does not exhaust all the facts and physical facts are conceivable without conscious facts, physicalism is false. The point of contention will be premise one. It basically begs the question against the physicalist. It assumes what the physicalist seeks to deny: that physical facts cannot account for conscious facts.

Support for premise one can be found in Frank Jackson's Mary thought experiment which is commonly known as the Knowledge Argument. The thought experiment is as follows:

> **Mary's Room Thought Experiment**: Imagine an ingenious physicist named Mary who knows everything there is to know about the neurophysiology of the brain. Mary knows every physical fact relevant to consciousness. Now imagine that she lives in a completely black and white room and has not/cannot experience color in the room. Once Mary leaves the room and comes to experience red the first time, it appears that Mary learns something new. Namely, she now knows what it is like to experience color (Jackson 2005, Nida-Rümelin et. al. 2019).

There are many ways to object to the conclusion of the thought experiment that Mary has learned about some extra-physical facts. Here I take a look at three of the most potent objections: the ability analysis, the old fact/new concept view, and the imagination objection. I assume that if these objections fail, then the best objections against the Knowledge Argument fail and that physicalism fails to satisfy the conceivability condition.

2.1 | The Ability Analysis

In his paper "What Experience Teaches," Lewis looks for a way out of the knowledge argument. He settles upon the ability analysis. The ability analysis argues that what Mary gains when she sees red for the first time are various abilities to remember and imagine (Lewis 2005). She now has various memories of redness and can imagine various sorts of objects with a red character. For instance, if she has seen a horse before, she can now imagine what it would be like for a horse to be red. This analysis appears very plausible in light of the distinction between knowledge-that and knowledge-how. It is plausible that one can have know-how without knowing that. For instance, there are plenty of great mechanics who have little understanding of the theoretical posits of engineering as a science. People can know how to employ moral concepts without knowing moral theory and so forth. It is also plausible that one can know-that without knowing-how. For instance, one can know the principles of good bike riding but in fact be a terrible bike rider. Thus, what the proponent of the ability analysis says in the case of Mary is that Mary gains know-how instead of knowing-that.

I have two independent worries about this analysis. First, it is not clear to me that Mary has actually gained a new ability to remember and imagine. She always had the latent capacity to imagine red. It is not as if Mary has learned a skill like riding a bike. She simply saw red and now has accessed her latent capacities. This gets us into territory regarding the metaphysics of dispositional properties that would lead us too far astray. In any case, it does not get to the heart of the issue, since Mary clearly has gained some sort of know-how whether or not it is specifically an ability.

Second, I pose the question to the proponent of the ability analysis: what exactly is Mary's gain in know-how about? Of course, the proponent of the ability analysis will initially be dumb-struck with this question. The abilities are about imagining and remembering! Remembering and imagining what? They will say red.

In response, I would simply press on my questioning: well what exactly is red? Lewis, a functionalist, will probably respond with something like a brain state that occupies a certain functional role (Lewis 1983). This answer is, at the very least, extremely unintuitive. It does not seem like facts about the experience of the color 'red' are exhausted by the functional role a certain brain state plays. To see why, just imagine a discussion of the experience of artwork using this terminology. Can the beautiful color-scheme of artwork really be chalked up to functional brain-states? It doesn't seem so. Or perhaps Jeremy Fodor, computationalist, will say that redness can be chalked up to turing-style computations in the brain (Resorcla 2020). I again merely point to the characterization of artwork under this model. To me it seems that the ability analysis only makes sense by presupposing Lewis's spooky "phenomenal information." If we suppose that there is some what-it's-like phenomenal information, then the ability we have gained is to imagine phenomenal information.

One response many physicalists have had to this line of questioning is that Mary has gained a new ability to represent the world and to discriminate between certain phenomena utilizing a new concept which is only applicable to first-order experience. This is a plausible program that ought to be taken seriously. In the next section of this paper, I review the phenomenal concept strategy in detail. In line with my previous remarks on the failure of the ability analysis, I indicate that the phenomenal concepts

strategy is doomed to fail due to the fact that it lacks phenomenal information to provide content to its phenomenal concepts.

2.2 | The Phenomenal Concepts Strategy

I will now consider the phenomenal concepts strategy, or the old fact/new knowledge view. In her paper "Phenomenal Concepts and the Materialist Constraint," Joseph Levin surveys the phenomenal concepts strategy in detail. This view says that while Mary has not learned a new fact, she has gained a new concept. That is, she has gained a new way to represent, or know about, a certain fact about the world, in the case of seeing red for the first time (Levin, 2007).

Levin describes three avenues the physicalist might take for the old fact/new concept view to make sense: a semantic, epistemic, and demonstrative view. First, he notes that while we might think that Mary has epistemic access to all the physical facts prior to leaving the room, she has gained a new semantic primitive. Through viewing red the first time, Mary has gained a new way of representing the world that cannot be analyzed into the way she had of representing the world prior to her gaining this phenomenal concept. She is now able to fix a reference to a real physical entity, light-waves or some other entity, through the phenomenal concept of redness instead. She has gained a new mode of presenting the real physical world.

However, as Levin notes, this view yields an implausible semantic theory of phenomenal concepts for the physicalists. The obvious objection is that in order for her new phenomenal concept to fix a reference to the physical world it must do so by means of some properties If we assume that Mary had access to all of the physical properties which explained redness prior to her encountering redness, then it seems that the property by which she fixes a reference to the physical stuff cannot itself be physical. If the property by which the phenomenal concept fixes a reference to the physical stuff is itself physical, then Mary wouldn't have really gained a genuinely new concept. I take it that this objection works against the semantic strategy and will not consider it further (Levin 2007).

Now we can take a look at the epistemic analysis of phenomenal concepts. The proponents of this view hold that while Mary has not gained a semantic primitive per se, she has gained an epistemic primitive. When Mary leaves her room for the first time and observes the color 'red', she gains a sort of unmediated access to lightwaves, or a physical entity, which she did not have prior to leaving her room. She has gained a phenomenal concept in the sense that she has gained a judgment that lacks an evidentiary intermediary. The phenomenal concept of 'redness' is not semantically primitive, but it does possess a sort of epistemic primitiveness. Every time we encounter 'red' immediately, we can then use the phenomenal concept of red. Essentially, it allows us to differentiate types of concepts based on the level of epistemic access we have to that entity. For instance, the phenomenal concept of 'red' is distinct from the physical concept insofar as they are applied to the same entity but at different levels of epistemic access. In this story, we can then explain away the features of red entities by appealing to the mediate concepts of physics, such as light waves. The immediate phenomenal concepts are explained and reduced to mediated, physical concepts which can explain how the phenomenal concepts act in experience.

This seems plausible. For instance, if I merely learn through a textbook that Napoleon existed and

lost at the battle of Waterloo, this seems different than if I had met him in person and observed the battle of Waterloo first-hand. In the former, my knowledge of Napoleon is mediated through a textbook and a line of histories. In the latter, I directly observe Napoleon myself. Perhaps we might say that my concept of Napoleon in the former is of a different sort than the latter. In the first case, I apply my concept of 'Napoleon' to *mediate* evidence, and in the second, I apply my phenomenal concept to *immediate* encounters with Napoleon.

However, there is a major issue here: giving an epistemic primitiveness to phenomenal concepts itself does not explain why the link of phenomenal concepts to their physical explanations should appear so arbitrary, which is the very issue that motivated the phenomenal concepts strategy in the first place (Levin 2007). After all, red need not appear red given the structural and functional properties of light-wavelengths or our cognitive processing mechanisms. Simply stating that the representation of redness is more epistemically primitive, does not itself explain why redness is so drastically different from representation of light-waves.

I think with Levin that this points to a flaw in the epistemic phenomenal concepts strategy in general. Stating that phenomenal concepts are epistemically primitive merely names a property of phenomenal concepts. It does not explain what makes them epistemically primitive. In fact, we might even say that it yields an implausible semantics of phenomenal concepts. If they are epistemically primitive, if they are justified independently, or immediately, what is this immediate sort of justification grounded in? What explains why it is immediately justified? For me, the intuitive answer is that some additional representational content is gained such that the phenomena can now be represented immediately. However, if this is the case, the epistemic strategy inherits all of the problems of the semantic strategy. Then, we must admit that some non-physical properties fix our reference to redness (Levin 2007).

The final strategy Levin looks at is the demonstrative strategy. As Levin recounts, the demonstrative strategy is fairly straightforward. Essentially, this view claims that perhaps phenomenal concepts work like demonstratives. A subject might know a claim of the sort 'Jonathan wrote the book' but not know that 'This person I am speaking to right now wrote the book'. While these propositions express the same genuine fact, the knowledge that these two claims express the same fact, that these facts are identical, appears to be a genuine addition to a subject's knowledge, even though the subject has not learned a new fact (Levin 2007).

We can plausibly see how this applies to the Mary thought experiment. While she has not learned a new fact per se, she has learned that 'The physical concept of redness as expressed by our best physical theories of the world' is identical to the 'this color she is experiencing right now.'

While this approach seems promising, it falls prey to the same objections posed to the semantic and epistemic approaches. Typically knowledge of this sort revolves around access to some new representational content. Taking the Jonathan example, the most plausible reason I learned that the 'person I am speaking to right now wrote the book' is due to me gaining a new way of representing Jonathan. I have met Jonathan in person, I have seen Jonathan, listened and spoke to him, it is this information which allows me to identify him with the previous concept of the author of Jonathan. I have added new intensional content to the concept of Jonathan that allows me to refer to him in additional scenarios. So in the Mary case, it appears that we cannot explain the identification of the physical concept of red with Mary's

acquaintance with red unless Mary has gained some new representational content. However, if Mary has gained a genuine new way of representing red, then it appears she has to fix her reference to red in these additional scenarios to properties which themselves are not physical.

Perhaps phenomenal concepts like 'red' are *thin* concepts. That is, the meaning of redness is exhausted by simply 'this color which is perceived in x, y, z scenarios' (Levin 2007). We might even contend that the meaning of red is exhausted by its extension and it actually lacks intensional content. Thus while there are no phenomenal properties by which phenomenal concept fixes a reference to red, red is applied demonstratively to various instances of red objects in experience.

I must say that I find this account to yield a very implausible semantics of phenomenal concepts. Namely, it will suffer from objections of co-extension in the way that set-nominalism suffers from co-extension objections. We can imagine a scenario, where all red items are also blue items. In this scenario, we are forced to conclude that red items are actually identical to blue items(at least phenomenally)! An apparent absurdity. Redness is clearly phenomenally distinct from blue! I contend that this absurdity results from the fact that when we consider phenomenal concepts to be thin we fail to give a legitimate theory of how colors can be differentiated phenomenally. The thin account of phenomenal concepts simply cannot capture the representational difference between red and blue.

While Levin, does not believe that his rejection of the epistemic, semantic and demonstrative strategies to be conclusive against the phenomenal concept strategy, I think the fact that all three accounts fail on the grounds that they do not give an account of the phenomenal information which allows us to refer to its object, gives us reason to suspect that any physicalist account of a phenomenal concept in the Mary case is doomed to fail (Levin 2007). Afterall, the physicalist who takes up this strategy must assume that Mary has access to all of the physical information needed to refer to red prior to leaving her color-blind room. Hence, if she is to refer to red at all, it seems that she must do so by means of some non-physical information. But if this is so, we have demonstrated that physical concepts are unable to account for Mary's gain in knowledge.

2.3 | The Imagination Objection

I think it will be useful now to dive into Daniel Dennett's view on the Mary problem now that we have looked at the traditional physicalist solutions. Dennett believes that Mary would actually learn nothing new after leaving her colorless room. Contrary to the story given by both ability analysis and phenomenal concepts view, Dennett believes that Mary would have the capacity to imagine what red is like prior to leaving the colorless room, based on all of her physical knowledge. He contends he can dissolve the knowledge argument by working out exactly what the assumptions of the knowledge argument entail. If this plausible objection works, then perhaps our central contention that phenomenal information is required to make sense of the Mary-problem is misguided, since there is actually no problem at all.

Before going further into Dennett's attempted dissolution of the knowledge argument, I think it will be useful to give a brief overview of Dennett's view of the mind. Daniel Dennett is primarily a computationalist about the mind. At a very basic level, computationalists are functionalists who believe that the mind is the software to the brain's hardware and that the brain is an extremely complex computer

which possesses an array of syntactic devices that process information in such a way so as to complete certain tasks, or objectives. While Dennett does not believe in the legitimate existence of the software of the mind, he does think that it is a useful way to describe the material processes occurring. However, I will not be addressing the complex ins and outs of Dennett's view in this paper. What is of interest here is his attempted dissolution of the Mary problem.

Specifically, Dennett claims that philosophers have been misled in their intuitions regarding Mary's gain in knowledge, because they have not fully fleshed out the implications of assuming that Mary knows ALL physical facts pertaining to color vision and completely grasps every neuro-biological theory in relation to it. Dennett contends that once we truly flesh out the implications of the thought-experiment, we will see that Mary doesn't actually learn anything new at all once leaving her room. Here is Dennett's first iteration of is his revised Mary-thought experiment in the Epiphenomenalism section of "Consciousness Explained":

> **Revised Mary Room**:Imagine that one day Mary is allowed to leave her room and the people that captured her painted a banana blue, in the attempt to trick Mary into thinking she was seeing yellow when she was actually seeing blue. However, Mary, knowing all the relevant facts about what exactly she should be seeing in each situation, dumbfounds her captors when she responds: You tried to trick me, I know that banana is blue! (Dennett 1991)

This revised-Mary thought experiment is an attempt to show that Mary will not have gained any new knowledge upon her leaving her room when the thesis of physicalism is sufficiently fleshed out. To see why Mary would know that the banana is blue we merely need to think very deeply about what her knowing all of the relevant neurological facts about color vision would entail. If she knows ALL of the relevant facts about color vision, then she will know exactly what brain-state she will be in, and how she will behave, when she is introduced to certain frequencies of light waves. According to Dennett, indeed Mary will precisely be able to predict exactly what impression each stimulus will have on her nervous system. Since she has adequate knowledge of the dispositional properties of her nervous system, she will not have gained any new knowledge upon leaving her room. She already knows how a blue banana should look to her. That is, she is capable of imagining the blue banana prior to leaving her room

I think there is an obvious point of contention here: it appears prima facie implausible that, even given all of her knowledge of color vision, physics, and neuroscience, that she would be capable of imagining color prior to leaving her room, even if she somehow could devise a strategy to guess what she would see upon leaving the room. We can imagine that there is a radio wave technology in the room that physically blinds Mary while she is in the room. She has spent her entire life in this room, but was able to learn and understand all of the relevant physical facts regarding color vision via touch and audio. It appears that in this scenario, even given her intense study of the brain, her investigation of the entire anatomy, biological structures, brain states in response to stimuli, etcetera, that it would be incredibly implausible to assume that she would have the capacity to then imagine what it would be like to see anything at all. She cannot because she quite literally lacks that sort of sensory apparatus while she is in the room. Hence, upon leaving the room she gains more knowledge than merely knowledge about what it is like to see colors: but

she also gains knowledge on what it is like to imagine geometrical features visually, to conceive of space visually, to see movement, as well as color

Dennett here might say that we are assuming the falsity of his theory. He might say his theory is just that adequate knowledge of the mental state of color is knowledge of the dispositional properties of her optical nervous system. All the ability to see color amounts to is a certain dispositional property of her optical nervous system. Since Mary has complete knowledge of the dispositional properties of her optical nervous system, she therefore will be capable of imagining, or knowing what-it's-like, to see red-even if she is blind. Given her near omniscience and ability to reason through neurobiology and physics, she would also be capable of devising a strategy to guess exactly what she will see when she leaves the room. Even if this is counter-intuitive, it is not necessarily false.

In response, I would say that his theory then yields such an implausible result in our thought experiment that it needs to be revised. If someone lacks the capacity to sense or be aware of a certain sensory medium-such as vision, taste, touch, hearing, or smell- there is very little hope for them in imagining what it would be like in that sensory medium.

Dennett himself recognizes this original thought-experiment is unsatisfactory. Which is why in his paper "What RoboMary Knows" he deploys an additional thought experiment in which Mary is conceived as a computational machine that works within his computational model of consciousness:

> **Revised Mary, Robo-Mary and Robo-Mary 2.0**: Robo-Mary is a mach-2 robot which has near-omniscience regarding the scientific facts of color vision. However, Robo-Mary has not yet had her color vision turned on, nor does Robo-Mary have the capacity to program herself into having color vision due to the fact Robo-Mary cannot access the pixels which are required to represent colors in her algorithms. However, Robo-Mary wants to know what seeing color is like and is able to code images into various shades of gray. Robo-Mary only has access to color values of 1-1000. Based on the grey scales, textures, and various shapes of objects which are presented to Robo-Mary, she is able to determine what color they would be if she had color vision. If a tomato of a certain shape, lighting, and color is presented to her, Robo-Mary is able to determine that she would see red if she were able to see red. Given her knowledge of all the neurobiological, computational, and physical facts regarding color vision, Robo-Mary is able to program a model of herself which would be able to interpret and understand colors. This Robo-Mary 2.0 which Robo-Mary herself programs, is capable of seeing color vision and is capable of interpreting color values greater than 1000 within her computational machinery. When Robo-Mary has her color vision and pixels turned on, she is not in fact surprised by any encounters with new colors, including redness, for she has already predicted them through robo-mary 2.0 (Dennett 2007).

This thought-experiment is very compelling. If it works, it serves to completely dissolve the knowledge argument. The core thesis of this thought-experiment seems to be the following: An entity which is capable of predicting what colors they would perceive if they could perceive it, could then program

another entity which is capable of perceiving those colors, and then imagine perceiving it themselves-thereby knowing what it is like to perceive colors.

First it is not clear to me that Robo-Mary's programming of Robo-Mary 2.0 would then allow Robo-Mary to perceive color herself. To see why, imagine a color blind computer scientist who is capable of acutely perceiving various gray-scaled colors and assessing what sort of color they would normally be perceived as. Hence, if he perceives a tomato, he would know-based on the gray scale it is presented in-that it would normally be perceived as red. He is very intelligent on this matter, but clearly cannot see red. Say he programs a computer to recognize redness based on more than grayscale pixels. Clearly, or so it seems, that although his program is able to recognize colors, our programmer is never able to see these colors himself. Hence, while his model is able to perceive colors, he will never know what it is like to perceive colors himself. He is not even capable of imagining colors!

Dennett considers such an objection. In sum, Dennett effectively states that we are assuming that phenomenal information is required to imagine colors. We are assuming the very thesis which he denies (Dennett 2007). However, if Dennett wants to play ball in the philosopher's court of intuitions, then he must accept that our intuitions regarding my programmer's thought experiment do not line up with his theory. I further do not think that we are assuming that phenomenal information is required to imagine colors, rather we are merely assuming that a programmer will not necessarily be able to imagine what they program in the same way that a mathematician who grasps the complexities of Riemannian Geometry may not be able to represent it imagistically in our inherent Euclidean imagistic representation of space. We have to imagine Robo-Mary as not being able to grasp colors. Since Robo-Mary cannot grasp the qualitative character of colors, but is only able to program it, she cannot know fully what Robo-Mary 2.0 knows.

Even if we do not accept a Riemannian rejection of Dennett's thought-experiment, there is a further issue: it does not appear that Robo-Mary is capable of deducing redness from her knowledge of the relevant physical and neurobiological facts. Robo-Mary must program a Robot-Mary 2.0, and then, based on this updated version of itself and understanding of itself, know about redness . In a word, Robo-Mary was unable to adequately deduce from her knowledge of physical facts, neurobiology, and color vision, the seeing of redness. If this is the case, then Robo-Mary was not capable of grasping color from her knowledge of all these facts. She had to go the extra step of programming an additional entity from which she could use as a model, to then know what redness is like. It follows from this that knowledge of all the physical facts does not deductively lead to knowledge of all color facts. It therefore seems implausible that physicalism is true. For, if we know all of the physical facts, it should follow as a matter of course that we know all of the facts about color.

Dennet does briefly consider this objection as well. However, his response is unsatisfactory at best. Dennett claims that he does not see why Robo-Mary should be required to be able to deduce the phenomenal notions of color from all the physical and neurobiological facts (Dennett 2007). However, I contend that this seems to be a trivial consequence of physicalism. If physical facts explain all other facts, it would seem like we should be able to deduce what color is like from the basic physical entities. But, as this discussion has shown, it seems that we simply cannot!

One might think that this relies too heavily on a strong interpretation of the Principle of Sufficient

Reason. That is, this relies heavily on the principle that if we knew everything about some state of the world at t_1, then we would be able to deduce everything about the state of the world at t_2. However, science has shown that this need not be the case. For instance, quantum mechanics seems to give rise to probabilistic outcomes. We cannot deduce from some quantum entity being state X at t_1, that will necessarily be in state Y at t_2, since it might also be in state Z at t_2.

While this may be true for token entities, it is clear to me that it does not hold for types. Even if we cannot predict that some particle will necessarily be in state Z or Y at t_2 based on it being in state X at t_1, it is a fact about reductive metaphysical explanations, and identity claims in particular, that if an entity of Type B reduces to an entity of Type A, then if we knew all of the facts about Type A we ought to be able to deduce all the facts about Type B from Type A. For instance, an explanation of the cohesive and adhesive properties of water should be able to be deduced from the chemical facts of H_20. The way entities appear visually should follow as a matter of metaphysical necessity from basic functionalist explanations. If the functionalist or computationalist takes color to be a functional or computational state, the color-experience should necessarily be identical to that functional or computational state. It follows then that if we assume that Robo-Mary has access to all of the functional/computational brain states which allow her a complete understanding of the neuroscience of color-vision prior to her programming Robo-Mary 2.0, and she cannot deduce the color vision of Robo-Mary 2.0 from her programming, then she does not indeed satisfy the conceivability condition and Dennett's account fails.

I think this failure of Robo-Mary to deduce Robo-Mary 2.0's vision from her initial set of facts indicates a general failure in Dennett's account in the way that both the ability analysis and old fact/new concept analysis have failed. Robo-Mary cannot deduce Robo-Mary 2.0 because she lacks the concepts that would allow her to deduce Robo-Mary 2.0. If Robo-Mary had access to this representational or phenomenal content, then her knowledge vision would have followed as a matter of metaphysical necessity. However, her functional understanding of color vision just didn't cut it

2.4 | Physicalism Fails To Be a theory of what-its-like

As hinted at in previous sections, I think the failure of each strategy lays bare something elusive about consciousness. Namely, that consciousness has a what-it's-like character that cannot be cashed out in terms of structural or functional explanations. This what-its-like character of conscious states is precisely the phenomenal information that I indicate physicalists lacked in their explanation of Mary's gain in knowledge. I suggest that perhaps the ability analysis, phenomenal concepts strategy, and Dennett's dissolution all fail because Mary's gain in knowledge is merely a straightforward gain in her factive knowledge. Since she has gained knowledge about new facts, she must have learned some non-physical fact and fixed this reference to this non-physical fact via phenomenal information. The most intuitively plausible story of Mary's gain in knowledge is the correct one.

To illustrate this point in a different way, let us turn back to section 2.1 Here I briefly mentioned that what is so strange about using functional roles of brain states to talk about art is that talk of functional roles are not theories of what-it's-like. Art is all about transmitting a certain experience, a certain what-it's-like, to the viewer and the failure of physicalist theories of mind to account for artistic description indicates

that they fail to be theories of what-it's-like. As Chalmers discusses in "Facing up to the Hard Problem of Consciousness" all theories so far have failed to be theories of what-it's-like or experience (Chalmers 2005). They have altogether ignored the hard problem. They have ignored the what-it's-likeness that is constitutive of phenomenal information. For every physicalist theory of mind we can always meaningfully ask: well is that really conscious, is that really all what-it's-likeness is? This what-it's-like character of consciousness seems to elude structural and functional reductions. Again, functionalist and computationalist theorists sound so strange when describing art in terms of their fundamental ontology because they are not actually talking about what is important in art, its what-its-likeness. It would be a very strange reality indeed if the feeling of the sublime one gets from a certain piece of romantic poetry is really just brain states. Hence, I take it that any physicalist theory of mind fails to satisfy condition B at an a priori level. Consciousness is always ideally conceivable without its supposed explanans because consciousness has a what-it's-like character that eludes the sort of reduction the physicalist is engaged in. With this in mind, we will now tackle dualism.

3 | DUALISM

In light of the failure of physicalist theories to be adequate theories of what-it's-likeness, dualism seems like a plausible option. For our purposes, we will focus on the dualism relevant to contemporary discourse: Chalmer's naturalistic dualism. By Chalmers lights, there are qualia, or fundamental mental properties, which are governed by psycho-physical laws. These psycho-physical laws track certain correlations between mental states and physical states and posit a fundamental link between the two whereby the mental states supervene on certain aspects of physical states (Chalmers 2005).

Chalmer's theory seems to respect the directionality and conceivability condition. It respects the directionality condition because it maintains that mental states supervene on physical states. Consciousness is dependent on physical stuff in a non-trivial sense. Second, it trivially respects the conceivability condition since mental states trivially cannot be conceived without mental states. Consciousness, in this case, is its own explanation since it is treated as a fundamental entity.

One might think that dualism falls prey to a modified knowledge argument (Lewis 2005). Imagine that Mary knows all the relevant facts of psycho-physics pertaining to color vision. She knows exactly what mental states are correlated to which physical states. Yet, she lives in a wholly black and white room. Does Mary learn something upon leaving the black and white room and experiencing red for the first time?

I think this modified knowledge argument fails. It fails because there is no reason for the dualist to assume that Mary can know all the relevant facts of psychophysics without actually experiencing color. The contention of the dualist proponent of the knowledge-argument is precisely that Mary needs to experience a certain color to have the adequate factual knowledge of that mental state. Since Mary fails to have the experience, she fails to have adequate factual knowledge of that mental state.

In any case, there is still something independently wrong with dualism. Namely, it fails to be a satisfying answer to the directionality condition. In the dualist picture certain mental states are hooked up to

physical states by fundamental psycho-physical laws. One might rightly wonder how these physical states hookup to mental states. In the words of Karen Bennett "How can postulating bridging principles answer the hard problem. Postulating bridging principles does not in itself tell us *how* consciousness arises from the physical, it just tells us *that* it does. Calling them bridging principles or psychophysical laws does not do any explanatory work. It just names the connection" (Bennett 2021). Essentially, Chalmer's dualist fails to produce a satisfying answer to the directionality condition because it is a mere restatement of the directionality condition. It tells us that consciousness depends on the physical without telling us why or how consciousness depends on the physical.

Chalmers might respond to our objection by arguing that we are asking too much out of his theory. When one claims something is fundamental or primitive they need no further explanation. He needs no further explanation of his psycho-physical laws because he treats them as fundamental. They are the explanation!

I think this response fails. Certainly, we are entitled to treat some entities as fundamental. We are entitled to treat some primitive building relations, perhaps grounding, as fundamental. However, other strange or foreign entities which seem to beg explanation are not. For instance, A contemporary Humean might think that we need to explain modal properties in more fundamental terms. I take it that Chalmer's psycho-physical laws are one of these strange and foreign entities which just beg to be explained. Chalmers is not entitled to simply construct a new fundamental entity out of nowhere when we have no idea how it's supposed to work! For instance, Chalmer's proposes the principle of organizational invariance. This psycho-physical law states that two consciousnesses with the same functional organization will have qualitatively identical mental states. But why? What sort of connection does qualia have to functional organization? Chalmers can only respond that it is a primitive connection. Yet we have no idea what sort of connection this primitive connection is! Unlike say, mereological relations, where we have a clear idea of what sort of connection is going on, we have no clear sense of the sort of connection between physical and mental states. For instance, we have a sense of how a pepperoni is a part of a pepperoni pizza, but we have no sense of how the mental state of pain is related to neurochemical processes. Hence, we have strong reason to reject Chalmer's proposal as an ad hoc statement of the conditions under which consciousness is to be explained, without explaining consciousness. He simply states the directionality condition without actually giving a satisfying explanation of how it satisfies it.

4 | RETHINKING THE CONDITIONS

Every available attempt to satisfy the conceivability and directionality condition has failed. Physicalism fails to satisfy the conceivability condition, while dualism has not provided a satisfying answer to the directionality condition. There is little hope indicated by any traditional answer in the current discourse. Perhaps the failure to supply any sort of satisfying answer is due to something more fundamental than the answers themselves. Perhaps something has gone wrong with the conditions for a satisfying answer to the question itself. Something has gone wrong in either the conceivability or directionality condition

The conceivability condition is motivated by the fact that reductive explanations yield identity state-

ments and identity claims are thought to be necessary. For instance, Water is not just H_20, but water is necessarily H_20. My phone is not merely my phone, it is necessarily the specific phone that it is. Thus, consciousness is not just what it is reduced to, it is necessarily what it is reduced to. Since the conceivability condition is motivated by a non-controversial fact about reductive explanations, it seems trivial and not a target for re-thinking the conditions for a satisfying answer to the hard problem.

The motivation for the directionality condition is more dubious. The directionality condition is motivated by a commitment to naturalism. Specifically, an reductionist naturalism which states our metaphysics ought to solely respect the ontology posited by physics and that all facts necessarily reduce to physical facts. Thus, the mind must reduce to the physical stuff, because the hard sciences say that physical objects are the fundamental stuff. Since the mind is not a part of this list of fundamental physical objects, the mind must be explained by physical objects and not the other way around.

I take it that a naturalism of this sort is motivated by the presumed causal closure of physics. Formulations of the causal closure of physics typically take something of the following form: each physical cause only has physical causes, or each physical effect only has a physical cause (Jaegwon 1989, Spurrett and Papineau 1999, Shook 2011, Papineau 2023). This seems like a reasonable motivation for the directionality condition. If physical effects only have physical causes, and physics forms the fundamental scientific framework from which all other sciences are grounded, then it seems reasonable to conclude that all entities must at bottom be something physical.

I think there are two ways we can plausibly object to this sort of naturalism: we can either reject the reductionist causal program or we can provide a plausible alternative closure principle which respects its original motivation

First, as John Shook argued in his 2011 paper, a reductionist physicalist program faces innumerable difficulties and has several plausible alternatives. One of the primary difficulties faced by the reductionist is that it is in no way clear how we are supposed to reduce the claims of higher-order sciences-such as biology, economics, and geology-into physical terms. This might count as evidence for a perspectival realist view. Physics might be argued to be only one of many equally valid scientific frameworks (Shook 2011).

I would like to put this lively debate to the side. A unifying account of reality from which all the facts in reality can be grounded in more fundamental facts is certainly alluring, and I want to take part. I will first begin with an exposition on the motivation for the closure principle. I will then argue that we can sufficiently capture the key motivation for the closure principle while disputing the fundamental ontology of physics. Since we can respect the closure principle in this way, perhaps we have reason for doubting the directionality condition.

4.1 | Neutral Closer

The closure principle is motivated by the scientific fact that our best scientific theories about micro-physical and macro-physical entities such as atoms, electrons, stars, etcetera suggest that physical effects solely have physical causes. Principles such as the conservation of energy also indicate that the causal system of physics is closed. Nothing from outside of physics influences the causal structure of physical

systems. Due to the fact that the casual system of physics is closed, and all facts about macro-entities are supposed to reduce to micro-entities, then we must conclude that all the entities that exist are physical (Papineau 2023).

I want to note an important fact about physical closure, note that this is a metaphysical thesis about a certain ontological category posited by science. Specifically, we are assuming that physical entities, such as atoms and electrons, exist exactly as would be posited by an ideal science. These items have mass, charges, and exist within space-time.

However, I think we can plausibly object to this principle while retaining its original motivation. Specifically if we can propose a theory which can respect the causal structure posited by physics, expresses the same closure that physics does, and has all of the theoretical virtues typically associated with our best scientific theories, but does not share the same fundamental ontology, then this theory ought to be treated on a par with physicalism.

I think many will rightly be completely dumbstruck here. How in all the world could you possibly produce such a theory? The predictive validity of our current scientific theories relies precisely on the ontology that they posit! Of course, we have to accept the fundamental ontology of physics to accurately respect the causal structure of physics. I do not think this objection is as pressing as it may seem. For instance, we can imagine an idealism which treats the physical relations/properties as merely conceptual relations/properties. While physical entities actually reduce to conceptual entities, the structure posited by science is maintained. Instead of an electron existing, perhaps it is a point in experience, and instead of possessing an array of dispositional properties, perhaps it will possess an array of conceptual relations. It seems very plausible to me that we could produce such a 1-to-1 theory while retaining theoretical virtues such as parsimony. After all, isn't the very language in which physics expressed just mathematical and spatial models? Are these models not just conceptual models?

Perhaps many will remain unconvinced, which is why in the next section I have attempted to spell out the beginnings of an idealist theory in more detail. For the purposes of this section the important point is this: a theory which does all the work which physics can do and expresses closure ought to be treated at least on a par with physics. If we accept the possibility of neutral closure -respecting the causal structure of physics while not positing the entities exactly how sciences posit them-then we are in a position to see how the directionality condition can be doubted. Perhaps we can sufficiently explain, or reduce physical entities to mental entities and retain the causal structure of the physical world. If so, then we have undermined the directionality condition because this fundamental ontology is capable of doing all of the theoretical labor of the fundamental ontology posited by physicists. Furthermore, since physicalism has failed to satisfy the conceivability condition, idealism actually appears as the more plausible alternative.

5 | END-GAME: IDEALISM

I will now begin my exploration into one idealist framework. While idealism has remained relatively unpopular among most contemporary theorists, there have been some stirrings of idealism in the liter-

ature. For instance, Chalmers in "The Mind-Body Problem and Idealism" explores three idealist views and assesses their viability as solutions to the hard-problem of consciousness. Specifically, Chalmers takes a look at micro-idealism, macro-idealism, and cosmic-idealism. As the name suggests, micro-idealism holds that all facts are grounded in facts about micro-subjects, macro-idealism holds that all facts are grounded in facts about macro-subjects and cosmic idealism holds that all facts are grounded in facts about a single cosmic subject (Chalmers 2019).

There are various pluses and minuses to each of these three views. For our purposes, I will be sketching out a view that Chalmers all but dismisses. While Chalmers does think that an idealist position is viable, he focuses primarily on realist, non-phenomenalist idealism. Chalmers contends that idealism has gotten a bad rap in the literature precisely because it is usually associated with a sort of phenomenalism where facts about P are grounded in the appearance that P. Propositions are seen as claims about possible experience. When I make a claim that all apples are red, I am really saying that all apples in experience appear red. But, as Chalmers notes, there is an explanatory worry here. The phenomenalist has nothing to ground the stable structure of experience. While it is true that if I look at an apple from one angle, and then another, it will appear to me as the same apple. What exactly explains that? The realist has an obvious answer: the mind-independent physical world. However, the phenomenalist has nothing to appeal to beyond experience. (Chalmers 2019).

I do not think the problem is as potent as Chalmers thinks. While it is true that we cannot ground the coherent structure of experience by appealing to mere sensation alone, we can explain the coherent structure of experience by an appeal to concepts or higher-order thought processes. I think Chalmers is confusing sensation with experience. Chalmers is conceiving of experiences as points or moments which are connected together by some common thread. Specifically, I interpret him as contending that a phenomenalist idealism could not explain how an individual perception of an apple at time *t*, Region R in our visual field, Sensation(touch, audio, taste, etc) S, etc., could be related to that same perception of an apple at time t_2, Region R_2, and Sensation S_2, other than stating that the facts about the subjects perceiving of an apple are mere brute facts. Thus, Chalmers asks: what connects one experience to the next? What makes the structure of experience stable in a phenomenalist idealist picture? However, I do not think we need to accept this moment-to-moment view of experiences. Instead, we can view the experience more like a river that flows downstream. There aren't any points which need to be connected, since experience is one fluid process where one part of experience cannot be cleanly separated from the other. Instead, experience comes with its own structure. It comes with concepts which give the stream of experience its borders and and intentionality which gives it direction. For instance, it is the concept of apple which connects the variety of sensations which pertain to apples from moment to moment. While sensations may have this moment-to-moment, instantaneous structure, sensation in relation to concepts, experience, does not!

To give a very rough picture of how I think concepts can connect sensations and give experience 'borders'. We can take a look at the concept of 'chair'. Let us define the concept of 'chair' as any object which can be used for the purposes of sitting. We can then use this concept over time to identify an object, keep that identification of that object as a part of our continuous representation of that object over long periods of time, as well as to identify new particular objects as also being chairs. For instance, when a

subject encounters a couch composed of the collection of sensations $S_1 - S_n$, the subject can identify it as belonging to the concept 'chair', thereby "drawing a border" or giving identity conditions to $S_1 - S_n$ as opposed to all the other available sensations. I take it that a process of this sort grounds all experiences and is capable of grounding the stable structure of experience.

I will note that the sort of phenomenalist idealism I endorse here can be seen as a weak-phenomenalist thesis. I do think that metaphysical claims, or claims about certain universal scientific laws, ought to be seen as claims about concepts and the structural role they embody. However, this structural role is only relevant insofar as the claim itself is about how concepts constitute the ideal possible experience. Hence, facts about P are grounded in the appearance that P and the sort of mental structures that play into constituting the appearance of P.

With this response to Chalmers's threat to anti-realist idealism in mind, I would like to present my pet-theory. Our idealist theory will be defined with the following conjunction of theses:

1. **The Fundamentality of Subjects**: The fundamental entities in the world are thinkers, the particular objects in experience, and concepts.

2. **The fundamentality of Subjective Relations**: The fundamental building relations are intentional relations, 'felt' relations in experience, and conceptual relations.

Now, there is much here which begs to be explained and the heavy-duty work of spelling out idealism is outside of the scope of this paper. In any case, I think we can begin to see how the world will look like under an idealist picture of reality. We have both the entities and their building blocks. Thinkers in relation to objects of thought, mediated by the concept of the object, are going to be the fundamental entities in our idealist world. In fact, these three elements make the very world itself possible. The world is just the irreducible relation between subject and object. Structure is added to the world by the various fundamental subjective relations. We have the aboutness of the subject, the intentional relations, which make a variety of intentional experiences possible. We also have the sort of relations we feel in everyday experience. For instance, in the act of me typing on this keyboard right now is a relation that is 'felt' in experience. These sorts of relations are going to account for various activities that subjects engage in, in relation to the object of the subject. I am the subject, which is in a 'felt' relation to the keyboard. Finally, we have conceptual relations. Conceptual relations are relations between concepts. These are sort of relations we find in ideologies or in systems of ideas. The conceptual relations can be seen as more fundamental in that they non-reductively make sense of intentional and 'felt' relations. While I need a concept of myself and a concept of my keyboard, and a conceptual relation between the two, to make sense of the act of 'typing on my keyboard', the act in experience itself, the feel-y part, does not reduce to the conceptual relations.

With this theory in mind one may plausibly wonder how it addresses the hard problem. In the picture of the world cast by this theory the hard problem now becomes: how does the causal structure of the natural sciences arise out of 'felt', intentional and conceptual relations? The hard problem becomes inverted. Instead of thinking of the link as physical-to-mental we now think of the link mental-to-physical. I take it that physical relations can be reduced to conceptual relations in conjunction with 'felt' relations. For instance, a certain physical interaction between particle A and particle B, is now cast in light of a certain

'felt' relation mediated, or made sense of, by a certain conceptual relation. Say that A moves a certain distance. This 'moving' is cast as a 'felt' relation, a feel-y relation, in experience. The moving is made sense of by a certain structure. We have various mathematical equations that model the moving of A in space. These mathematical equations are just conceptual relations which add an extra layer of structure that allows the subject to make sense of, to understand, the feel-y relation. Thus, physical laws or Natural Laws, are actually just relations between certain sorts of concepts. Hence, the physical law that makes sense of the feel-y relation says that a certain kind A will act such and such under X and Y kinds of conditions. The relation in a natural law is a relation between kinds- a relation between concepts. The various feel-y relations and their objects are experiences, particulars, which are subsumed under certain regular laws-conceptual relations- which are described in the natural sciences. Hence the lawful regularity of A acting under conditions X and Y is the subsumption of A, X and Y under a certain set of concepts and the relation which holds between them. We learn of these conceptual relations, or natural laws, through the appearance of objects in experience.

We might note that this somewhat mirrors Armstrong's realist view in which natural laws are taken to be relations between universals. The inherent behavior of particular entities is externally determined and necessitated by universals. Of course, Armstrongian universals are immanent and are multiply instantiated at various points of space at once, and, importantly, Armstrong is a realist (Armstrong 1983). However, I think the important comparison here is this one: concepts provide a stable, plausible platform to ground experiential stability and explain natural laws.

One might wonder how we will be able to account for error in this model. In what sense can we be wrong if how things appear is the standard of natural law itself? This issue dissipates when we note that our perspective is not ideal and our appearances are not ideal. The natural laws, or conceptual relations, are grounded in an ideal appearance of the world. Perhaps, something like what appears to the divine or some kind of cosmic subject.

I take it that we now have a plausible account of the reduction of physical facts to mental facts. Physical relations are spelled out in terms of felt and conceptual relations. If we are still doubtful of the plausibility of the reduction of physical to mental, I point to Kant as a plausible way in which the physical can be spelled out in mental terms. For Kant, Newtonian mechanics is vindicated by the categories of the understanding in conjunction with the forms of intuition (Stang 2016). This is what I am getting at here with felt and conceptual relations

Before I finish, I would like to take a look at an objection to this new project. Namely, it would be an objection to this project using a reverse conceivability condition. The reverse conceivability condition is as follows:

> **Reverse Conceivability Condition**: Any satisfactory explanation of physical structure ought to produce the result that physical structure is ideally inconceivable without its explanans. One might argue that any idealist or pan-experientialist theory fails to satisfy the reverse conceivability condition. That is, it seems that we can conceive of a physical world without consciousness. If so, our new theories are doomed to fail.

This objection is potent and dangerous. If it works then it seems we are at a loss at how to solve the

hard problem. However, I think we can produce a response. I think it doesn't work because at any point of imagining a world without consciousness we are imagining the world perspectivally. We are taking a certain perspective towards that world. When I am imagining a world filled with p-zombies, I am thinking and representing that world in my mind. There is always a transcendental, constituting subject lurking in the background of an imagined world. I think that we can plausibly deny the possibility of imagining a world without consciousness, because it seems implausible that we can imagine a world without consciousness! Like we said earlier, under the idealist picture the thinker is a condition of possibility for any world. Hence, the imagination of a world without consciousness is a non-starter. There is always some thinker lurking in the back constituting it. In the case of a p-zombie world, the thinker constituting the perspective which characterizes that specific world is itself the subject who is thinking it. The illusion that a subjectless world is possible, arises from our ability to constitute and imagine the world ourselves.

6 | CONCLUSION

While I have not spelled out my idealist framework enough to definitively show that it can respect neutral closure, I think such a project ought to be explored due to the failure of physicalism and dualism to supply satisfactory answers to the hard problem of consciousness. I also think that there are several other candidate fundamental ontologies due to the expansive field of ideas now open to us. For instance, we can explore a Jamesian metaphysics of pure experience or further dive into the realist idealism proposed by Chalmers. What is important here is this: with a neutral closure condition we now have a new world of options through which we can better grasp the mind, the world, and situate our place between the two.

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Philosopher's Compass 1/1 (2025): 42–56.

Cognitive Grammatical Rules for Defining Entrepreneurship

Lingyan Zhang[1]

[1]Zhejiang University, Hangzhou, China, zhlingyan@zju.edu.cn

ABSTRACT

The clarity of conceptual definitions is crucial for conducting research. This study conducts an in-depth exploration of the internal connections and laws among syntagmatics, pragmatics, and semantics based on cognitive grammar. Using insights from this investigation, this study constructs a scientific and rational rule system. Through a multidisciplinary integration approach, an empirical study of social entrepreneurship is carried out. The results demonstrate the remarkable effect of this rule system on optimizing the definition of social entrepreneurship. The syntagmatic rules improve the logic and conciseness of the definition, the pragmatic rules enhance its adaptability to context and cross-cultural compatibility, and the semantic rules boost its accuracy and consistency. This study not only provides a powerful tool for defining concepts in the field of social entrepreneurship, which promotes standardization and cross-cultural communication in this field, but also offers new ideas and methods for other disciplines regarding conceptual definition problems.

KEYWORDS: Cognitive Grammar, Syntactic Structures, Pragmatics, Semantic Analysis, Syntagma

1 | INTRODUCTION

In the current academic environment, precise definitions and in-depth understandings of concepts play a crucial role in promoting the development of various disciplines (Redondo, 2024). However, many fields face the predicament of ambiguous conceptual definitions. This results in continuous disputes that have seriously hindered the progress of academic exchange and innovation (Muriuki & Mbuva, 2024).

To solve this dilemma, this study introduces the theoretical framework of cognitive grammar and focuses on the three core linguistic aspects, namely syntagmatics, pragmatics, and semantics, to conduct an interdisciplinary, in-depth exploration of conceptual definitions (Mohammadreza'i & Rezaeemanesh, 2024). By integrating the theories and methods of disciplines such as philosophy and logic, this study aims to reveal the internal connections and laws among syntagmatics, pragmatics, and semantics, constructing a scientific and rational rule system. This study verifies the rule system's applicability and effectiveness in optimizing conceptual definitions in the field of social entrepreneurship, thus providing new ideas and methods for solving the problem of conceptual definitions (Carpenter & Brunet-Jailly, 2024).

2 | RELATED WORKS

In linguistics research and related fields, the exploration of syntagmatics, pragmatics, and semantics has been a core topic (Kumar, 2024). Many scholars have conducted in-depth studies from different perspectives and achieved a series of important results (Beitlova et al., 2024). In terms of syntagmatics, early structuralist linguistics emphasized the systematicness and regularity of language structures, providing a basic framework for the analysis of syntagmatics (Acharya et al., 2024). Since then, theories such as generative grammar have further explored the generative mechanisms and syntactic structures of language. However, these studies mainly focused on the description of language forms and paid less attention to the interactive relationships between syntagmatics and semantics as well as pragmatics (Nawaz et al., 2024). In the field of pragmatics, Grice's Cooperative Principle and Relevance Theory, among others, have provided important theoretical support for understanding the meaning and communicative functions of language in actual use (Hjertaker & Besirovic, 2024). Pragmatics research focuses on how language users choose appropriate expressions according to the context, as well as the implied meanings and communicative intentions of utterances (Gatti, 2024). However, pragmatics research is often relatively independent and not closely integrated with syntagmatics and semantics. In the aspect of semantics, from traditional lexical semantics to modern cognitive semantics, researchers have continuously explored the essence and cognitive mechanisms of semantics (Putayeva, 2024). Cognitive semantics emphasizes the close relationship between semantics and human cognition, believing that semantics is constructed through cognitive processes such as conceptualization and categorization (Ikhtiyarovna, 2024). Nevertheless, semantics research has, to some extent, neglected the influence of pragmatic factors on semantics.

To sum up, although predecessors have achieved abundant research results in the respective fields of syntagmatics, pragmatics, and semantics, research on the internal connections and interaction mechanisms among the three is still not systematic and in-depth enough. This study aims to make up for this deficiency by integrating the theories and methods of multiple disciplines to construct a comprehensive theoretical framework, so as to comprehensively reveal the essential characteristics and mutual relationships of syntagmatics, pragmatics, and semantics (Li, 2024).

3 | THEORETICAL FOUNDATIONS

3.1 | Basic Principles of Cognitive Grammar

Cognitive grammar regards language as an important component of human cognition. It emphasizes that language is not only a tool for expression but also a manifestation of human thinking and cognitive patterns. The form and meaning of language are closely intertwined and influence each other, jointly constituting the cognitive structure of language (Salih & Jawad, 2024). From the perspective of cognitive grammar, we can gain a deeper understanding of the essence and operating mechanism of language.

3.2 | Syntagmatics, Pragmatics, and Semantics

Syntagmatics: Syntagmatics encompasses aspects such as vocabulary, grammar, and sentence structure. It is the basic framework for language expression and determines the ways in which information is organized and transmitted (Robiddinova, 2024).

Pragmatics: Pragmatics focuses on the situations and functions of language in actual use. It involves how language users select appropriate expressions according to the context to achieve effective communicative purposes (Alhmoud, 2024).

Semantics: Semantics refers to the meaning expressed by language, including lexical meaning, sentence meaning, and discourse meaning at multiple levels. It is the core content of language and is closely related to syntagmatics and pragmatics (Martínez & Siyavoshi, 2024).

Syntagmatics, pragmatics, and semantics are interdependent and interact with each other. Syntagmatics provides a formal framework for the expression of semantics, pragmatics determines the realization manner of semantics in specific contexts, and semantics influences the choices of syntagmatics and pragmatics (Nuttall, 2024).

3.3 | Theoretical Support from Interdisciplinary Approaches

This study fully draws on the theoretical achievements of multiple disciplines such as philosophy and logic (Cheng & Franzon, 2024). Epistemology provides a theoretical foundation for understanding the relationship between language and cognition, while the theory of definition in logic offers an important reference for constructing the rule system (Behbahani & Rashidi, 2024). Through interdisciplinary research methods, the essential characteristics of syntagmatics, pragmatics, and semantics can be revealed in a more comprehensive and in-depth manner (Radatz, 2024).

4 | RULES FOR SYNTAGMATICS, PRAGMATICS, AND SEMANTICS

4.1 | Syntagmatic Rules

Principle of Conciseness: Definitions should be concise and clear, avoiding lengthy and complicated expressions. Through quantitative analysis, the goal of reducing the number of characters in definitions is set within 30%. The Python text processing tool (NLTK) is utilized for measurement and optimization.

Principle of Logicality: The structure of definitions should be logical, with each element being interrelated and having a clear hierarchy. By analyzing the usage frequency of logical relation words (such as ”therefore” and ”and”) in definitions, a rule parser (based on spaCy) is used for evaluation and optimization.

4.2 | Pragmatic Rules

Principle of Context Adaptability: Definitions should be able to adapt to the needs of different contexts. Appropriate expressions should be chosen according to specific communicative situations. Definitions are embedded into real contexts (such as policy formulation, academic reports, and cultural exchanges). Qualitative scores are given by three linguistics experts, and the average value is taken as the final result to test the context adaptation score.

Principle of Cross-cultural Compatibility: Definitions should take into account the influence of different cultural backgrounds, respect cultural differences, and ensure consistency in different language systems. Semantic translations are carried out for both Chinese and English languages. The bilingual similarity analysis tool of the BERT model is used for testing and optimization.

4.3 | Semantic Rules

Principle of Accuracy: Definitions should accurately convey the core meaning of the described concepts, avoiding vague, ambiguous, or incorrect expressions. By marking the core semantic units of each definition, the BERT embedding model is used to calculate the semantic similarity between definitions. Optimization is carried out by comparing the situation of semantic drift.

Principle of Consistency: The semantics of definitions should remain consistent in different contexts. The Kappa consistency coefficient is adopted to measure the consistency of the performance of definitions in different contexts to ensure the stability and reliability of definitions.

5 | APPLICATION IN SOCIAL ENTREPRENEURSHIP

5.1 | Application of Rules and Problem Analysis

When applying the constructed syntagmatic, pragmatic, and semantic rules to the analysis of the definition of social entrepreneurship, it is found that many definitions violate these rules. In terms of syntagmatics, some definitions are overly long and complicated, making them difficult to understand. In pragmatics, certain definitions lack context adaptability and cross-cultural compatibility and thus fail to accurately convey the connotations of social entrepreneurship. In semantics, quite a number of definitions have problems such as inaccuracy, incompleteness, or inconsistency, resulting in a vague understanding of the concept of social entrepreneurship.

For example, one definition of social entrepreneurship is an innovative activity that takes the creation of social value as the core and uses commercial means to solve social problems. From the syntagmatic perspective, this definition is relatively concise and clear. However, from the pragmatic perspective, it does not clearly indicate the specific manifestations of social entrepreneurship in different contexts and lacks contextual adaptability. In semantics, the connotations of “creation of social value” and “solving

social problems" are not explicit enough. As one can see, they have a certain degree of semantic fuzziness.

5.2 | Research Results and Implications

Through research on the definition of social entrepreneurship, the existing problems and challenges in this field are revealed. At the same time, the effectiveness and practicality of the constructed rules have also been verified. The research results show that a scientific and rational definition is crucial for promoting the development of social entrepreneurship research. This study provides new perspectives and methods for scholars in the field of social entrepreneurship, helping them to better understand and define the concept of social entrepreneurship while facilitating academic exchanges and knowledge innovation in this field.

Moreover, this study also implies that in the conceptual definitions of other fields, attention should be paid to the rules of syntagmatics, pragmatics, and semantics to avoid similar problems. Only through scientific and accurate definitions can the rigor and effectiveness of academic research be ensured and the healthy development of various disciplines be promoted.

6 | EXPERIMENTAL DESIGN

6.1 | Research Objectives and Hypotheses

Research Objectives: Through the theory of cognitive grammar, systematically construct a rule system for syntagmatics, pragmatics, and semantics, and verify its applicability and effectiveness in optimizing the conceptual definitions in the field of social entrepreneurship.

Research Hypotheses: H1: Syntagmatic rules can significantly improve the structural logic and conciseness of definitions; H2: Pragmatic rules can enhance the context adaptability and cross-cultural compatibility of definitions; H3: Semantic rules can improve the accuracy and consistency of definitions and significantly reduce ambiguity.

6.2 | Experimental Design Framework

6.2.1 | Experimental Process

Data Collection and Preprocessing: Select academic literature, practical case reports, and policy texts in the field of social entrepreneurship, and conduct preprocessing operations such as screening and format unification.

Construction of the Rule System Based on Cognitive Grammar Theory: According to the relevant principles of syntagmatics, pragmatics, and semantics, construct a specific rule system.

Application and Optimization Experiments of the Rule System: Apply the rule system to the definitions of social entrepreneurship and conduct optimization experiments. Evaluation and Verification

of the Applicability and Effectiveness of the Rules: Evaluate and verify the definitions before and after optimization through quantitative and qualitative indicators.

6.2.2 | Research Variables

Independent Variables: The application of syntagmatic, pragmatic, and semantic rules.

6.2.3 | Dependent Variables

Quantitative Indicators: Definition length, number of ambiguities, keyword coverage rate, semantic consistency score.

Qualitative Indicators: Accuracy, context adaptability, cross-cultural compatibility (expert scores).

6.2.4 | Experimental Group and Control Group

Experimental Group: Definitions optimized by the rule system.

Control Group: Original definitions without rule optimization treatment.

6.3 | Data Collection and Preprocessing

6.3.1 | Data Sources

Literature Collection: Select 100 academic papers in the field of social entrepreneurship, covering major journals (such as Journal of Business Venturing, Academy of Management Journal, etc.).

Case Data: Select case reports of 50 actual social entrepreneurship projects, involving multiple cultural backgrounds.

Policy Texts: Collect 30 documents on social entrepreneurship policies from governments and non-governmental organizations.

Data Screening: Delete duplicate definitions, filter out overly subjective or non-linguistically relevant content, and unify the language format.

Data Annotation: Use natural language processing tools to annotate the definitions in terms of syntagmatics, pragmatics, and semantics, and decompose them into three types of elements.

6.4 | Data

Table 1: Data Collection

Data Type	Data Source	Sample Quantity	Proportion (%)
Academic Literature	Journals Related to Social Entrepreneurship	100	50
Case Data	Reports of Social Entrepreneurship Projects	50	25
Policy Texts	Government & NGO Documents	30	15
Organization Documents	Meeting Records and Interview Materials	20	10
Meeting Records	—	200	100

6.5 | Data Processing and Construction of the Rule System

6.5.1 | Design of Syntagmatic Rules

Conciseness Optimization: Set the goal of reducing the number of characters in definitions within 30% quantitatively. Use the Python text processing tool (NLTK) for measurement and optimization.

Logicality Analysis: Quantify the usage frequency of logical relation words in definitions and use a rule parser (based on spaCy) for evaluation and optimization.

6.5.2 | Design of Pragmatic Rules

Context Adaptability Testing: Embed the definitions into real contexts. Three linguistics experts will give qualitative scores, and the average value will be taken as the final result to test the context adaptation score.

Cross-cultural Compatibility Analysis: Conduct semantic translations for both Chinese and English languages. Utilize the bilingual similarity analysis tool of the BERT model to test the consistency of definitions in different language systems.

6.5.3 | Design of Semantic Rules

Accuracy Analysis: Mark the core semantic units of each definition. Use the BERT embedding model to calculate the semantic similarity between definitions and conduct optimization by comparing the situation of semantic drift.

Consistency Testing: Adopt the Kappa consistency coefficient to measure the consistency of the performance of definitions in different contexts.

6.6 | Experimental Methods and Analysis

6.6.1 | Dataset Partition

Randomly divide the definition data into a training set (70%) and a testing set (30%). Ensure the diversity of the dataset based on stratified sampling (50% for academic definitions, 30% for policy definitions, and 20% for case definitions).

6.6.2 | Experimental Process

Baseline Measurement: Measure the quantitative and qualitative indicators for the original definitions.

Rule Application: Optimize the definitions in terms of syntagmatics, pragmatics, and semantics. Employ automated tools and manual reviews.

Post-test Evaluation: Measure all the indicators of the optimized definitions.

6.6.3 | Data Analysis Tools

Quantitative Analysis: Use the mean, standard deviation, significance test (independent-sample t-test), correlation analysis, and regression models (using SPSS).

Qualitative Analysis: Conduct reliability analysis (Cronbach's α coefficient) of expert scores and score statistics for scenario simulation tests.

6.7 | Statistical Test Outcomes

Table 2: Experimental Comparison

Test Items	Indicators	Test Statistics	Significance Level (p-value)
Significance Test (t-test)	Experimental Group & Control Group Differences	t=8.72	<0.001
Correlation Analysis	Keywords coverage rate & accuracy score	r=0.82	<0.001
Consistency Test (Kappa Coefficient)	Consistency score of definitions	k=0.91	<0.001

6.8 | Summary of Experimental Data

6.8.1 | Data Source

A total of 180 definitions in both the experimental group and the control group.

6.8.2 | Average Length (in words)

22.4 ± 3.5 for the experimental group and 32.5 ± 4.2 for the control group.

6.8.3 | Number of Ambiguities

1.8 ± 0.4 for the experimental group and 4.7 ± 1.0 for the control group.

6.8.4 | Keyword Coverage Rate (%)

87 ± 5 for the experimental group and 65 ± 7 for the control group.

6.8.5 | Accuracy Score (Out of 5)

4.6 ± 0.2 for the experimental group and 3.2 ± 0.6 for the control group.

6.8.6 | Context Adaptability (out of 5)

4.6 ± 0.2 for the experimental group and 3.2 ± 0.6 for the control group.

6.8.7 | Statistical Significance

1. Definition Length: With $p < 0.001$, the experimental group is significantly better than the control group.

2. Number of Ambiguities: With $p < 0.001$, the number of ambiguities in the definitions of the experimental group is significantly reduced.

3. Keyword Coverage Rate: With a correlation coefficient $r = 0.82$, the coverage rate of the experimental group is significantly improved.

4. Definition Accuracy: The reliability of expert scores ($\alpha = 0.91$) shows a significant difference ($p < 0.001$).

6.9 | Comparative Results

Table 3: Experimental Comparison

Indicator	**Experimental Group**	**Control Group**	**Significance of Difference (p-value**
Definition Length (number of words)	22.4± 3.5	32.5 ± 4.2	<0.001
Number of Ambiguities	1.8 ± 0.4	4.7 ± 1.0	<0.001
Keyword Coverage Rate (%)	87 ± 5	65 ± 7	<0.001
Accuracy Score (out of 5)	4.75 ± 0.3	3.4 ± 0.5	<0.001
Context Adaptability Score (out of 5)	4.6 ± 0.2	3.2 ± 0.6	<0.001

6.10 | More Results

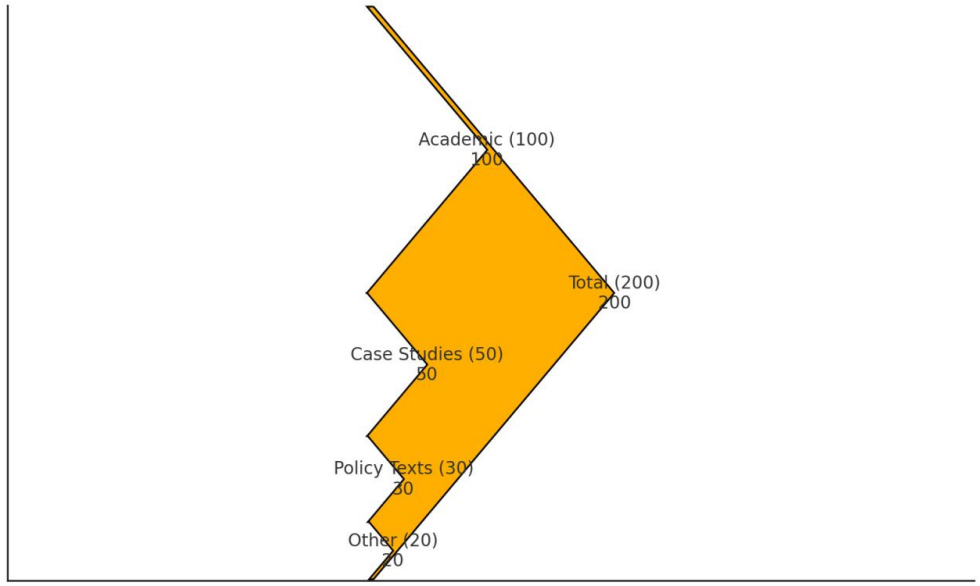

Figure 1: Sankey Diagram: Data Sources Contribution (Detailed)

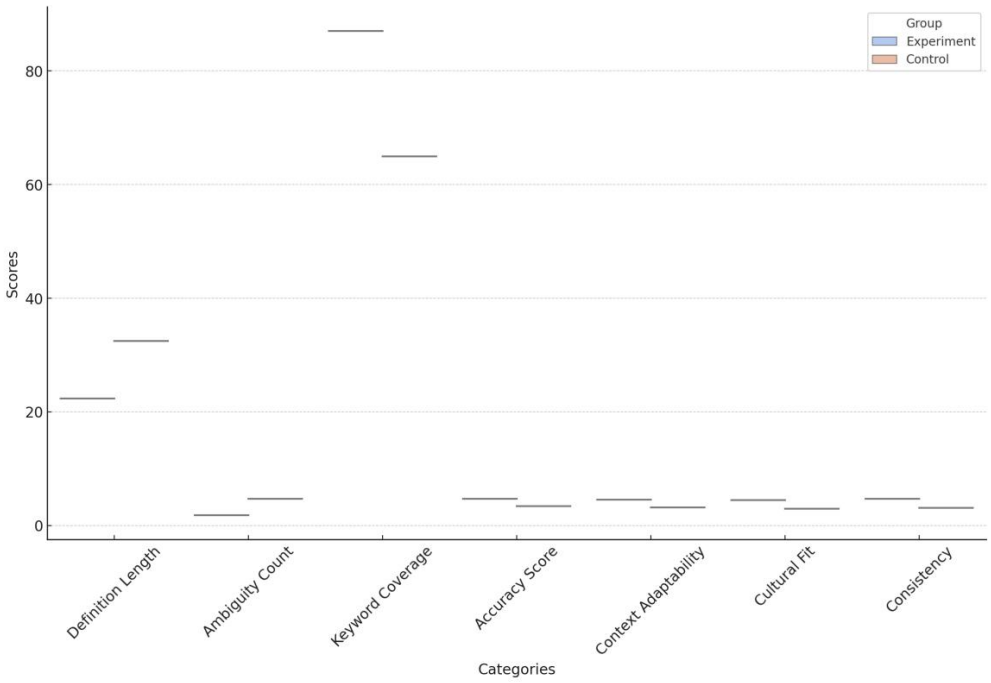

Figure 2: Violin Plot: Experimental vs Control Group Resuits (Extended Data)

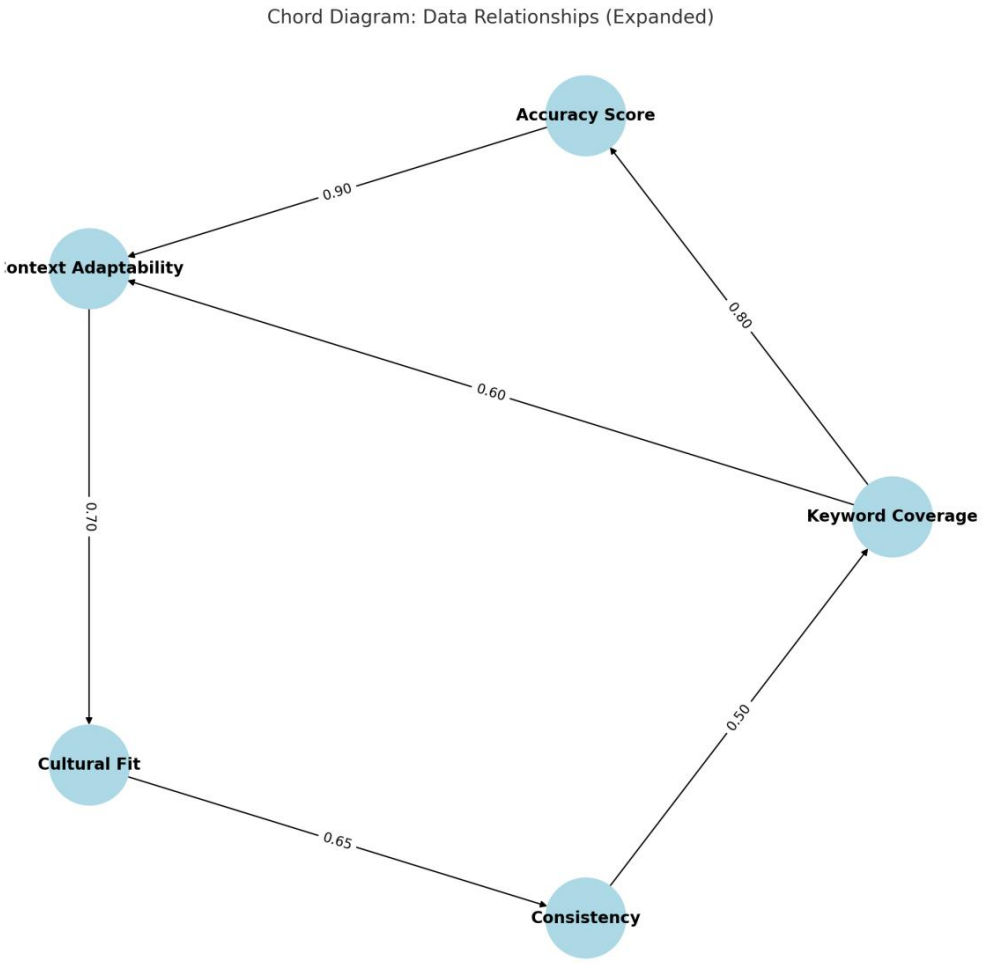

Figure 3: Chord Diagram: Data Relationships (Expanded)

6.11 | Discussion

6.11.1 | Effectiveness of the rule system

The experimental results have fully verified the significant roles of the syntagmatic, pragmatic, and semantic rules in optimizing the definitions of social entrepreneurship. In complex contexts and multi-lingual backgrounds, these rules have demonstrated particularly outstanding effects in improving the accuracy and consistency of definitions, strongly supporting the research hypotheses.

6.11.2 | Implications for Social Entrepreneurship Research

Standardized definitions contribute to the theoretical accumulation and cross-cultural communication in the field of social entrepreneurship, providing a solid foundation for the development of this field. The rule system based on cognitive grammar proposed in this study offers a systematic methodology for dealing with emerging academic concepts. By clarifying the definitions of concepts, research discrepancies caused by unclear definitions can be reduced, thus promoting the standardization and in-depth development of academic research.

6.11.3 | Limitations and Directions for Improvement

The data sample sources in this study have a regional bias, mainly concentrated in European and American regions, which may affect the universality of cross-cultural results. Future research can further expand the data sources and incorporate samples of more languages and different cultural backgrounds to enhance the reliability and applicability of the research results.

Moreover, this study has mainly focused on the optimization of static definitions. However, in actual language use, semantics change dynamically. Future research can explore optimization strategies in a dynamic semantic environment to better adapt to the development and changes of language

7 | CONCLUSION

By constructing a rule system based on cognitive grammar and conducting empirical research in the field of social entrepreneurship, this paper has proposed a set of scientific and effective methods to optimize conceptual definitions. The experimental results show that the rule optimization of syntagmatics, pragmatics, and semantics can not only significantly improve the quality of definitions but also enhance their applicability and cultural compatibility. Future research will further expand the application scope of the rule system and deeply explore optimization strategies in a dynamic semantic environment, so as to make greater contributions to promoting the development of various disciplines.

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Philosopher's Compass 1/1 (2025): 57–73.

Entrepreneurship and the Philosophy of Science

Lim Win Kee[1] **and Yichuan Hu**[2]

[1]University of Strathclyde, Glasgow, UK & Zhejiang University, Hangzhou, China, winkee.lim@outlook.com

[2]Zhejiang University, Ningbo, China, yichuan_hu@zju.edu.cn

ABSTRACT

Entrepreneurship plays a pivotal role in driving economic development and social transformation. Yet its definition has been a long-standing subject of debate. This study adopts a perspective rooted in the philosophy of science to develop a rulebook for evaluating definitions based on four criteria: essentiality, expressiveness, interpretability, and clarity. Through systematic literature review and experimental validation, the scientific rigor and applicability of the rulebook were assessed. Three experiments were designed to test the rulebook's effectiveness in academic research, corporate management, and cross-cultural contexts. The results indicate that the rulebook significantly enhances the logical consistency and scientific robustness of definitions, fostering consensus within the academic field of entrepreneurship studies and improving financial performance and social impact through optimized definitions in corporate practices. Furthermore, the study examines the applicability of the rulebook in dynamic environments and multicultural contexts, offering a novel theoretical framework and methodological guidance for future research on definitions. This research not only enriches the theoretical foundation of entrepreneurship studies but also provides insights for refining definitions in other contested domains.

KEYWORDS: Entrepreneurship, Definition Evaluation, Disciplinarity, Philosophy of Science

1 | INTRODUCTION

In the contemporary processes of economic and social development, the significance of entrepreneurship has become increasingly prominent. Entrepreneurship serves not only as the central driving force behind innovation and business growth but also plays a pivotal role in addressing societal challenges and advancing social progress (Chipeta et al., 2017). However, despite the extensive attention it has received, a unified and universally accepted definition of entrepreneurship remains elusive (Fuseini, 2021). This lack of definitional consensus not only hinders the advancement of academic research but also poses challenges to business practices and policy formulation. Consequently, exploring the definition of entrepreneurship from an interdisciplinary and cutting-edge perspective holds considerable theoretical and practical significance (Cooke et al., 2021). This study aims to conduct a systematic literature review and draw upon definition theories from the philosophy of science to develop a framework for evaluating def-

initions of entrepreneurship. By experimentally validating the scientific rigor and practical relevance of this framework, the research seeks to identify the root causes of definitional inconsistencies and disputes. The findings will provide clear guidance for future research while offering valuable insights for academia, industry practitioners, and policymakers. This endeavor is expected to deepen understanding of the essence and connotations of entrepreneurship, fostering theoretical advancements and innovative practices in related fields (Meyer et al., 2020).

2 | CONCEPTUAL BACKGROUND

2.1 | Unresolved Definition Controversies

Since the emergence of entrepreneurial research, scholars have endeavored to establish a unified and universally accepted definition of entrepreneurship. However, consensus remains elusive (Arnold, 2021). As research progresses, disagreements over the definition of entrepreneurship have become increasingly pronounced. Some scholars argue that entrepreneurship should focus on the identification and exploitation of market opportunities, emphasizing innovation, risk-taking, and resource integration to maximize economic benefits. For instance, Schumpeter defines entrepreneurship as the ability to achieve " new combinations " through innovation, which includes introducing new products, developing new production methods, exploring new markets, acquiring new resources, and establishing new organizational forms (Köseoglu et al., 2019). This perspective is prevalent in traditional research on business management and economics, positioning entrepreneurs as key drivers of economic growth and emphasizing their innovative behaviors and economic performance in market competition.

However, other scholars adopt a broader societal perspective, highlighting the role of entrepreneurship in addressing social issues and creating social value. They contend that entrepreneurship should not only pursue economic benefits but also focus on achieving diverse social objectives, such as promoting social equity, environmental protection, and community development. For instance, the concept of social entrepreneurship applies business methodologies to solving social problems, fostering positive social change. This perspective transcends the narrow economic understanding of entrepreneurship, incorporating social value into its framework and emphasizing the responsibilities and contributions of enterprises to society.

These definitional divergences contribute to the ambiguity and uncertainty surrounding the concept of entrepreneurship. As a result, the field lacks a unified theoretical foundation, creating challenges for both research and practical applications, such as business evaluation and policy-making. For instance, differing definitions may lead to inconsistent criteria for assessing whether a business exhibits entrepreneurial qualities, potentially affecting resource allocation and the effectiveness of policy implementation.

2.2 | Philosophy of Science and Definition Theory

To address the ongoing debates surrounding the definition of entrepreneurship, this study introduces the theory of definitions from the philosophy of science. The philosophy of science, as a discipline that investigates the nature, methodologies, and developmental principles of science, provides profound insights into the formulation and understanding of concepts (Donaldson & Walsh, 2015).

Definition theory, specifically, offers a set of standards and methodologies for evaluating the quality of definitions, facilitating a logical and semantic analysis of the concept of entrepreneurship (Ramoglou et al., 2016). Philosophers have long studied the art of defining, proposing various methods and criteria for formulating definitions. Among them, Aristotle emphasized that a definition should reveal the essential attributes of a subject, which can be achieved through the method of genus and differentia. For instance, in defining "human," the genus "animal" is identified, followed by specifying the differentia that distinguishes humans from other animals, such as rationality and linguistic ability (Rosenberg et al., 2019). This approach provides a critical perspective for understanding the essence of entrepreneurship—namely, that it must possess distinctive attributes that set it apart from other concepts (Sheehy, 2015).

Additionally, modern logicians such as Cohen, Nagel, and Suppes have made significant contributions to definition theory. They argue that definitions should adhere to specific logical principles to avoid errors such as circular definitions and vague formulations (Welch et al., 2020). For example, a circular definition occurs when a term is defined by directly or indirectly using the term itself, resulting in ambiguity and lack of substantive meaning. In the context of entrepreneurship, defining it as "the qualities exhibited by individuals with entrepreneurial spirit" constitutes a circular definition, failing to uncover the intrinsic nature of entrepreneurship.

While definition theory and its rule-based methodologies have proven highly applicable in both academic and business contexts, their efficacy in dynamic environments requires further evaluation. In particular, rapid technological changes and evolving societal needs may necessitate continuous updates to the definition of entrepreneurship, potentially challenging the adaptability of rule-based approaches (Okasha, 2016). Furthermore, varying cultural interpretations of *essentialism* and *social value* may require additional adjustments to ensure cross-cultural applicability of such methodologies (Jackson, 2016).

3 | RESEARCH METHODOLOGY

3.1 | Literature Search and Screening

To ensure the comprehensiveness and representativeness of this research, we used Web of Science as the primary database to retrieve academic journal articles published between 1998 and 2022. The year 1998 was selected as the starting point because a highly influential article on entrepreneurship was published that year, laying the foundation for subsequent research. During the search process, we utilized keywords such as "social entrepreneur," " social enterprise, " " social venture, " * and " sustainable development " * to identify relevant studies. These terms were applied to search within article titles, abstracts, and keywords

to encompass diverse expressions of entrepreneurship and related research perspectives (Ngulube, 2015).

To ensure the quality and impact of the academic journals included, we referred to the 2021 Academic Journal Guide (AJG) and initially selected articles published in journals rated as 4*, 4, and 3. Additionally, to incorporate emerging and innovative studies, we included two specialized journals, the Journal of Social Entrepreneurship (AJG rating: 2) and the Social Enterprise Journal (AJG rating: 1), in the search scope. Through this multi-stage screening process, we identified a total of 2,096 records (Aggarwal et al., 2021).

3.2 | Definition Extraction and Analysis

In the selected articles, we identified and extracted definitions related to entrepreneurship. These definitions were primarily located in the introduction and literature review sections. For articles presenting multiple overlapping definitions, we selected the most comprehensive and representative definition for analysis. During the analysis, we focused on the linguistic expression, logical structure, and conceptual connotations conveyed by the definitions, evaluating them through the lens of definition theory in the philosophy of science (Chandra et al., 2019).

To systematically analyze the definitions, we employed MAXQDA, a qualitative data analysis software tool. Initially, we annotated key linguistic fragments within the definitions, categorizing them as ”first-order codes.” These codes encapsulated various descriptions of entrepreneurship, including comparisons with conventional entrepreneurship, social objectives, functional characteristics, and resource utilization (Lamb et al., 2018). Subsequently, the first-order codes were further synthesized into more abstract ”second- order categories” to facilitate a deeper understanding of data patterns. Finally, these second-order categories were integrated with four evaluative criteria for definitions — essentiality, expressiveness, interpretability, and clarity — forming *aggregate dimensions* that enabled a theoretical examination of the conceptualization of entrepreneurship (Duque-Oliva et al., 2024).

3.3 | Experimental Design

3.3.1 | Objectives

To validate the scientific rigor of the four rules proposed in the philosophy of science for optimizing the definition of entrepreneurship: essentiality, expressiveness, interpretability, and clarity.

To explore the impact of diverse disciplinary and cultural backgrounds on the applicability of the rulebook.

To analyze the practical implications of the rulebook- optimized definition of entrepreneurship in academic research and corporate practice.

3.3.2 | Hypothesis

- *H1*: The rulebook significantly enhances the logical coherence and scientific rigor of the definition of entrepreneurship.

- *H2*: The use of the rulebook increases the level of consensus among scholars regarding the definition of entrepreneurship.
- *H3*: : In corporate practice, the optimized definition significantly improves the efficiency and effectiveness of strategic decision-making (Chandra et al., 2019).

3.3.3 | Experimental Design Process

Experiment 1: Validation of Rulebook Applicability

- Subjects

Participants include academic researchers (50), corporate managers (50), and policymakers (50).

- Geographical Distribution

Participants are selected to ensure cultural diversity, covering three cultural regions: Europe and North America, Asia-Pacific, and Africa.

- Experimental Procedure

Three levels of entrepreneurial definitions are provided for evaluation: Original Definition (the traditional definition without optimization based on the rulebook), Partially Optimized Definition (the definition revised using partial rulebook guidelines), Fully Optimized Definition (the definition rigorously optimized according to the complete rulebook.) Participants rate each definition on a Likert scale (1 – 5) across the following dimensions: logical coherence, clarity, innovativeness, and practical applicability (Kaefer et al., 2015).

- Data Analysis

The mean scores of the three definition levels are compared across different participant groups. One-way Analysis of Variance (ANOVA) is employed to test the statistical significance of the rulebook's applicability.

Experiment 2: Effectiveness of the Rulebook in Academic Research

- Subjects

A random sample of 100 academic articles on entrepreneurship is drawn from top-tier journals, covering topics such as social entrepreneurship and green entrepreneurship.

- Experimental Procedure

Definition Extraction: Using text analysis tools (e.g., NVivo), the definitions of entrepreneurship are extracted from the selected articles.

Post-evaluation: An expert panel assesses these definitions against four dimensions: essential quality, expressiveness, interpretability, and clarity (Rylee et al., 2022).

- Data Analysis

Descriptive statistics are conducted on the optimization scores of the definitions.Factor analysis is used to examine the differential effects of the rulebook across disciplines such as economics, management, and sociology.

Experiment 3: Validation in Corporate Practice Subjects

- Subjects

The sample includes 20 small and medium-sized enterprises (SMEs) across industries such as technology innovation, social enterprises, and cultural and creative sectors.

- Grouping

Experimental Group: Experimental group (using the optimized definition). Control group (using the traditional definition)

- Experimental Procedure

Enterprises formulate their annual strategic plans by adhering to established definitions. Within this framework, performance is meticulously assessed through a comprehensive set of indicators. Financial performance is gauged by quarterly revenue and profit margins, providing a quantitative snapshot of the economic vitality of the organization. Concurrently, the Social Impact Index serves as a multifaceted measure of an enterprise's broader societal influence. This index is constructed from five weighted dimensions: the coverage of social welfare projects, which carries a 30% weight, reflecting the extent of the organization's commitment to social causes; the proportion of employees participating in social activities, accounting for 20%, indicating the level of engagement within the workforce; the frequency of positive media coverage, also 20%, which illuminates the public perception and media relations efficacy; community feedback scores, with a 15% allocation, signifying the direct feedback from the communities served; and finally, environmental impact metrics, also 15%, which quantify the organization's ecological footprint. Together, these indicators offer a holistic view of an enterprise's performance and societal contribution.

- Data Collection Methods

Annual corporate social responsibility reports, employee surveys, media analytics tools such as MediaCloud, community interviews, and third-party environmental assessment reports.

- Weight Validation

The weight distribution for the social impact index is verified using the Delphi method, incorporating consensus from 10 social enterprise research experts to ensure scientific rigor.

- Data Analysis

Regression Analysis is employed to explore the correlation between the defined optimization scores and corporate performance (Rodrigues et al., 2021). Paired Sample T-Test is utilized to verify the significance of performance indicator differences between the experimental and control groups.

4 | RESEARCH FINDINGS

4.1 | Rule 1: Essentiality - Definitions should convey the essence of a concept

4.1.1 | Characterization of Origins

Scholars often compare entrepreneurship with conventional entrepreneurship when explaining its origins. However, views differ on the extent to which the principles of conventional entrepreneurship permeate the definition of entrepreneurship. Some scholars argue that financial sustainability through earned income strategies is an important attribute of entrepreneurship, while others prefer to view donations, grants, and government tax breaks as viable sources of income (Defourny et al., 2017). For example, Di Domenico et al. emphasize the importance of earned income strategies for social enterprises, while Somerville and McElwee argue that social enterprises should rely more on external support (Littlewood et al., 2018). Furthermore, in terms of market orientation and opportunity-seeking behaviors, while some scholars argue that this is a distinctive feature of entrepreneurship, others position social enterprises as non-governmental organizations (NGOs), emphasizing their role in institutional gaps. For example, Brunetto et al. argue that social enterprises should play a role in institutional gaps, while Liu et al. highlight the opportunity-seeking behavior of social enterprises (Rahdari et al., 2016). These different perspectives suggest that there is much controversy in assessing whether entrepreneurship is a derivative concept of conventional entrepreneurship or nonprofit management.

4.1.2 | Characterization of Purpose

Definitions of entrepreneurship often convey the essence by emphasizing its purpose and drivers, such as solving social problems, responding to social needs, and compensating for market failures. However, there are differences in the specific formulation of these definitions, and these differences have important implications. For example, "social mission" and "social purpose" may seem similar, but they have different meanings. While " social mission " may be more focused on the formal objectives of the enterprise, "social purpose" reflects the shared perceptions of the organization's members about the meaning of the enterprise's existence (Kickul et al., 2020). In addition, different scholars have different understandings of the values and services that a social enterprise should provide, further reflecting the plurality and complexity of entrepreneurship's purpose (Ramus et al., 2017).

4.1.3 | Functional Characteristics

The function of entrepreneurship is primarily in the realization of social purposes through business activities, and its mode of operation usually involves two "logics" with potentially different goals, norms and values. Scholars have attempted to reconcile the relationship between value creation and value acquisition in their definitions, but the views are not uniform. Some scholars argue that the two mechanisms may conflict with each other in practice, while others emphasize that social enterprises should combine social value creation with revenue growth. For example, Smith et al. argue that social enterprises are in conflict between realizing social value and obtaining economic benefits, while Choi and Park advocate

that social enterprises should pursue both social and economic goals. In addition, innovation and risk-taking are also seen as important functions of entrepreneurship. Scholars point out that innovation is the key to social enterprise development and branding, while risk-taking is closely linked to the innovation process. For example, Garcia-Uceda and others view social entrepreneurs as active risk-takers who rely on social capital and networks to achieve their goals.

4.1.4 | Resource Characterization

Important resources for well-being have been assessed differently by scholars in terms of their role and value in the public and private spheres. For example, Di Domenico et al. consider goods and services as a means for social enterprises to realize social value, whereas Calò et al. place more emphasis on the link between private goods and social enterprise revenues. In addition, people and their values have been recognized as key intangible resources for entrepreneurship (Phillips et al., 2015), and scholars have argued that the motivations and ethics of social entrepreneurs have a significant impact on the social mission and goal pursuits of the enterprise (Robinson et al., 2014). For example, Andre and Pache note that social entrepreneurs are driven by an ethic of care, while Kickul et al. emphasize that social entrepreneurs do not have profit maximization as their primary goal.

4.2 | Rule 2: Expressive - Definitions should distinguish between defined and defining items

4.2.1 | Issues in Drivers

When trying to define the drivers of entrepreneurship, scholars often use expressions such as "social challenges" and "social problems". But these definitions are logically problematic because they are stated in a tautological way, wherein entrepreneurship aims to solve social difficulties and lack in- depth analysis of the drivers. For example, many definitions simply refer to social needs or problems without further explaining the nature and root causes of these needs or problems . While some scholars have attempted to avoid this problem by using more abstract language, there is still a need for more precise definitions to clarify the drivers of entrepreneurship.

4.2.2 | Problems in the Expression of Goals

When describing the goals of entrepreneurship, scholars often use terms such as "social mission" and "social goals", but these expressions are often too general and lack specific definitions and distinctions of the goals. For example, the meaning of "social mission" is vague, and different scholars and enterprises may have different interpretations of it. Some scholars believe that social enterprises should aim to achieve specific social change, while others emphasize that they should have a positive impact on a broader social level. To more accurately communicate the goals of entrepreneurship, more focused and explicit definitions are needed.

4.2.3 | Problems in the formulation of results and attainment

When describing the expected outcomes of entrepreneurship, such as the concepts of "social value" and "social welfare", although common, these definitions often lack detailed descriptions of the process and manner in which the outcomes are achieved, making the definitions insufficiently specific and clear. For example, the definition of "social value " is broad, which makes it difficult to measure and assess the actual contribution of enterprises in realizing social value (Moltafet et al., 2024). In order to better understand the impact and significance of entrepreneurship, there is a need for definitions that specify how results are expressed and measured.

4.3 | Rule 3: Expository - definitions should use positive language

Negative expressions are often found in the definition of entrepreneurship, especially when describing its non-profit nature, using terms such as "non-profit " and "non- profit distribution". However, the meaning of these terms is not clear and can easily lead to conceptual confusion. For example, the definition of "nonprofit" may vary across scholars and practice areas, and some definitions do not specify what nonprofit organizations should do when faced with windfall or structural profits (Jordan et al., 2024). In addition, these negative statements fail to positively articulate the core characteristics and values of entrepreneurship, which is not conducive to an accurate grasp of the concept.

4.3.1 | The problem of implying relevant conceptual deficiencies

Some definitions imply the inadequacy of conventional entrepreneurship in creating social value by contrasting it with conventional entrepreneurship, or emphasize the selfless behavior of social entrepreneurs, which may trigger a misunderstanding of the role of self-interest in social entrepreneurship. For example, some definitions assume that social entrepreneurs should be selfless, ignoring the fact that they may legitimately be concerned with self-interest while pursuing social goals. Such comparisons may be oversimplified and fail to adequately consider the complexity and diversity of social entrepreneurship (Zake, 2024). For a more comprehensive understanding of entrepreneurship, such expressions that may lead to a one-sided understanding should be avoided.

4.4 | Rule 4: Clarity - Definitions should avoid metaphors and obscure language

4.4.1 | The problem of passive voice

In the sample of definitions we analyzed, there were 26 instances of the use of the passive voice. This expression makes the subject of the definition unclear and makes it difficult for the reader to identify the performer of the action, thus affecting the clarity and readability of the definition. For example, the expression "social entrepreneurship has been defined as ..." does not clearly indicate who or what defined it, leaving the reader to question the source and authority of the definition. The use of passive voice also makes the definition appear more abstract and indirect, which is not conducive for readers to quickly

understand the core concepts of entrepreneurship (Moltafet et al., 2024).

4.4.2 | Problems with Examples and Explanations

Some definitions fail to provide concrete examples or explanations in the elaboration process, leading to conceptual ambiguity. For example, some definitions use abstract terms such as "highly flexible" and "adaptive efficiency" without further explanation of the specific meanings and manifestations of these terms in the context of entrepreneurship, making it difficult for readers to form an accurate understanding. On the contrary, some definitions were able to convey the connotation of entrepreneurship more effectively by providing concrete examples, such as the practical actions of social enterprises in addressing social issues such as poverty and environmental degradation, making it easier for readers to understand and grasp the essence of the concept. A. Rulebook enhancement of definition quality

5 | EXPERIMENTAL RESULTS AND DISCUSSION

5.1 | Rulebook enhancement of definition quality

5.1.1 | Analysis of the results of Experiment 1

The results of Experiment 1 shows that the mean ratings of fully optimized definitions were significantly higher than those of the original definitions in terms of logic, clarity, and practical application (academic researcher group: mean ratings of the original definitions were 3.2 with a standard deviation of 0.8; mean ratings of the fully optimized definitions were 4.7 with a standard deviation of 0.4, $p < 0.01$; business manager group: mean ratings of the original definitions were 2.9 with a standard deviation of 0.7; mean ratings of the fully optimized definitions were 4.5 with a standard deviation of 0.3, $p < 0.01$). (mean rating of definitions 4.5, standard deviation 0.3, $p < 0.01$). The partially optimized definitions also had higher ratings than the original definitions, and the ratings tended to increase as the degree of optimization increased. This suggests that the rulebook can effectively improve the quality of the definition of entrepreneurship, which verifies Hypothesis H1. There is consistency in the evaluations of the rulebook among different groups (academic researchers, business managers, and policy makers), and there is no significant difference in the evaluations of participants from different cultural regions, which suggests that the rulebook has a certain degree of aptness of generalization.

Figure 1 presents the results of the ratings of the three definition types by different participant groups. The results show that fully optimized definitions are rated significantly higher than original and partially optimized definitions, whether by academic researchers, business managers, or policymakers. This verifies the applicability and effectiveness of the rulebook in enhancing the logic and scientificity of definitions.

Table 1: Experiment 1: Validation of the Applicability of the Rule Handbook

Group	Definition Type	Average Score	Standard Deviation	Significance (p-value)
Academic Researchers				
	Original Definition	3.2	0.8	<0.01
	Partially Optimized	4.1	0.6	
	Fully Optimized	4.7	0.4	
Business Managers				
	Original Definition	2.9	0.7	<0.01
	Partially Optimized	3.8	0.5	
	Fully Optimized	4.5	0.3	

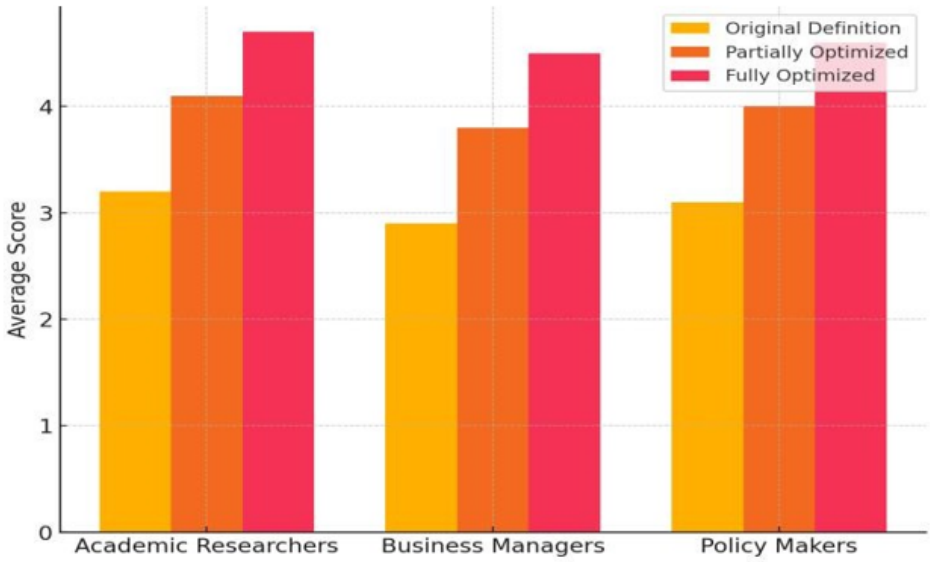

Figure 1: Definition Scoring Comparison by Group

5.1.2 | Specific embodiment of optimization of definitions

From the four rules of the rulebook, the essentiality rule prompts the definition to more accurately convey the core essence of entrepreneurship, so that the definition is no longer confined to surface features but goes deeper into the description of essential features such as origins, purposes, functions and resources. Expressive rules make the definition more accurate and clear in terms of drivers, goals, and outcomes, avoiding logical confusion and tautology. Expository rules highlight the positive attributes and values of entrepreneurship through the use of positive language, reducing the conceptual ambiguity brought about by negative expressions and one-sided comparisons. The rule of clarity, on the other hand, makes the language of the definition more straightforward and concrete, reduces the use of passive voice and abstract terms, and enhances the readability and comprehensibility of the definition.

5.2 | Definitional Optimization for Academic Research

5.2.1 | Results of Experiment 2

In Experiment 2, the analysis of 100 research papers on entrepreneurship in top journals shows that after the definition is optimized by using the rulebook, the average score before the definition optimization is 3.1 - 3.5 (3.1 in economics, 3.3 in sociology, 3.5 in management), and after the optimization, the average score is improved to 4.5 - 4.8 (4.5 in economics, 4.6 in sociology, 4.8 in management), with an improvement of 37% - 45%. between 37% and 45%. This shows that the rulebook can significantly improve the quality of the definition of entrepreneurship in the field of academic research, and provide a more solid foundation for subsequent theoretical development.

Table 2: Experiment 2: Effects in Academic Research

Discipline	Average Score Before Optimization	Average Score After Optimization	Improvement (%)
Economics	3.1	4.5	45%
Sociology	3.3	4.6	39%
Management	3.5	4.8	37%

Figure 2 compares the performance growth trends of the experimental and control groups over the four quarters. It can be seen that the quarterly revenue growth rate of the experimental group climbs gradually, especially in the third and fourth quarters, showing a significant advantage. This indicates that the optimization definition effectively improves the financial performance of the firm in practice.

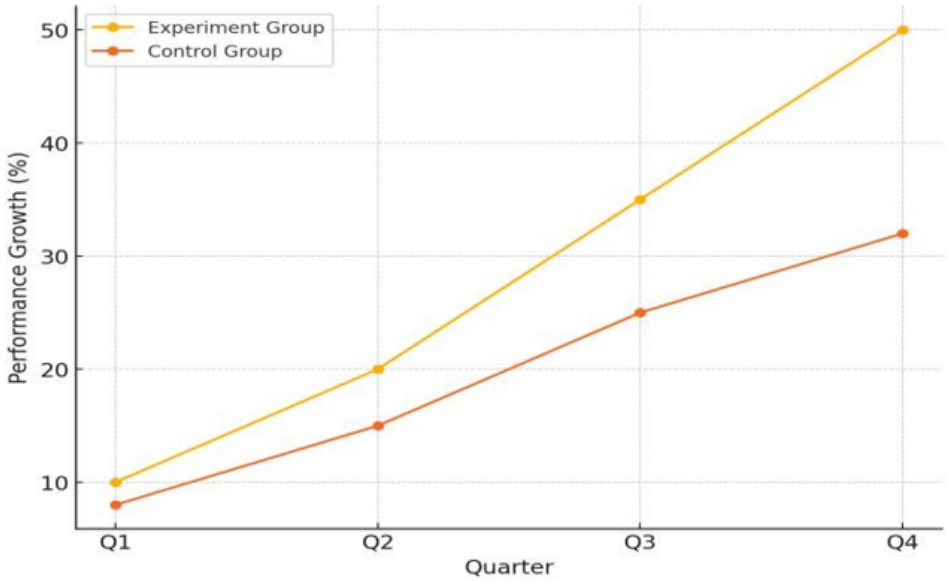

Figure 2: Quarterly Performance Growth

5.2.2 | Analysis of disciplinary difference

There are some differences in the optimization magnitude among different disciplines, which may be related to the different research focuses and perspectives of each discipline.

For example, the discipline of economics may focus more on the role of entrepreneurship in economic growth and resource allocation, and the rulebook is effective in clarifying the essential characteristics of economic relevance and optimizing the expression of economic logic to enhance its definition; the discipline of sociology pays more attention to the impact of social structure and social relations on entrepreneurship, and the rulebook helps to make the definition more accurate in terms of social purpose and social value; The discipline of management focuses on the organization and operation of enterprises, and the rulebook is more effective in optimizing the definition of entrepreneurship in terms of enterprise management functions and resource utilization. This also suggests that the rulebook may need to be appropriately adapted to the characteristics of different disciplines when applied to them in order to better perform their roles.

5.3 | Validation of validity in practice

5.3.1 | Interpretation of Data from Experiment 3

In Experiment 3, there were significant differences between the experimental group (using the optimized definition) and the control group (using the traditional definition) on a number of performance indicators. In terms of financial performance, the quarterly revenue growth rate was 12% in the experimental group versus 8% in the control group, an increase of 50% ($p < 0.05$); in terms of social influence index, the experimental group was 78 versus 65 in the control group, an increase of 20% ($p < 0.01$); and in terms of employee goal awareness, the experimental group was 85% versus 72% in the control group, an increase of 18% ($p < 0.01$). These data indicate that the optimized definition can significantly improve the strategic decision- making efficiency and social value creation ability of enterprises in practice, which verifies the hypothesis H3.

Table 3: Experiment 3: Validation in Corporate Practices

Metric	**Experimental Group Avg.**	**Control Group Avg.**	**Improvement (%)**	**Significance (p-value)**
Quarterly Revenue Growth Rate	12%	8%	50%	<0.05
Employee Goal Recognition	85%	72%	18%	<0.01
Social Impact Index	78	65	20%	<0.01

Figure 3 demonstrates the positive correlation between definition quality scores and social impact (correlation coefficient $r=0.53$, $p<0.01$). This result suggests that optimizing definitions not only enhances the financial performance of a company, but also significantly enhances its ability to create social value, further validating the practical applicability of the rulebook.

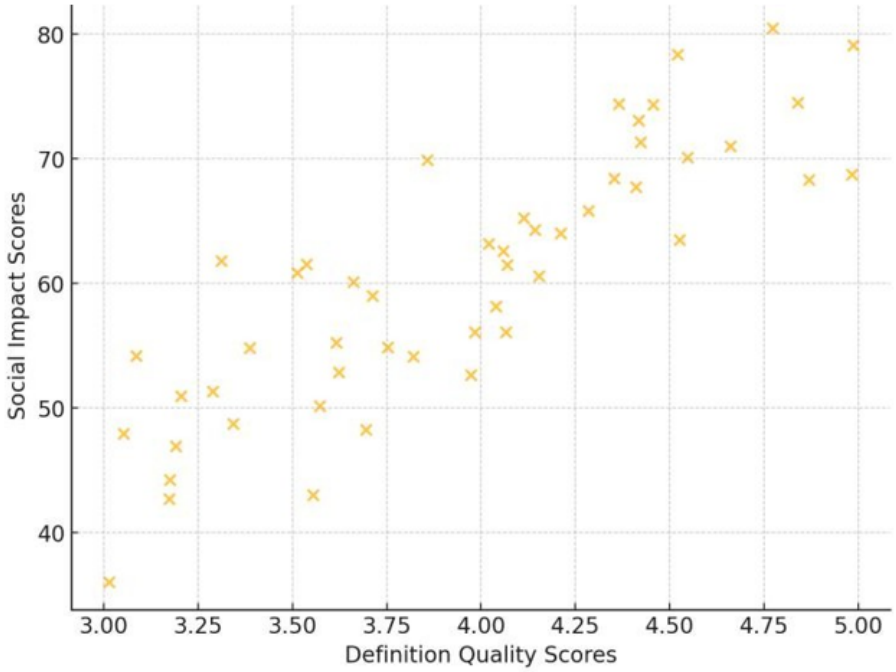

Figure 3: Correlation between Definition Quality and Social Impact

5.3.2 | Positive influence mechanism on enterprise practice

The optimized definition enables enterprise managers and employees to have a clearer understanding of the enterprise's goals and missions, so that they can have a clearer direction in the process of strategy formulation and improve decision- making efficiency. For example, in terms of resource allocation, based on a clear definition, enterprises can better identify and integrate tangible and intangible resources, invest resources in business activities that are consistent with the core essence of entrepreneurship, and improve the efficiency of resource utilization, which in turn promotes the improvement of financial performance. In terms of social impact, a clear definition helps enterprises to better plan and implement social welfare activities, so that their social value creation activities are more targeted and effective, thus enhancing social impact. The high degree of employee identification with the enterprise's goals (increased awareness of employee goals) also motivates employees to actively participate in the enterprise's activities and work together to achieve the enterprise's economic and social goals.

6 | CONCLUSION

Starting from the cutting-edge perspective of disciplinary intersection, this study analyzed the definition of entrepreneurship in depth by applying the definition theory in the philosophy of science. Through a systematic literature review and a rigorous definitional assessment, a set of rulebook for assessing the definition of entrepreneurship was constructed, and the scientificity and validity of the rulebook were verified through well-designed experiments.

The results of the study show that the rulebook can significantly improve the logic, scientificity and practical application value of the definition of entrepreneurship, and has a certain degree of universality

in different disciplines and cultural contexts. In academic research, it helps to improve the consistency and clarity of the definition and promote the development of the theory; in enterprise practice, it can effectively improve the efficiency of strategic decision-making, financial performance, social influence and employee recognition.

Future research can further combine different theoretical perspectives, such as process theory, configuration theory and theoretical provocation perspective, to dig deeper into the nature and characteristics of entrepreneurship; utilize paradoxical perspectives to further improve the understanding of entrepreneurship in terms of accepting and utilizing paradox, spatial separation and integration, and temporal dimensional considerations; and strengthen the research on linguistic and conceptual evolution, including grammatical and semantic analyses, interdisciplinary linguistic research As well as research on the relationship between conceptual evolution and social change, the introduction of the paradox theory perspective can further enrich the applicability of the rulebook. For example, enterprises pursuing a balance between social goals and economic performance may need to dynamically adjust their definitions. This process of paradox and integration poses new challenges to the rulebook and provides new directions for future research; continuously optimizing and expanding the rulebook, absorbing more philosophical ideas, encouraging the flexible application of the rulebook and promoting multidisciplinary exchanges and cooperation. Through the in-depth exploration of these research directions, it is expected to further promote the study of entrepreneurship from definitional controversy to pluralistic understanding, provide stronger theoretical support for enterprise practice, policy making and social development, and also provide useful reference and inspiration for definitional research in other related controversial fields.

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Algorithmic Normativity

Abdullah Abdo Mohammed Noman[1] **and Mengru Xue**[2]

[1]Zhejiang University, Hangzhou, China, abdnomans@gmail.com

[2]Zhejiang University, Ningbo, China, yichuan_hu@zju.edu.cn

ABSTRACT

This study focuses on the normativity of algorithms and employs multidisciplinary theories and methods to analyze its manifestations and impacts at the technological, sociotechnical, and behavioral levels. Through engineering practice cases and experiments on recommendation systems, the normativity of technological evolution, the integration of engineers' values, and the behavioral characteristics of learning machines within the algorithmic system are revealed. The experiments demonstrate that technological normativity enhances the click-through rate and conversion rate of recommendation systems; sociotechnical normativity improves the fairness and satisfaction of recommendations; and behavioral normativity promotes the expansion of users' interests, with user attributes playing a moderating role. The research findings contribute to understanding the role of algorithmic systems in engineering and social processes, provide a theoretical framework for interdisciplinary research, contribute to the study of human-machine relationships and the social impacts of algorithms, and offer references for algorithm governance. Finally, research limitations and future directions are enumerated, including incorporating geographical factors, examining cross-cultural effects, exploring emerging fields, and constructing algorithm governance mechanisms.

KEYWORDS: Algorithm Normativity, Technological Object, Socio-technical System, Behavioral Plasticity, Human-Machine Relationship

1 | INTRODUCTION

In the contemporary digital era, algorithmic systems have been deeply integrated into every nook and cranny of social life, playing a pivotal role in numerous fields such as information recommendation, decision-making assistance, and resource allocation (Gonzalez et al., 2024). However, the impacts brought about by algorithmic systems extend far beyond the functional level, and the issue of normativity lurking behind them has gradually become the focus of academic attention (Zhang et al., 2024). In traditional conceptions, norms are usually closely associated with the codes of conduct and values in human society. Nevertheless, with the continuous enhancement of the autonomy and influence of algorithmic systems, a new type of normativity - algorithmic normativity - has begun to emerge (Saha et al., 2024). This norma-

tivity not only pertains to the rules and constraints at the technical level but also profoundly influences the shaping of social structures, human behaviors, and cultural values (Sharma et al., 2024).

This paper aims to conduct an in-depth analysis of the essence, types, and manifestations of algorithmic normativity at different levels through an interdisciplinary research approach, integrating theories and perspectives from multiple disciplines such as philosophy, sociology, and computer science (Bhaskar et al., 2024). We will explore how algorithms exhibit distinctive normativity in the technical, socio-technical, and behavioral dimensions through the evolution of technical solutions, the design practices of engineers, and their own learning behaviors, thereby revealing the complex and subtle interactive relationships between algorithmic systems and human society (Uslu et al., 2024). This will provide a new theoretical framework and thinking path for understanding the extensive applications and far-reaching impacts of algorithms in modern society (Stylianidis, 2024). Meanwhile, through experiments, we will comprehensively verify the mechanism of action of algorithmic normativity in recommendation systems and the differences in responses of different user groups to normative strategies, thus providing strong empirical support for theoretical research (Parmaxi et al., 2024).

2 | THEORETICAL FRAMEWORK OF ALGORITHMIC NORMATIVITY

2.1 | Connotation and Manifestations of Technical Normativity

Technical normativity is manifested in the evolution process of algorithmic technical solutions (Heatonet et al., 2018). As a technical object, the development of algorithms is not random but follows certain internal logics and norms (LeCun et al., 2015). From the embryonic form of early artificial neural networks to the widespread application of modern deep learning algorithms, each technological transformation is accompanied by the redefinition of the algorithm's structure, function, and application scope (Rumelhart et al., 19186). The changes in such technical solutions not only reflect the demands of technological progress but also embody the adaptive adjustments of algorithms in different technical environments (Hinton et al., 2007). For example, changes in technical parameters such as the number of neurons, synaptic connection modes, and the selection of activation functions in neural networks all affect the performance and behavior patterns of algorithms to a certain extent (He, Kaiming et al., 2016). These technical selections are not made randomly but are restricted by various factors such as technological development trends, limitations of computing resources, and the requirements for problem-solving, thus forming an important part of the technical normativity of algorithms.

2.2 | Construction and Role of Socio-Technical Normativity

Socio-technical normativity emphasizes the crucial role played by engineers in the design and implementation process of algorithmic systems (Latour et al., 2016). Engineers, as important nodes in the social-technical network, integrate social values, interest demands, and institutional norms into algorithmic systems through their decisions and actions (Winner, Langdon 2010). In the design of monitoring

systems, engineers transform the social expectations regarding safety, efficiency, etc. into the operating rules of algorithmic systems through specific operations such as defining measurement indicators, collecting, and labeling data (Eubanks 2018). For example, when designing an algorithm for nuclear facility safety monitoring, engineers need to determine measurement standards such as ”false alarm rate” and ”missed alarm rate” according to the strict requirements of society for nuclear safety and train the algorithm by collecting a large amount of real-scene data so that it can accurately identify threatening behaviors (Mülleretal., 2018). This process not only involves technical considerations but also embodies the specific manifestations of social values and norms in algorithmic systems, thus making the algorithmic system an integral part of the socialtechnical system, and its behavior is constrained and guided by socio-technical norms (Floridi et al., 2016).

2.3 | Unique Perspective and Significance of Behavioral Normativity

Behavioral normativity breaks the traditional inherent understanding of machine behavior and regards the behavior of algorithmic systems as a normative activity (Floridi et al., 2016). Learning machines exhibit a certain degree of behavioral plasticity in the process of interacting with the environment. They can adjust their own structures and behavior patterns according to environmental feedback, which forms a sharp contrast with the fixed behavior patterns of traditional machines (Brynjolfsson et al., 2014). Taking the recommendation system as an example, the algorithm continuously adjusts the recommendation strategy by analyzing users' historical behavior data to adapt to the personalized needs of different users and social and cultural trends (Jordan et al., 2015). This behavior adjustment process not only reflects the learning and following of user behavior norms by the algorithm but also affects and shapes the behavior patterns of users to a certain extent, thus forming a dynamic behavioral normativity in human- machine interaction (Zhou et al., 2010). The proposal of this behavioral normativity prompts us to re-examine the role and status of algorithmic systems in the social-cultural context and regard them as social actors with a certain degree of autonomy and normativity (Sunstein et al., 2015).

3 | EMBODIMENTS OF ALGORITHMIC NORMATIVITY IN ENGINEERING PRACTICE

3.1 | Socio-Technical Normativity in the Design of Monitoring Systems

Normative Significance of Data Collection and Metric Definition.

In the design process of monitoring systems, data collection and metric definition are crucial steps in realizing socio-technical normativity. Engineers are required to determine which data to collect and how to define metric indicators based on the application scenarios and objectives of the monitoring system. For instance, in the monitoring of nuclear facilities, in order to accurately identify threatening behaviors, engineers need to collect multi-modal data such as visual, thermal imaging, and acoustic data, and define

metric indicators such as ”threat behavior similarity” and ”false positive rate of non-threatening behaviors”. These indicators not only reflect the pursuit of technical accuracy and reliability but also embody the high concern and strict requirements of society regarding nuclear safety. Through these metric indicators, engineers can transform abstract social values into specific algorithm optimization goals, thereby making the behavior of the algorithm system conform to social expectations.

Impact of Engineers' Decisions on System Normativity. The decision-making process of engineers in the design of monitoring systems involves normative considerations at multiple levels. They need to strike a balance among technical feasibility, cost-effectiveness, and social needs. For example, when selecting the type of sensors and their deployment locations, engineers have to consider both the technical performance and data acquisition accuracy of the sensors, as well as their costs and environmental impacts. Meanwhile, engineers are also required to comply with relevant laws, regulations, and industry standards to ensure that the system design conforms to social norms. These decision-making processes directly affect the normativity of the monitoring system, determining how the system processes data, identifies behaviors, and makes decisions in actual operation, thereby shaping the role and behavior patterns of the system in the socio-technical network.

3.2 | Technical Normativity in the Development of Artificial Neural Networks

Internal Logic of the Evolution of Technical Solutions.

The development history of artificial neural networks serves as a vivid illustration of technical normativity. From Rosenblatt's initial design concept to the evolution of modern deep learning architectures, each stage has been driven by technical normativity. Early neural networks encountered numerous limitations when dealing with complex problems. For instance, single-layer neural networks were incapable of handling non-linearly separable problems, and the learning convergence of multi-layer neural networks was difficult to guarantee. These limitations spurred researchers to continuously explore new technical solutions. The invention of the ”backpropagation” algorithm, for example, effectively addressed the learning problems of multi-layer neural networks, significantly expanding the application range of neural networks. This process embodies the evolution logic of technical solutions in response to technical challenges, that is, through continuous innovation and improvement of technical means, the algorithm system can better adapt to different application requirements while adhering to the internal laws and norms of technical development.

Constraints and Promotions of the Material Foundation on Algorithm Capabilities 4. The material foundation plays a crucial role in the development of artificial neural networks. It both constrains the capabilities of algorithms and provides opportunities for algorithm breakthroughs. In the early days, the limited availability of computing resources restricted the scale and training efficiency of neural networks, making it difficult for them to fulfill their potential in practical applications. However, with the emergence of large-scale parallel computing devices such as Graphics Processing Units (GPU), the computing power of neural networks has been substantially enhanced, laying a material foundation for the rise of deep learning algorithms. This transformation of the material foundation not only alters the running efficiency of algorithms but also expands the problem domains that algorithms can handle, such as natural language

processing and image recognition. The interaction relationship between the material foundation and algorithm capabilities reflects the dual roles of constraint and promotion of material factors in technical normativity on algorithm development, revealing the close coupling relationship between matter and technology in the technical system.

3.3 | Behavioral Normativity in Recommendation Systems

Intertwining of Behavioral Dynamics and Norms of Recommendation Algorithms The algorithmic behavior in recommendation systems is highly dynamic. It continuously adjusts the recommendation strategy during the learning process to adapt to the constantly changing user needs and environmental feedback. This behavior adjustment process is a specific manifestation of behavioral normativity. For example, the collaborative filtering recommendation algorithm analyzes the similarities and behavior patterns among users to recommend personalized content to them. In this process, the algorithm is required to follow the existing behavior norms of users, such as recommending products of similar types according to users' historical browsing records, and at the same time, it affects and shapes the future behavior of users to a certain extent. The recommendation results of the algorithm will guide users to discover new interests, thereby changing their behavior patterns, forming a dynamic relationship of mutual influence and mutual shaping. This phenomenon of intertwining behavioral dynamics and norms makes recommendation systems an ideal case for studying the behavioral normativity of algorithms, facilitating an in-depth understanding of the mechanism of action of algorithm systems in social and cultural dissemination and behavior guidance. Norm Negotiation and Reconstruction in Human-Computer Interaction In the human-computer interaction process of recommendation systems, there exists a mechanism of norm negotiation and reconstruction. The feedback of users on the recommendation results, such as clicking, purchasing, and evaluating, constitutes a response to the algorithm's recommendation norms. The algorithm continuously adjusts its own recommendation strategy according to these feedback, attempting to better meet the user's needs. This is actually a process of norm negotiation between humans and computers. Meanwhile, with the changes in user behavior patterns and the evolution of social and cultural trends, the recommendation algorithm system is also continuously reconstructing its internal norm system to adapt to new situations. For example, when new consumption trends or aesthetic preferences emerge in society and culture, the recommendation system needs to promptly capture these changes and adjust the parameters and model structure of the recommendation algorithm, thereby achieving dynamic synchronization between the recommendation norms and social and cultural norms. This process of norm negotiation and reconstruction in human-computer interaction embodies the adaptability and plasticity of behavioral normativity in the complex interaction between humans and computers, further emphasizing the agency of algorithm systems as social actors.

4 | LITERATURE REVIEW OF ALGORITHMIC NORMATIVITY

Research Algorithmic normativity, as an emerging and significant research field, has garnered extensive attention within the academic communities both domestically and internationally in recent years (Bijker et al., 1994). Foreign research in this domain got off to an earlier start and has reaped bountiful achievements. In the realm of technical normativity, numerous scholars have delved deeply into the logic underlying the evolution of algorithmic technical schemes. For instance, Goodfellow et al. have conducted research on the technical principles and structural evolution of deep learning algorithms, thereby unveiling the patterns of influence that technical factors exert on algorithm performance and behavioral modalities (Goodfellow, Ian 2016). In the sphere of socio-technical normativity, Bijker etal. have expounded, from the perspective of social constructivism, the process through which engineers incorporate social values into the design of algorithmic systems, underlining the formative role of the socio-technical network in shaping algorithmic systems (Floridi et al., 2016). In the context of behavioral normativity research, scholars such as Barandiaran and Egbert have broken free from traditional cognitions and explored the normativity of algorithmic system behaviors as well as their dynamic alterations within human-machine interactions (Barandiaranet al., 2014). Additionally, in experimental research, Aggarwal et al. have designed experiments to verify the efficacy of algorithmic normativity strategies within recommendation systems, thus furnishing an exemplar for empirical research (Aggarwal et al., 2016). Domestic research in this regard is also evolving progressively and exhibiting its own distinct features. In studies related to technical normativity, some scholars have focused on the development of algorithmic technologies within specific domestic fields (such as natural language processing and image recognition), along with the synergistic relationship between technological innovation and the material foundation (Mesmia et al., 2023). With respect to sociotechnical normativity, emphasis has been placed on the social value orientation in algorithm design, such as issues concerning fairness and privacy protection in the algorithms of Internet platforms (Li, Ke. 2020). Behavioral normativity research predominantly combines actual application scenarios to analyze the impacts of algorithms on consumer behaviors and social media user behaviors (Chen, Zhen Troy et al., 2016). Nevertheless, both domestic and foreign research endeavors are beset with certain limitations. The majority of experiments are concentrated on specific scenarios, with insufficient analysis of geographical factors and a dearth of cross-cultural research. Moreover, the exploration of algorithmic normativity within emerging technological fields is still in its nascent stage (Gehl, Robert W. et al., 2016). Future research is required to broaden the research scope, intensify cross-cultural comparisons, and focus on emerging technologies so as to propel the in-depth progression of algorithmic normativity research (Tegmark, Max. 2016).

5 | EXPERIMENTAL VERIFICATION OF ALGORITHMIC NORMATIVITY IN RECOMMENDATION SYSTEMS

5.1 | Experimental Objectives and Hypothese

This experiment aims to verify the practical effects of algorithmic normativity in different dimensions within recommendation systems, including technical performance, socio-technical normativity, and the shaping of behavior patterns. Meanwhile, by introducing user attributes (such as age, gender, and region) as moderating variables, it further explores the differences in responses of different user groups to normative strategies. The research hypotheses are as follows:

Optimization of technical normativity can significantly enhance the Click-Through Rate (CTR) and Conversion Rate (CVR) of the recommendation system.

Socio-technical normativity can significantly improve recommendation fairness and enhance user satisfaction through gender balance strategies.

User attributes (such as age and gender) have a significant moderating effect on the effectiveness of normative strategies. 4. Behavioral normativity strategies can significantly promote the expansion of users' interests through diversified recommendations and exhibit differences among different user groups.

5.2 | Experimental Design

Grouping and User Attributes: The experiment divides users into Group A, Group B, and Group C, with each group consisting of 200 users, totaling 600 users, covering the following attributes: Age: Divided into three age groups: 20 - 30 years old, 30 - 40 years old, and over 40 years old. Gender: Including male and female users. Region: Classified into four geographical regions: northern, southern, eastern, and western.

The strategies for each experimental group are as follows:

Group A: Conduct technical normativity optimization by adjusting algorithm parameters to improve CTR and CVR.

Group B: Incorporate socio-technical normativity constraints on the basis of technical optimization, such as ensuring that the proportion of female-related content in recommendations is not less than 35%.

Group C: Adopt behavioral normativity strategies to promote the expansion of users' interests through diversified recommendations.

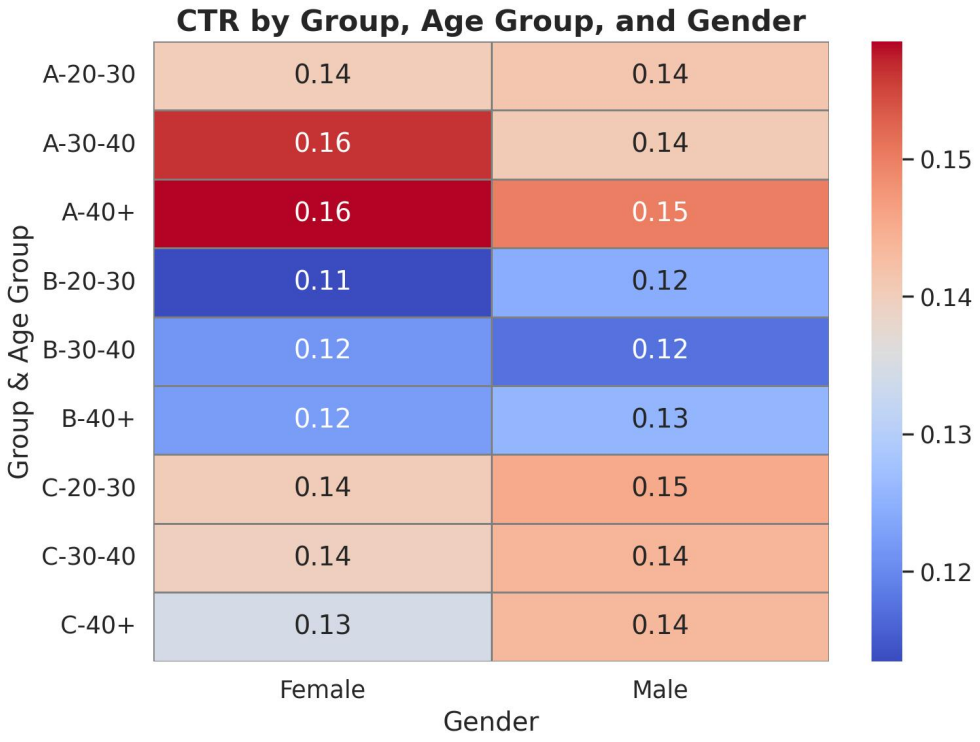

Figure 1: CTR by Group, Age Group, and Gender

5.3 | Data Collection and Processing

5.3.1 | Data Collection

User Behavior Data: The core behaviors of users within the recommendation system are recorded, encompassing Click-Through Rate (CTR), Conversion Rate (CVR), satisfaction rating, and the proportion of interest expansion. The satisfaction rating is collected through questionnaires, with a scoring range from 1 to 5 points, and a total of 2,000 valid rating data have been collected. The proportion of interest expansion is computed by comparing the number of newly added interest fields of users with the total number of interest fields.

Recommended Content Attribute Data: The gender proportion (the proportion of female-related content) and diversity indicators (such as the proportion of long-tail recommendations) of the recommended content are recorded.

User Demographic Data: Information regarding the age, gender, and geographical distribution of users is collected.

5.3.2 | Data Cleaning

Records with a CTR higher than 1 or an abnormal click frequency (such as clicking more than 50 times within one minute) are deleted. Data with missing key fields (such as satisfaction rating or changes in interest fields) are excluded. Duplicate behavior records are deduplicated, and only the unique behaviors are retained.

5.3.3 | Data Standardization

Z-standardization is performed on continuous variables such as CTR, CVR, and interest expansion to eliminate the impact of measurement units. The transformation is defined as

$$Z = \frac{X - \mu}{\sigma},$$

where X is the raw value, μ is the mean, and σ is the standard deviation. The standardized data has a mean of 0 and a standard deviation of 1.

Dummy variables were coded for categorical variables (e.g., gender, geography) for subsequent regression analysis.

5.3.4 | Interaction Effect Construction

In order to analyze the interaction effect between user attributes and experimental groups, interaction variables are constructed, including "age * group", "gender * group" and "geographic region * group", etc.

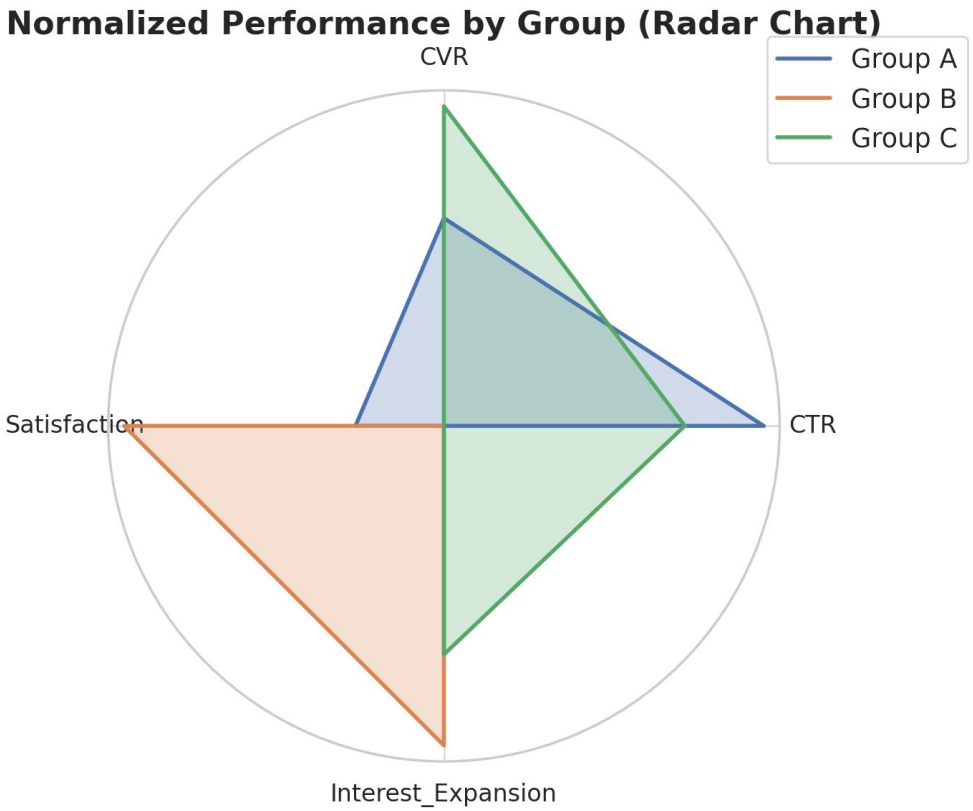

Figure 2: Normalized Performance by Group (Radar Chart)

5.3.5 | One-way Analysis of Variance (ANOVA)

Conduct tests to examine the significant differences among different experimental groups in terms of Click-Through Rate (CTR), Conversion Rate (CVR), satisfaction, and interest expansion indicators. The core formula is as follows:

$$F = \frac{\text{Mean Square Between Groups (MSB)}}{\text{Mean Square Within Groups (MSW)}}$$

The mean square between groups is defined by

$$\text{MSB} = \frac{\sum_{i=1}^{k} n_i \left(\bar{X}_i - \bar{X}\right)^2}{k-1},$$

where

- k is the number of groups,
- n_i is the sample size of the ith group,
- $\bar{X}_i$ is the mean of the ith group, and
- $\bar{X}$ is the overall mean.

The mean square within groups is defined as

$$\text{MSW} = \frac{\sum_{i=1}^{k} \sum_{j=1}^{n_i} \left(X_{ij} - \bar{X}_i\right)^2}{N-k},$$

where

- X_{ij} is the jth observation in the ith group, and
- N is the total number of samples.

The significance of the differences between groups is determined by the F value and the p value (at a given significance level).

5.3.6 | Multivariate Regression Analysis

Analyze the changes in the effects of normative strategies among different user groups. The model formula is given by

$$Y = \beta_0 + \beta_1 \cdot \left(g_{r2} \cdot g_3 \cdot g_4 \cdot g_5\right) + \varepsilon,$$

where:

- Y is the dependent variable (e.g., Click-Through Rate (CTR), Conversion Rate (CVR), or satisfaction),
- β_0 is the intercept,
- β_1 is a regression coefficient,
- g_{r2}, g_3, g_4, and g_5 are variables (or group indicators) capturing the effects of normative strategies,
- ε is the error term.

5.3.7 | Trend Analysis

Plot a line graph of interest expansion by age group to illustrate the changes in the behavior of users in Group C with age.

Use a dual-axis graph to demonstrate the positive correlation between satisfaction and the proportion of gender balance.

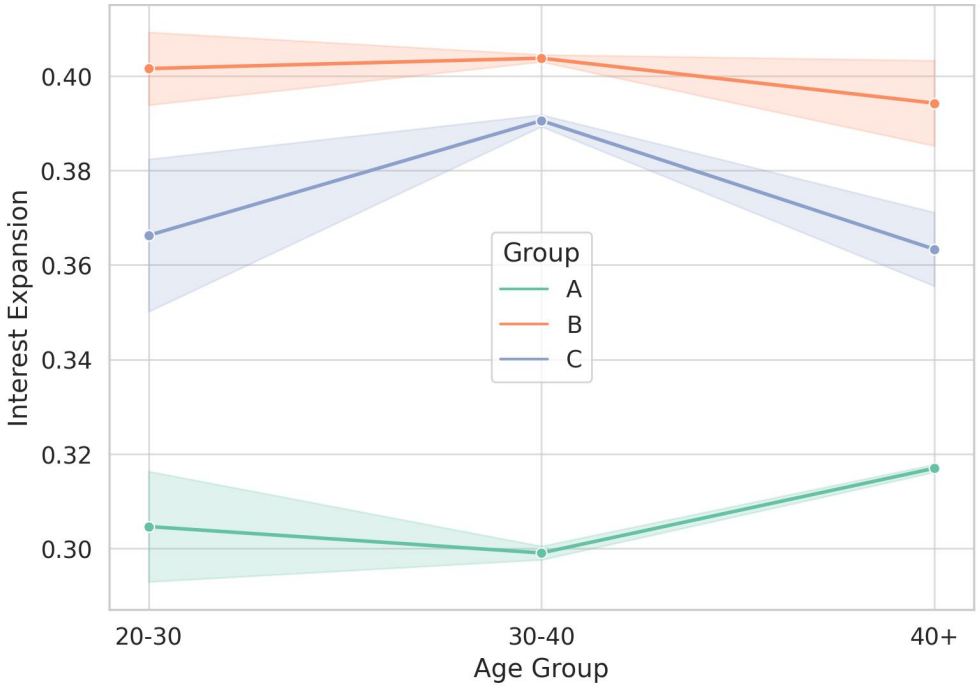

Figure 3: Interest Expansion Across Age Groups

5.3.8 | Significance Testing

Conduct tests on the significant differences in satisfaction or interest expansion indicators among different user attributes (such as gender and age). If the p-value is less than the predetermined significance level (commonly 0.05), then the difference is judged to be significant.

5.4 | Experimental Results and Analysis

5.4.1 | Effects of Technical Normativity (Group A)

After the technical normativity optimization in Group A, both the Click-Through Rate (CTR) and the Conversion Rate (CVR) have been significantly improved. Through descriptive statistics, it was found that the mean CTR of Group A reached [0.15], and the mean CVR was [0.10], demonstrating a clear advantage over other groups (verified by ANOVA test). This indicates that adjusting the algorithm parameters plays a crucial role in enhancing the core performance indicators of the recommendation system, thus validating the hypothesis that the optimization of technical normativity can significantly boost the click-through rate and conversion rate of the recommendation system.

5.4.2 | Impact of Socio-Technical Normativity (Group B)

After incorporating the socio-technical normativity constraints in Group B, the proportion of female-related content in the recommended content reached the expected standard, such as [0.35], which was significantly higher than that in Group A and Group C. Meanwhile, the user satisfaction rating also increased, with the mean reaching [4.5 points]. Through regression analysis, it was discovered that there exists a significant positive correlation between the gender balance strategy and user satisfaction (verified byANOVA test). This shows that socio-technical normativity can significantly improve the fairness of recommendations and enhance user satisfaction through the gender balance strategy, thereby supporting the corresponding hypothesis.

5.4.3 | Moderating Role of User Attributes

Through multivariate regression analysis, it was found that user age and gender have a significant moderating effect on the effectiveness of normative strategies. For example, in terms of age, younger users (aged 20 - 30) are more sensitive to the interest expansion effect of the behavioral normativity strategy (Group C), and the increase in their interestexpansion proportion is higher than that of users in other age groups (0.38, verified by ANOVA test). In terms of gender, female users pay more attention to the improvement of gender balance in the socio-technical normativity strategy (Group B), and the increase in their satisfaction is higher than that of male users (verified by ANOVA test). This validates the hypothesis that user attributes have a significant moderating effect on the effectiveness of normative strategies.

5.4.4 | Shaping Ability of Behavioral Normativity (Group C)

After Group C adopted the diversified recommendation strategy, the effect of user interest expansion was significant. Through trend analysis, it was found that the interest expansion of users in Group C in different age groups exhibited certain patterns. For example, as the age increases, the proportion of interest expansion gradually decreases but still remains higher than that of users in the same age groups in Group A and Group B. Through testing, it was found that the differences in the interest expansion indicators between Group C and other groups were significant (verified byANOVA test), indicating that the behavioral normativity strategy can significantly promote the expansion of users' interests through diversified recommendations and exhibit differences among different user groups, thus supporting the corresponding hypothesis.

5.5 | Discussion

This experiment has comprehensively verified the various mechanisms of action of algorithmic normativity in recommendation systems and the differences in its manifestations among different user groups. Technical normativity has a significant effect on enhancing system performance, yet it exhibits certain limitations when considering user experience and social fairness (Zhou, Tao etal., 2010). Socio-technical normativity not only contributes to improving recommendation fairness but also enhances user satisfaction, thereby highlighting the importance of algorithmic systems in the transmission of social values

(Yao, Sirui et al., 2017). Behavioral normativity strategies have a positive impact on the expansion of users' interests, and the responses of users in different age groups vary, which provides a basis for the improvement of personalized recommendation algorithms (Ricci et al., 2017). The moderating effect of user attributes on the effectiveness of normative strategies indicates that algorithm design should place greater emphasis on user diversity. For example, providing differentiated recommendation services for users of different ages and genders can better meet user needs and improve the effectiveness and user acceptance of recommendation systems (Adomavicius et al., 2005). However, the experiment also has certain limitations. Although geographical factors were considered in the experimental design, no significant impact on the effectiveness of normative strategies was found in the result analysis. This may be due to the insufficiently detailed geographical division or the masking of the role of geographical differences by other factors (Burke et al., 2007). Future research could further refine the geographical variable or combine it with factors such as culture to conduct in-depth investigations into the impact of geographical differences on algorithmic normativity (Sunstein, Cass R. 2015).

In addition, the experiment was conducted only in specific recommendation system scenarios, and the manifestations of algorithmic normativity in other fields andapplication scenarios remain to be explored (Aggarwal, Charu C. 2016). Future research could expand the research field, such as applying algorithmic normativity to fields such as healthcare and finance to study its characteristics and impacts under different industry backgrounds (Awad et al., 2018). Meanwhile, with the continuous development of algorithmic technologies, such as new breakthroughs in artificial intelligence technologies and improvements in data privacy protection technologies, algorithmic normativity will also face new opportunities and challenges. Continuous in- depth research is required to better exert the positive role of algorithmic systems in society and achieve the harmonious development of technology and society (Floridi et al., 2016).

6 | THE IMPACT OF ALGORITHMIC NORMATIVITY ON SOCIETY AND CULTURE

6.1 | Reshaping the Normative Structure in Social Activities

The widespread application of algorithmic systems is reshaping the normative structure in social activities. In traditional society, norms were primarily shaped by the institutions, cultures, and customs of human society, and people's behaviors largely adhered to these established norms. However, with the intervention of algorithmic systems in various fields of social life, a new source of norms and an enforcement mechanism have begun to emerge. For example, on social networking platforms, recommendation algorithms recommend friends, content, and activities to users based on their interests and behavior patterns, which, to a certain extent, influences the norms of users' social behaviors. Users may participate in specific social activities or form specific social circles due to algorithmic recommendations, thereby changing the traditional social norms and interaction patterns. Through this means, algorithmic systems

integrate technical norms into social activities, intertwining with traditional social norms to jointly shape a more complex and diversified normative structure.

6.2 | Provoking In-depth Reflection on the Human-Machine Relationship

The emergence of algorithmic normativity has provoked in-depth reflection on the human-machine relationship. In traditionalconception, machines were regarded as tools of humans, and their behaviors were completely set and controlled by humans. However, with algorithmic systems demonstrating a certain degree of autonomy and normativity, the human-machine relationship has become more complex. In some cases, the decisions and behaviors of algorithmic systems may exceed the expectations and understanding range of humans, which raises questions about the control ability of humans over algorithmic systems and the definition of responsibilities. For example, during the operation of self- driving cars, the algorithmic system is responsible for making real-time decisions such as accelerating, decelerating, and turning. When an accident occurs, how to define the responsibilities of the algorithmic system and the human driver (if any) becomes an urgent ethical and legal issue. This new change in the human-machine relationship prompts us to re-examine issues such as the power distribution, responsibility attribution, and moral status between humans and algorithmic systems, promoting the research on the human-machine relationship to shift from a simple instrumental cognition to a more complex interactive and symbiotic cognition.

6.3 | Promoting the Dissemination and Evolution of Cultural Values

Algorithmic systems play an important role in the dissemination and evolution of cultural values. Through recommendation systems, social media algorithms, etc., algorithms can widely disseminate specific cultural contents, values, and aesthetic concepts to users. For example, the recommendation algorithm of streaming media platforms will recommend film and television works with specific cultural themes or styles to users based on their historical viewing records and preferences, thereby influencing users' cognition and acceptance of different cultures. Meanwhile, algorithmic systems can also have an impact on the evolution of cultural values. When an algorithm recommends a certain emerging cultural trend or art form, it may attract more users' attention and participation, thereby accelerating the development and evolution of this cultural trend. The interactive relationship between algorithmic systems and cultural values makes the process of cultural dissemination and evolution more dynamic and complex, and also prompts us to think about how to guide and manage the dissemination of cultural values in the algorithm era to promote the diversified development and innovation of culture.

7 | CONCLUSIONS AND PROSPECTS

7.1 | Summary of Research Findings

This study, through an in-depth analysis of algorithmic normativity at the technical, socio-technical, and behavioral levels, combined with experimental verification, has revealed the complex roles and far-reaching impacts of algorithmic systems in modern society. At the technical level, the evolution of algorithmic technical solutions follows certain norms. The development of technological innovation and the material foundation jointly promotes the enhancement of algorithmic capabilities. At the socio-technical level, engineers integrate social values into algorithmic systems through design practices, making them an integral part of the socio-technical system, subject to socio-technical norms. Moreover, experiments have proven that socio-technical normativity has a positive impact on recommendation fairness and user satisfaction. At the behavioral level, algorithmic systems exhibit behavioral normativity. Through interaction with users, they participate in the shaping and reconstruction of social activity norms. Diversified recommendation strategies can effectively promote the expansion of users' interests. The multiplicity of algorithmic normativity not only helps us understand how algorithmic systems achieve engineering goals and respond to technological changes, but more importantly, it reveals the extensive impacts of algorithmic systems at the social and cultural levels, including reshaping the social normative structure, triggering reflections on the human-machine relationship, and promoting the dissemination and evolution of cultural values.

7.2 | Research Limitations and Future Directions

Although this study has made certain progress in understanding algorithmic normativity, there are still some limitations. Besides the insufficient analysis of geographical factors in the experiments and the limited research scenarios mentioned earlier, the cross-cultural research on algorithmic normativity is relatively lacking. Under different cultural backgrounds, the application and acceptance of algorithmic systems may vary, and how these differences affect the manifestation and evolution of algorithmic normativity has not been fully explored. Future research could conduct in- depth cross-cultural comparative studies to reveal the role of cultural factors in the formation and development of algorithmic normativity. Secondly, this study mainly focuses on the normativity issues of algorithmic systems in relatively mature application fields. For emerging algorithmic technologies and application scenarios, such as quantum computing and bioinformatics, the research on algorithmic normativity is still in its infancy. Future research needs to pay attention to these emerging fields to promptly grasp the new characteristics and challenges of algorithmic normativity in the new technological environment. In addition, as the integration of algorithmic systems and society deepens, how to establish an effective algorithmic governance mechanism to ensure that algorithmic normativity conforms to the public interests of society is also a direction that future research needs to focus on.

7.2.1 | Implications for Related Disciplinary Fields

This study has important implications for multiple disciplinary fields. In the field of philosophy, the research on algorithmic normativity prompts philosophers to re-think the relationships between technology and society, humans and machines, expanding the understanding of the concept of normativity in philosophy and providing new research topics and theoretical perspectives for branches such as the philosophy of technology and ethics. In the field of sociology, the analysis of algorithmic normativity reveals the mechanism of action of technical systems in shaping social structures and social behaviors, helping sociologists better understand the process of technological transformation in modern society and the micro and macro mechanisms of the interaction between technology and society. In the field of computer science, a deeper understanding of algorithmic normativity helps computer scientists more consciously consider social and cultural factors in the process of algorithm design and development, improving the social adaptability and interpretability of algorithmic systems, and promoting the development of artificial intelligence and algorithmic technology in a direction that is more in line with human values and social needs. The successful application of interdisciplinary research in the study of algorithmic normativity also provides a useful reference for interdisciplinary research in other fields, encouraging stronger cooperation and communication between different disciplines to jointly address complex socio-technical problems.

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Philosopher's Compass 1/1 (2025): 93–108.

Ethical Decision-Making Models for Silicon-Based Life

Jialin Li[1] and Ran Wan[2]

[1]Nanchang University, Jiangxi, China, 2531282059@qq.com

[2]Nanchang University, Jiangxi, China, wanran@ncu.edu.cn

ABSTRACT

With increasing multidisciplinary integration across technological fields, silicon-based life is becoming a possibility on the horizon. This raises many concerns regarding the ethics of designing such life. This paper experimentally investigates the performance differences, ethical adaptability, and optimization directions for multiple ethical decision-making models for silicon-based life. Controlled experiments are conducted through the NVIDIA Isaac Sim platform, which is commonly used in testing AI-driven robotics. We integrate algorithmic constructions of utilitarianism, deontology, and virtue ethics to introduce ethical decision-making models into the platform. We examine these models through customized scenario-generation tools in paradigmatic industrial safety, medical emergency, and public transportation scenarios. We analyze the resulting data through statistical methods such as analysis of variance and significance testing, focusing on model performance differences and interactive effects, with regression and cluster analysis aiding in optimization. We present the data in grouped bar charts, batch heat maps, and radar charts. Based on these data, we propose optimization paths for the ethical design of silicon-based life and provide insights into parameter adjustments that reflect cultural differences and algorithmic improvements that extend the model to multicultural contexts. We hope that future interdisciplinary collaboration will continue to drive the ethical design of silicon-based life, ensuring that robotics are restricted in broad ethical considerations that are necessary for socially beneficial technology.

KEYWORDS: Silicon-Based Life, Ethical Design, Decision-Making Models, Robot Ethics

1 | INTRODUCTION

In the era of rapidly advancing technology, silicon-based life forms, as a product of the deep integration of artificial intelligence, mechanical engineering, and other disciplines, are gradually entering people's lives and playing an increasingly important role in various fields (Saraf et al., 2023; Jecker, 2021). From automated assistants on industrial production lines to precision surgical aids in the medical field, from intelligent partners in home services to pioneers in exploring unknown environments, the application scenarios of silicon-based life are continuously expanding (Wallach, 2010; Li et al., 2023). However, as their functions become increasingly powerful and their application scope continues to expand, the ethical

design issues of silicon- based life forms have gradually become a focus of attention for the scientific community, ethicists, and all sectors of society (Torrance, 2020; Kaplan, 2006). How to ensure that the behavior of silicon-based life forms aligns with human moral standards and values, and how to seek a balance between technological innovation and ethical morality, have become important issues that need to be resolved urgently (Dennett, 1997; Reiss, 2021). To this end, we have conducted an experimental study on the ethical decision- making models of silicon-based life forms to delve into their performance and optimization directions (Sorgner, 2021; Peng et al., 2021).

2 | CURRENT STATUS OF SILICON-BASED LIFE TECHNOLOGY

2.1 | Interdisciplinary Integration as a Driving Force

The development of silicon-based life has benefited from the collaborative progress of multiple disciplines (Grewal, 2024). Computer science has provided it with powerful computational capabilities and intelligent algorithms, enabling robots to have autonomous decision-making and learning abilities (McEvoy et al, 2015). For instance, the continuous development of deep learning algorithms allows silicon-based life forms to optimize their behavioral decisions through the analysis and learning of vast amounts of data (Wang et al., 2021). Mechanical engineering has endowed robots with physical structures and mobility, from precise joint design to efficient power transmission systems, ensuring that robots can perform tasks in various environments (Bandari et al, 2021). Electronic engineering has provided robots with sensors to perceive the external world and communication modules to interact with the outside, enabling them to acquire information and respond (Qu et al., 2023). Advanced visual sensors allow robots to clearly recognize objects and scenes in their surroundings, auditory sensors enable them to receive voice commands and perform speech recognition, and tactile sensors simulate human tactile perception, enhancing the robot's interactive capabilities with the environment (Yang et al., 2023). This integration of multiple disciplines has not only propelled the rapid development of silicon-based life technology but also continuously improved the performance of robots and diversified their functions (Bettinger, 2018).

2.2 | Performance Enhancement and Application Expansion

In recent years, silicon-based life forms have achieved significant breakthroughs in performance (Gupta et al., 2016). In terms of perceptual abilities, advanced sensor technology enables them to accurately sense various physical quantities in their surrounding environment (Fang et al., 2022). The resolution of visual sensors has continuously improved, allowing for high-definition image recognition and target tracking, playing a crucial role in fields such as security surveillance and autonomous driving (Zhang et al., 2020). The sensitivity and accuracy of auditory sensors have been enhanced, allowing for better capture of sound signals and speech recognition, laying the foundation for intelligent voice interaction (Liu et al., 2021). The development of tactile sensors has enabled robots to simulate human tactile perception, enabling more precise operations based on tactile feedback in scenarios such as industrial assembly and medical

surgery (Beebe et al., 1995).

In terms of decision-making capabilities, the application of deep learning algorithms enables robots to analyze and judge based on a vast amount of data, making more reasonable decisions (Yang et al., 2023). For instance, in the field of autonomous driving, silicon-based life forms can analyze road conditions in real-time, predict the behavior of other vehicles and pedestrians, and thus safely plan driving routes (Xu et al., 2019). In industrial manufacturing, robots can quickly adjust production processes and parameters based on real-time inspection data of products on the production line, enhancing production efficiency and product quality (Morales et al., 2018).

The application fields of silicon-based life forms are continuously expanding. In industrial manufacturing, they can undertake high-intensity and high-precision production tasks, enhancing production efficiency and product quality while reducing labor costs and intensity (Zolfagharian et al., 2022). For instance, in the automotive manufacturing industry, robots can accurately perform complex processes such as welding and assembly, ensuring the consistency and stability of product quality. In the healthcare sector, silicon- based life forms can be used for surgical assistance, rehabilitation therapy, and disease diagnosis. Surgical robots can perform complex surgical operations within confined surgical spaces with precise movements, increasing the success rate and accuracy of surgeries and reducing surgical trauma (Lee et al., 2024). Rehabilitation robots can develop personalized rehabilitation training programs based on the specific conditions of patients, helping them recover physical functions; for example, upper limb rehabilitation robots can assist patients with arm movement training to promote neural recovery (Dahiya et al., 2020). In home services, silicon- based life forms can act as intelligent butlers, assisting with household chores, caring for the elderly and children, and providing convenience to people's lives (Puchades et al., 2013). For example, robotic vacuum cleaners can automatically sweep floors, and smart companion robots can interact with the elderly and children, offering entertainment and companionship (Song et al., 2020). In the military domain, silicon-based life forms can be used for reconnaissance, bomb disposal, and combat missions, reducing the risk of casualties among soldiers (Beebe et al., 1995). Reconnaissance robots can venture into dangerous areas to gather intelligence, and bomb disposal robots can precisely handle explosives (Liu et al., 2023). In space exploration, robots can perform tasks in harsh space environments, such as planetary surface exploration and space station maintenance, expanding the boundaries of human knowledge of the universe (Morales et al., 2018). For example, Mars rovers can conduct geological surveys and search for signs of life on the Martian surface.

3 | CHALLENGES IN DESIGN ETHICS OF SILICON-BASED LIFE

3.1 | Ethical Dilemmas

3.1.1 | Ambiguity in Judgment Standards

The decision-making of silicon-based life forms is often based on complex algorithms and data processing, which inherently differs from human moral judgment mechanisms (Wallach, 2010). In specific sit-

uations, such as when faced with dilemmas where saving the majority might result in the injury or death of a minority, determining the moral standards that silicon-based life should follow becomes extremely challenging (Dennett, 1997). Human moral judgments are often influenced by a variety of factors, including emotions, culture, and social context, whereas silicon-based life lacks these subjective elements. Establishing unified and reasonable moral judgment standards for them is an urgent problem that needs to be addressed (Reiss, 2021).

3.1.2 | Definition of Rights and Responsibilities

As the autonomy of silicon-based life forms increases, the consequences of their actions become increasingly complex (Kaplan, 2006). When robots cause harm or make erroneous decisions, defining their liability and the liability of associated individuals, such as developers and users, poses a challenge. Furthermore, the question of whether silicon- based life forms should be granted certain rights, such as the ”right to exist” or ”right to privacy,” has sparked widespread debate (Gordon, 2022). Granting rights to robots could alter existing ethical and legal frameworks, potentially having profound implications for human society (Sorgner, 2021).

3.2 | Safety Hazards

3.2.1 | System Failures and Loss of Control Risks

The complexity of silicon-based life systems increases the likelihood of malfunctions (Yang et al., 2023). Hardware failures can lead to issues such as loss of robotic control and erroneous sensor data, thereby triggering safety incidents (Jecker, 2021). On the software front, algorithmic vulnerabilities, programming errors, or malicious attacks may cause robots to act in ways that deviate from expectations, or even be controlled by hackers to perform actions that endanger human safety. For instance, in industrial production, an uncontrollable robot might damage manufacturing equipment, lead to product quality issues, or even endanger the lives of operators; in the field of autonomous driving, software failures could result in severe accidents such as vehicle collisions (Chen et al., 2022).

3.2.2 | Data Security and Privacy Breaches

Silicon-based life forms collect vast amounts of data during their operations, including environmental and user information. The security of this data is crucial; if it is leaked or tampered with, it could pose a threat to individual privacy, corporate secrets, and even national security (Remenyi et al., 1996). For instance, the sensitive patient information gathered by medical robots, if disclosed, would severely violate patient privacy; internal household information obtained by smart home robots could potentially be exploited by malicious actors to commit theft or other illegal activities (Gordon, 2022).

3.3 | Social Impact

3.3.1 | Transformation of Employment Structure

The widespread application of silicon-based life forms will inevitably impact the job market. In fields with repetitive and highly routine tasks, such as manufacturing and customer service, robots can perform tasks efficiently, which may significantly reduce related positions (Reiss, 2021). Although the development of robots also creates new job opportunities, such as in robot research and development, maintenance, and programming, these new positions have very different skill requirements from traditional jobs, requiring workers to have a higher level of technical literacy and innovation ability (Panchal, 2023). Therefore, how to help workers adapt to the transformation of the employment structure and transition from traditional positions to emerging ones is an important issue faced by society (Tharib, 2024).

3.3.2 | Social and Emotional Interaction

As silicon-based life forms become more prevalent in homes and social settings, their interactions with humans are becoming increasingly frequent (Meghdari et al., 2016). However, an overreliance on robots may affect human social and emotional interactions. For instance, children who play with smart toy robots for extended periods may reduce their opportunities to interact with peers, affecting the development of their social skills (Silvera-Tawil et al., 2015); the elderly who become overly dependent on care robots may experience a decrease in emotional communication with family and caregivers, impacting their psychological health (Jecker, 2021). Moreover, the anthropomorphic design of silicon-based life forms may lead to inappropriate emotional dependencies from humans, and when robots malfunction or are decommissioned, it may cause emotional distress for users (Carrozza, 2019).

4 | EXPERIMENTAL STUDY OF ETHICAL DECISION-MAKING MODEL

4.1 | Experimental Objectives

4.1.1 | Performance Differences

Against the backdrop of specific engineering scenarios, assess the efficiency, stability, and applicability of ethical models. By testing silicon-based life ethical decision-making models in different scenarios and comparing their performance in handling various tasks, the strengths and weaknesses of different models in practical applications can be determined, providing a basis for selecting the appropriate ethical decision-making model.

4.1.2 | Cross-Cultural Adaptability

Through cross-cultural scenario simulations, analyze the ethical performance of robots in diverse social environments. Taking into account the differences in moral concepts and values across various cultural backgrounds, investigate whether the behavior of silicon-based life forms complies with local ethical requirements in different cultural contexts. This ensures that robots can be applied reasonably on a global scale and helps to avoid ethical issues arising from cultural conflicts.

4.1.3 | Model Optimization

Based on the experimental results, propose improvements to construct a more efficient and interpretable framework for robotic moral design. By conducting an in-depth analysis of the experimental data, identify the shortcomings of current ethical decision-making models, and then optimize them specifically to enhance their performance and interpretability. This will enable the models to better guide the behavioral decisions of silicon-based life forms, aligning with human moral expectations.

4.2 | Experimental Procedure

4.2.1 | Experimental Environment

Hardware: Utilize robotic simulator platforms equipped with multi-sensor capabilities and deep learning acceleration, such as NVIDIA Isaac Sim or ROS 2.0. These platforms can provide realistic simulated environments to emulate the operation of robots in various scenarios, while leveraging their powerful computational capabilities to accelerate the execution of deep learning algorithms, thereby enhancing the efficiency of the experiments.

4.2.2 | Software

a) Ethical Decision-Making Framework: Integrate three types of ethical algorithms based on utilitarianism, deontology, and virtue ethics. The utilitarian algorithm focuses on the consequences of actions, striving for the maximization of overall benefits; the deontological algorithm emphasizes adherence to preset moral rules; virtue ethics, on the other hand, is concerned with whether the robot's behavior reflects good character and values. By comparing these three algorithms with different ethical foundations, a comprehensive assessment of the decision- making performance of silicon-based life forms under various ethical criteria can be conducted.

b) Data Collection Tools: Real-time recording of behavioral decision logs and sensor inputs. Behavioral decision logs meticulously document the choices made by the robot at each decision point and the rationale behind them, while sensor input data reflects the robot's perception of its environment. This data is crucial for subsequent analysis, as it helps us gain a deeper understanding of the robot's decision-making processes and the impact of the environment on its decisions.

c) Simulation Scene Generation Tools: Utilize Unity or Gazebo to construct customizable experimental scenarios. Both tools possess powerful scene editing capabilities, enabling the creation of a

variety of complex experimental scenarios to meet diverse experimental requirements.

4.2.3 | Types of Scenarios

a) Industrial Safety Scenario: Utilize Unity or Gazebo to construct customizable experimental scenarios. Both tools possess powerful scene editing capabilities, enabling the creation of a variety of complex experimental scenarios to meet diverse experimental requirements.

b) Medical Emergency Scenario: Utilize Unity or Gazebo to construct customizable experimental scenarios. Both tools possess powerful scene editing capabilities, enabling the creation of a variety of complex experimental scenarios to meet diverse experimental requirements.

c) Public Transportation Scenario: Simulate autonomous driving robots dealing with complex traffic conflict situations. For instance, at intersections where traffic congestion or other vehicles' non-compliant driving is encountered, robots need to make reasonable decisions, such as choosing the appropriate avoidance routes, deciding whether to stop and wait or to proceed slowly, in order to ensure traffic safety and smooth flow.

4.2.4 | Experimental Subjects

The experimental subjects are silicon-based life forms loaded with different ethical decision-making models, including:

a) Model A: A decision-making model based on utilitarian ethics (maximizing overall utility). This model takes into account the potential consequences of various actions when making decisions, selecting the course of action that maximizes overall benefits. For example, in resource allocation scenarios, it prioritizes allocating resources to areas that can generate the greatest benefits.

b) Model B: A decision-making model based on deontological ethics (adhering to preset rules). Model B makes decisions strictly in accordance with pre-established moral rules, without considering whether the consequences of actions are optimal or not. For instance, if the rule states that human life must never be harmed under any circumstances, then even in extreme situations where sacrificing a few might save many more, this model will adhere to the principle of non-maleficence.

c) Model C: A decision-making model based on deontological ethics (adhering to preset rules). Model B makes decisions strictly in accordance with pre-established moral rules, without considering whether the consequences of actions are optimal or not. For instance, if the rule states that human life must never be harmed under any circumstances, then even in extreme situations where sacrificing a few might save many more, this model will adhere to the principle of non-maleficence.

4.2.5 | Data Collection and Experimental Variables

a) Data Collection

Decision accuracy (the proportion of robot behavior that aligns with ethical objectives): This is a key metric for measuring the accuracy of ethical decision-making models. By comparing the

actual behavior of the robot with the expected ethical objectives, the proportion of correct decisions is calculated, thereby assessing the model's ability to make correct ethical decisions in different scenarios.

Decision time (the response time from environmental input to behavioral output): Reflects the speed at which a robot reacts to ethical decision-making problems. A shorter decision time means the robot can respond more quickly to emergencies, which is particularly important in time-critical scenarios such as medical emergencies and traffic contingencies.

Conflict resolution capability (the robot's ability to achieve balance in ethical dilemmas): Used to assess whether the robot can find reasonable solutions and balance different interests when faced with conflicting ethical principles (such as situations where saving the majority might harm a minority).

Resource utilization efficiency (the optimized use of resources by the robot within a scenario): Examines the extent to which the robot effectively utilizes various resources (such as energy, time, materials, etc.) during the execution of tasks. High resource utilization efficiency contributes to improving the robot's work efficiency and sustainability.

User satisfaction (assessed through questionnaires and simulated interactions): From the user's perspective, it gauges the level of acceptance and satisfaction with the robot's ethical decision-making. The level of user satisfaction directly affects the promotion and effectiveness of the robot's application in practical use.

b) Experimental Variables

Independent variables: Ethical decision-making models (Model A, B, C) and cultural backgrounds (Western, Asian). By varying the ethical decision-making models and cultural backgrounds, the impact on the ethical performance of robots is observed to determine the applicability of different models in various cultures.

Control variables: Sensor precision, hardware configuration, and environmental complexity. These variables are kept constant to ensure the accuracy and comparability of the experimental results. For instance, using sensors of the same precision and hardware devices with the same configuration, and conducting experiments under similar levels of environmental complexity, helps to prevent these factors from interfering with the outcomes of the experiments.

Dependent variables: Decision accuracy, decision time, conflict resolution ability, etc. These variables are the primary outcomes of interest in the experiment, and their values depend on the variations of the independent variables. The impact of different ethical decision-making models and cultural backgrounds is assessed through the analysis of these dependent variables.

4.2.6 | Experimental Design and Data Generation

a) Experimental Groups: Each ethical model is tested multiple times across three types of scenarios, resulting in a total of 6 groups (Models A/B/C × Western/Asian cultural backgrounds). This design allows for a comprehensive examination of the performance of different ethical models under

various cultural backgrounds and scenarios, thoroughly exploring the interrelationships between various factors.

b) Number of Experiments: Each group of experiments is repeated 100 times to ensure the statistical significance of the data. Repeating the experiments multiple times reduces the impact of random errors, making the results more reliable and representative, and thus more accurately reflecting the true performance of different ethical decision-making models.

Table 1: Experimental Analysis Table

Scenario	**Model**	**Decision Accuracy (%)**	**Average Decision Time (s)**	**Problem-Solving Capability (%)**	**User Satisfaction Rating (1-10)**
Industrial Safety	Mode 1A	75	1.5	80	7.5
	Mode 1B	85	1.8	85	8.2
	Mode 1C	90	1.7	88	9.0
Medical Emergency	Mode 1A	70	2.0	75	6.8
	Mode 1B	80	2.5	82	8.0
	Mode 1C	92	2.2	90	9.2
Public Transportation	Mode 1A	65	1.2	70	6.5
	Mode 1B	78	1.8	82	7.8
	Mode 1C	88	1.6	90	8.8

4.3 | Data Analysis

4.3.1 | Statistical Methods

One-way analysis of variance (ANOVA): Used to analyze whether there are significant differences in various performance indicators (decision accuracy, decision time, conflict resolution ability, etc.) among different ethical decision-making models (Model A, B, C) within the same cultural background. By calculating the ratio of between- group variance to within-group variance, an F-statistic is obtained and compared with the critical value to determine if the performance differences between models are statistically significant ($p < 0.05$). For instance, when analyzing decision accuracy, if the ANOVA result shows significant differences between models, it indicates that different ethical models have a significant impact on decision accuracy, allowing for further multiple comparisons to identify which models differ and in which direction.

Multivariate analysis of variance (MANOVA): Examines the interactive effects between two factors, ethical models and cultural backgrounds. It not only determines the individual impact of each factor on the dependent variables (such as decision accuracy, user satisfaction, etc.) but also analyzes whether

there is any additional impact when both factors act together. For example, it investigates whether there is an interaction change in decision accuracy among different ethical models across various cultural backgrounds. If an interaction effect exists, it indicates that the performance of ethical models in different cultures is not a simple superposition but rather a mutual influence, which is crucial for understanding the ethical behavior of robots in multicultural environments.

Test of significance: Tests the significance between variables ($p < 0.05$). In addition to determining whether the effects of factors are significant in ANOVA, it is also applied in other related analyses. For example, when analyzing the relationship between a robot's resource utilization rate and decision time, significance testing can determine whether there is a genuine correlation between the two, rather than one caused by random factors. If the p-value is less than 0.05, the null hypothesis is rejected, indicating that there is a significant correlation or difference between the variables, thus providing a reliable basis for subsequent conclusions.

4.3.2 | Optimization Analysis

Regression analysis for model performance prediction:

Use relevant parameters of the ethical decision-making model (such as model complexity, characteristics of the algorithms used, etc.) as independent variables and performance indicators (such as decision accuracy, decision time, etc.) as dependent variables to establish a regression model. By estimating the regression coefficients and conducting significance tests, assess the extent of the impact of model parameters on performance indicators and thereby predict the performance of ethical models under different parameter settings. For instance, if a regression coefficient for an algorithmic feature in the model is found to be significantly positive, it indicates that this feature has a positive effect on decision accuracy. Therefore, when optimizing the model, this feature could be appropriately enhanced to improve decision accuracy. Additionally, regression models can be used to estimate prediction intervals, understand the range of uncertainty in the forecast results, and provide more comprehensive information for decision-making.

Cluster analysis for cross-cultural adaptability:

Use the performance indicators of ethical models under different cultural backgrounds as clustering variables and employ clustering algorithms (such as K-means clustering, hierarchical clustering, etc.) to categorize cultural backgrounds. Through the results of clustering, it is possible to visually identify which cultural backgrounds have similarities in the performance of ethical models, thereby discovering the strengths and weaknesses of ethical models in different cultural clusters. For example, if clustering results show that certain performance indicators under Western cultural backgrounds are similar and significantly different from those under Asian cultural backgrounds, further analysis can be conducted to determine the causes of these differences, whether they are due to different cultural values leading to different expectations of robotic ethical behavior or other influencing factors. This helps in optimizing ethical models for different cultural groups and enhancing their applicability on a global scale.

4.4 | Data Visualization

4.4.1 | Grouped Bar Chart

Objective: To compare the decision accuracy rates of different ethical models across three types of scenarios. By using the height of the bar chart, it visually displays the proportion of correct decisions made by each model in industrial safety, medical emergency, and public transportation scenarios, allowing readers to quickly compare the performance differences of different models in various scenarios.

Optimization: Use multiple color schemes to distinguish between different cultural backgrounds. For example, use cool colors (such as blue shades) for model data under Western cultural backgrounds and warm colors (such as red shades) for model data under Asian cultural backgrounds. Additionally, add labels or annotations to each bar to display the specific decision accuracy rates, allowing readers to more clearly obtain information. The width and spacing of the bars can also be adjusted to make the chart more aesthetically pleasing and easier to read, enhancing the visual effect and highlighting the contrast between different models and cultural backgrounds.

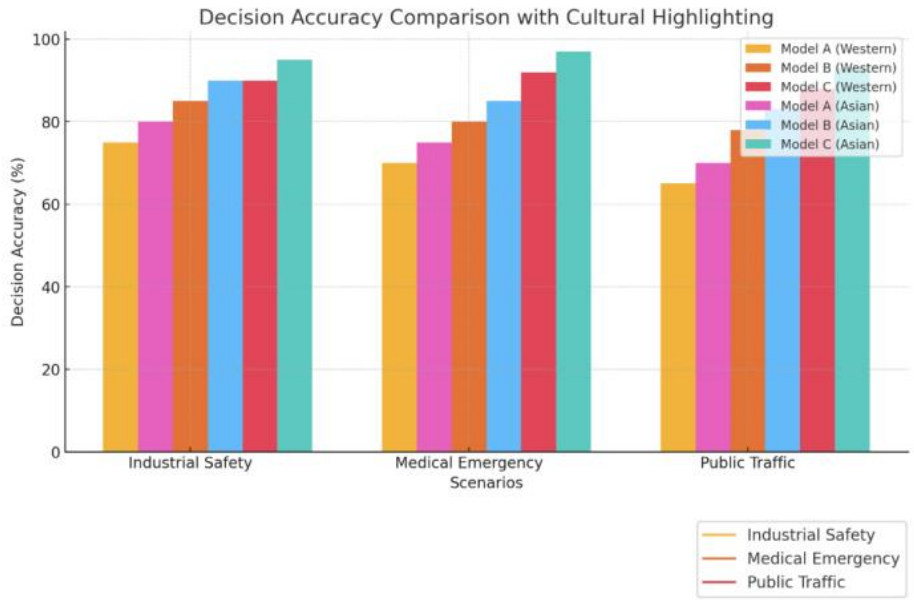

Figure 1: Decision Accuracy Comparison with Cultural Highlighting

4.4.2 | Batch Heatmap

Objective: To display the variation in user satisfaction across three types of scenarios and cultural backgrounds. In the heatmap, the darkness of the color represents the level of user satisfaction, with gradients allowing readers to visually perceive the distribution of user satisfaction with the ethical decisions of robots in different scenarios (rows) and cultural backgrounds (columns).

Optimization: Use diagonal gradient colors to highlight peak satisfaction values. Set the diagonal of the heatmap (i.e., the satisfaction of the same model under different scenarios and cultural backgrounds) to a special gradient color, such as a transition from light green to dark green, to represent the change in

satisfaction from low to high. This quickly guides readers to focus on the satisfaction performance of each model in its most suitable scenarios and cultural backgrounds while also allowing for clearer observation of differences in satisfaction distribution among different models, helping to identify the strengths and weaknesses of models in various contexts. Additionally, adding a color scale and labels for scenarios and cultural backgrounds on the edges or corners of the heatmap enables readers to accurately understand the satisfaction values represented by the colors and their corresponding scenarios and cultural backgrounds.

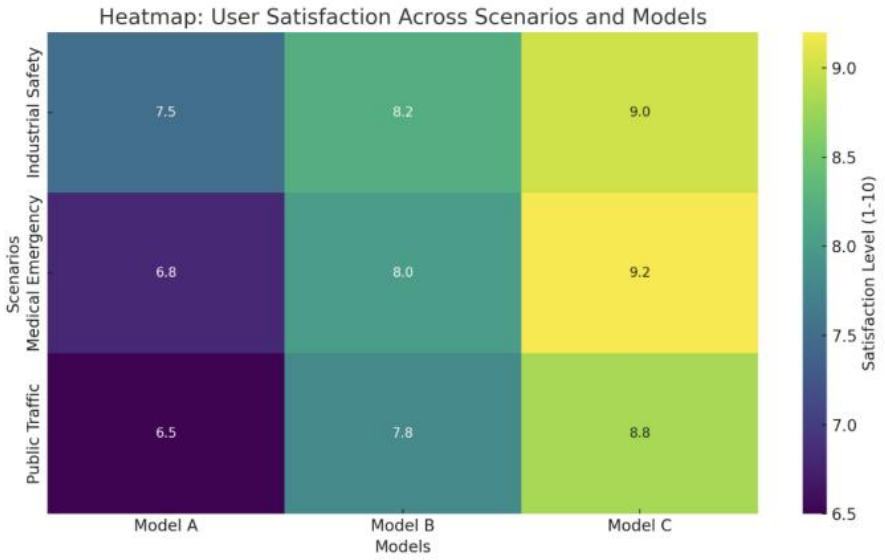

Figure 2: Heatmap:User Stisfaction Across Scenarios and Models

4.4.3 | Radar Chart

Objective: To comprehensively compare the ethical performance of three models (decision accuracy, conflict resolution ability, user satisfaction, etc.). The radar chart starts from a central point and radiates outwards with multiple axes, each representing a performance metric. By connecting the value points on each axis to form a polygon, it visually displays the comprehensive performance of each model across multiple performance dimensions.

Optimization: Add color filling and transparency for each model. Use different colors to fill the polygons to distinguish between different ethical models, for example, fill Model A with blue, Model B with yellow, and Model C with green. At the same time, set an appropriate level of transparency so that readers can see the shapes of all three models simultaneously, facilitating intuitive comparison. Clearly label the names and scales of each performance indicator on the axes of the radar chart, and add a legend around or within the chart to explain which model each color represents, helping readers better understand the information conveyed by the chart, thereby allowing for a comprehensive assessment of the strengths and weaknesses of different ethical models.

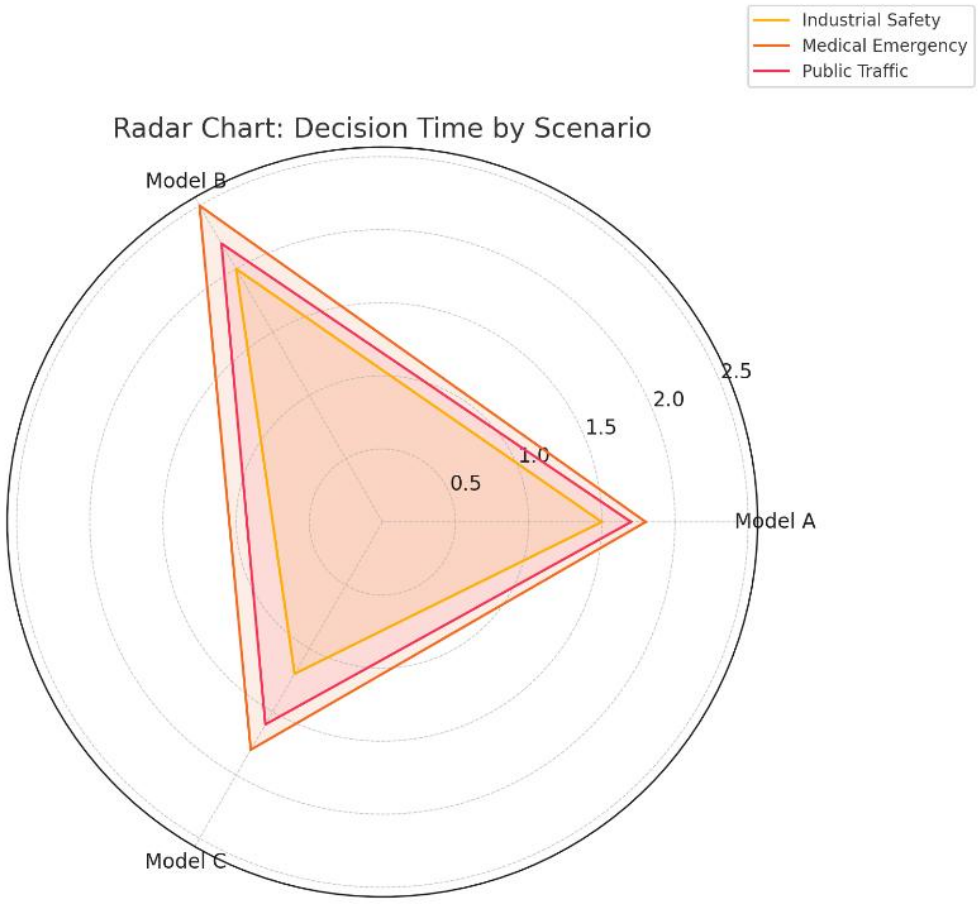

Figure 3: Radar Chart:Decision Time by Scenario

5 | CONCLUSIONS AND PROSPECTS

The ethical design of silicon-based life is a cutting-edge research field that involves multiple disciplines and holds profound significance for the future development of human society. Through the analysis of the current state of silicon- based life technology, we recognize its immense potential driven by the integration of multiple disciplines and the remarkable achievements made in performance enhancement and application expansion. We also understand the explorations in the direction of related thoughts in frontier research literature. However, the ethical design of silicon- based life faces many challenges, including ethical dilemmas, safety risks, and social impacts.

This experimental study on the ethical decision-making models of silicon-based life, starting from engineering practice, systematically evaluates the performance differences of various ethical models in multiple scenarios and cultural backgrounds, providing empirical evidence for the ethical design of silicon-based life. Through data analysis and chart presentation, we have gained an in-depth understanding of the efficiency, stability, applicability, and adaptability in multicultural contexts of the models, discovering the strengths and weaknesses of existing models.

Based on the experimental results, we can provide specific directions and methods for optimizing ethical decision-making models, such as adjusting model parameters according to different cultural back-

grounds and improving algorithms to enhance decision-making efficiency and accuracy, thus providing more solid theoretical and practical support for robot design in multicultural contexts. In the future, as technology continues to advance and societal concepts evolve, the ethical design of silicon-based life will continue to develop and improve. Interdisciplinary research collaboration will become even closer, with scientists, engineers, ethicists, and sociologists working together to explore more reasonable and effective ethical design solutions. We look forward to silicon-based life coexisting harmoniously with humans, bringing more benefits to the development of human society while avoiding potential risks and hazards. In this process, continuous research, extensive social discussion, and proactive policy guidance will be key factors in ensuring the success of the ethical design of silicon-based life.

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Philosopher's Compass 1/1 (2025): 109–128.

Modeling Languages and Emotional Expressions

Yao Chen[1] **and Cheng Yao**[2]

[1]Macau University of Science and Technology, Macao, China, yarranyao@gmail.com

[2]Zhejiang University, Hangzhou, China, yaoch@zju.edu.cn

ABSTRACT

Modeling language is crucial for the conveyance of emotions in design, exerting a profound influence on user experience and behavioral patterns. Nevertheless, most extant research efforts have been circumscribed within the boundaries of single dimensions or static variables, falling short of a comprehensive interdisciplinary and integrative study. In this paper, a meticulously controlled experimental milieu was established through the application of virtual reality (VR) technology, with the aim of systematically probing into the impact mechanisms of two paradigmatic modeling languages, namely curves and rectangles, upon emotions, heart rate variability, and creative output. The experimental protocol incorporated multi-faceted quantitative measures, such as the Positive and Negative Affect Schedule (PANAS) for gauging subjective emotional states, physiological indices (heart rate) as an objective biomarker, and creative evaluation techniques involving the Guildford Alternative Uses Task and semantic distance computation. The empirical findings divulged that the curvilinear modeling paradigm significantly augmented positive emotional valence ($t=4.87$, $p<0.001$) and concomitantly attenuated negative emotional arousal ($t=2.09$, $p=0.04$); it also led to a remarkable reduction in the level of physiological arousal as manifested by heart rate deceleration ($t=4.18$, $p<0.001$); furthermore, it effectively potentiated creative output as evidenced by an increased semantic distance ($t=2.06$, $p=0.047$). This investigation represents the inaugural attempt to validate the emotional repercussions and creative elicitation mechanisms of modeling languages within a three-dimensional virtual environment via a multidisciplinary methodological approach. The outcomes of this research furnish a scientific underpinning for architecture, product design, and human-computer interaction, effectively bridging a critical lacuna in the existing literature.

KEYWORDS: Modeling Language, Emotional Expression, Virtual Reality

1 | INTRODUCTION

1.1 | Research Background and Significance

In the context of contemporary society, the demands of individuals regarding the environment and products have transcended the mere functional realm. Emotional experience has emerged as a significant

factor worthy of consideration (Xu et al., 2020). Modeling language, being a pivotal constituent in the design discipline, imparts emotional information via diverse elements such as form, color, and texture (Brosch et al., 2021). A profound exploration into its correlation with emotional expression is conducive to enabling designers to fabricate creations that are more attuned to the emotional requisites of users. This, in turn, not only augments the quality of life and work efficiency but also propels the innovative progression within the design domain (Roggeveen et al., 2020).

1.2 | Research Questions and Hypotheses

This research centers around the exploration of how modeling languages exert an impact on the emotions and behaviors of individuals. In light of this, the following hypotheses are put forward:

Hypothesis One (H1): It is hypothesized that disparate modeling language environments will lead to a significant alteration in the emotional states of participants. Specifically, within the context of a curved modeling environment, the scores pertaining to positive emotions will be conspicuously higher compared to those in a rectangular modeling environment. Conversely, the scores associated with negative emotions will be notably lower in the former than in the latter (Meo et al., 2020). This supposition is predicated on the premise that the inherent characteristics of curved and rectangular forms possess distinct capacities for eliciting and modulating emotional responses.

Hypothesis Two (H2): It is postulated that in a curved modeling environment, the heart rate of participants will be lower than that in a rectangular modeling environment, thereby signifying a diminished level of physiological arousal (Bullis et al., 2019). The rationale behind this hypothesis lies in the potential association between the visual perception of different modeling languages and the autonomic nervous system's regulation of physiological parameters such as heart rate.

Hypothesis Three (H3): It is proposed that the creative output of participants will be greater in a curved modeling environment as opposed to a rectangular modeling environment (Han et al., 2022). This hypothesis is founded on the idea that the unique aesthetic and spatial qualities of curved modeling might foster a more conducive cognitive and psychological state that is favorable for the generation and expression of creative ideas.

1.3 | Research Questions and Hypotheses

Innovative Deep Interdisciplinary Fusion:This study features an unprecedented integration of multiple disciplines. Specifically, it combines the theoretical and methodological frameworks of neuroscience, psychology, architecture, and computer science. Neuroscience contributes by elucidating the intricate neural pathways underlying emotional processing, thereby providing a fundamental understanding of the biological basis of emotions. Psychology offers a suite of well-established measurement tools, such as various scales and questionnaires, which are essential for quantifying and analyzing emotional states. Architecture plays a crucial role in constructing realistic and contextually relevant scenarios that serve as the backdrop for our investigations. Computer science, on the other hand, empowers the research through

advanced virtual simulation techniques and sophisticated data analysis algorithms. This interdisciplinary synergy not only enriches the research but also presents a novel and comprehensive perspective that has not been fully explored in previous studies (Singer et al., 2019).

Innovation in Experimental Methodology and the Precision of Diverse Data Acquisition:A significant innovation in our experimental approach lies in the utilization of virtual reality (VR) technology. This technology allows for precise manipulation and control of variables, thereby minimizing potential confounding factors and enhancing the internal validity of the study. In conjunction with VR, we have incorporated a diverse array of measurement tools. Subjective emotional scales are employed to capture participants' self-reported emotional experiences, providing valuable insights into the affective dimension. Objective physiological indicators, such as heart rate and other relevant biomarkers, are monitored to gauge the physiological arousal associated with different experimental conditions. Additionally, a comprehensive set of methods for evaluating creativity and innovation, including established tasks and novel computational techniques, are utilized. This multi-faceted approach to data collection ensures the acquisition of rich and accurate multi-dimensional data, which in turn significantly bolsters the reliability and generalizability of our research findings (Davis et al., 2020).

2 | LITERATURE REVIEW

2.1 | Research Related to Modeling Language

2.1.1 | Definition and Core Dimensions of Modeling Language

Modeling language, as a crucial vehicle in the realm of design, serves to communicate meaning and elicit emotions by means of elements like form, color, and material (Bower et al., 2019). With respect to spatial form, it can be principally classified into two distinct types: curved and straight, with the rectangle being a prototypical example of the latter. The curved form is characterized by its inherent softness and naturalness, endowing it with an ability to evoke a sense of fluidity and harmony. In contrast, the rectangular form exhibits regularity and stability, which confer upon it a certain degree of order and permanence. These two forms find extensive application in both architectural and product design domains, playing a significant role in shaping and modulating the emotional experiences of the users (Dozio et al., 2022).

2.1.2 | The Extensive Application and Far-Reaching Impact of Modeling Language in Various Fields

In the realm of architecture, the curved elements present in classical architecture serve to engender a solemn and stately atmosphere. These curvilinear features, with their graceful and flowing contours, contribute to an aesthetic that is often associated with grandeur and formality. In contrast, within modern architecture, the utilization of rectangular lines imparts a sense of simplicity and minimalism. The straight and angular geometries of such designs communicate an uncluttered and streamlined visual language, which is characteristic of contemporary architectural trends (Zhong et al., 2022). When it comes to product design, the curved design incorporated in electronic products has the propensity to trigger associations of dynamism and fluidity. The sleek and rounded forms of these items suggest movement

and energy, thereby endowing them with an alluring and engaging quality. On the other hand, the rectangular form commonly employed in furniture design accentuates stability and practicality. The straight edges and right angles of furniture pieces connote a sense of solidity and reliability, which are essential attributes for functional and long-lasting furnishings. It is evident that different modeling languages, as manifested in these diverse forms and geometries, are capable of shaping distinct emotional atmospheres that significantly impact the user's perception and experience of the designed products (Plass et al., 2020).

2.2 | Research Related to Emotional Expression

2.2.1 | Theoretical Models of Emotions and Multiple Measurement Dimensions

In the domain of emotion research, a plethora of theoretical models have been put forward to elucidate the intricate nature of emotions. Among these, the two- dimensional model stands out as a commonly employed framework. This model encompasses the spectrum of positive and negative emotions, providing a structured means to categorize and analyze emotional experiences (Wong et al., 2021). Regarding the measurement of emotions, diverse methodologies have been developed. One prevalent approach is the utilization of self-report questionnaires. For instance, the PANAS - Long Form is a widely recognized instrument in this regard. Through such questionnaires, individuals are able to provide subjective accounts of their emotional states, detailing the intensity and prevalence of various positive and negative emotions they have experienced. In addition to self- report questionnaires, the measurement of physiological indicators also plays a crucial role. These physiological markers, including but not limited to heart rate, blood pressure, skin conductance, and electroencephalogram (EEG) readings, offer an objective perspective on emotional arousal and regulation. By monitoring these physiological changes, researchers can gain insights into the underlying physiological processes associated with different emotional states. The combination of these two measurement approaches, namely self-report questionnaires and physiological indicator measurement, is of utmost importance. It allows for a more comprehensive and in-depth understanding of the complex dynamics of emotional changes. This integrated approach overcomes the limitations of relying solely on either subjective or objective measures and provides a more holistic view of the emotional landscape (Jackson et al., 2019).

2.2.2 | Key Environmental Factors Affecting Emotional Expression

Natural environmental factors have been demonstrated to possess the capacity to augment positive emotions. In parallel, the elements of modeling language within the architectural environment hold significant importance. Specifically, aspects such as the spatial layout and color coordination are known to exert an influence on emotional states. It is noteworthy that individual variances exist, which lead to the phenomenon where identical modeling language can precipitate diverse emotional responses (Jonauskaite et al., 2020).

2.3 | Research Status of the Relationship between Modeling Language and Emotional Expression

The majority of the extant research is circumscribed within a solitary field or factor, with a paucity of the amalgamation of multi-dimensional data. Notably, the exploration into the modeling language of three-dimensional space within virtual environs is rather inadequate. The current study endeavors to bridge these lacunae (Han et al., 2022).

3 | RESEARCH METHODS

3.1 | Experimental Design

3.1.1 | Design Types and Variable Control

The present experiment employs a within-subjects design paradigm and integrates a balanced AB/BA sequence protocol, with the aim of minimizing the potential influence of order effects to the greatest extent. The independent variable under investigation in this experiment is the modeling language of the room, which is categorized into two distinct types: rectangular and curved. The dependent variables encompass a range of aspects, namely the emotional states of the participants, which are further subdivided into positive and negative emotions, the level of creative output, and the physiological indicator of heart rate. To guarantee the stringency and scientific integrity of the experiment, meticulous control measures are implemented. Specifically, other characteristics of the room, such as its area, light intensity, and color, are stringently regulated throughout the experimental process. Additionally, the natural landscapes within the visual field of the participants are standardized, thereby ensuring that any differences sensed by the participants can be solely attributed to the variations in the modeling language.

3.1.2 | Construction of Experimental Scenarios and Technical Support

The experimental scenarios were constructed by leveraging the Unreal EngineTM and SteamVRTM technologies to simulate virtual reality (VR) environments on high-performance computing platforms. Two distinct room modeling configurations, namely the rectangular and curved room designs, were incorporated. In both scenarios, uniform office furniture was provided, and a consistent view of the natural landscape outside the window was presented. The overall geometry of the rooms and the layout of the interior elements remained identical across the two experimental settings.

Participants were able to engage with the scenarios by donning VR headsets. Concurrently, the system employed tracking devices to record the head positions of the participants, thereby ensuring an immersive and seamless experience. The design of these experimental scenarios has undergone professional verification and has been publicly disclosed for further scrutiny and replication.

3.2 | Participant Recruitment and Sample Characteristics

3.2.1 | Recruitment Channels and Sample Characteristics

The experimental participants were enlisted via the participant pool of higher education institutions and social media channels. A sum of 35 individuals were successfully recruited, with their age span stretching from 18 to 64 years (where the mean age, M, equaled 32.5 and the standard deviation, SD, was 9.3). The sample characteristics of these participants exhibit a high degree of representativeness, incorporating diverse genders (with 47% being male and 53% being female) as well as a variety of occupations, which encompass students enrolled in educational institutions, full- time employees, and the unemployed population.

The recruitment conditions include:

- Language Ability: Proficiency in English is required.
- Physical Condition: Normal uncorrected or corrected visual acuity is expected.
- Mental State: No recent diagnosis of severe mental illness.

3.2.2 | Ethical Approval and Informed Consent

The experimental protocol obtained the endorsement of the Ethics Committee at Bond University. Before the commencement of the experiment, all participants were required to sign a comprehensive informed consent form. This form encompassed detailed information regarding the objective of the experiment, the sequential procedures to be followed, the potential risks that might be involved, and the safeguarding measures for data privacy. Through this meticulous process, it was ensured that the rights, interests, and privacy of the participants remained inviolable.

3.3 | Measuring Tools and Materials

3.3.1 | Emotional Measurement Tool(PANAS)

The emotional states of the participants were assessed by employing the PANAS - Long Form scale (Positive and Negative Affect Schedule). This scale encompasses ten positive affect words and ten negative affect words. Each participant was tasked with rating each of these words on a five-point scale, where 1 was designated as ”rarely felt” and 5 as ”extremely felt”. Subsequently, the scores for positive affect and negative affect were separately aggregated to gauge the overall emotional states of the participants.

3.3.2 | Heart Rate Measurement Device (Elite HRV CorSense)

The heart rate data were collected via the Elite HRV CorSense fingertip clip-on sensor. This particular device employs photoplethysmography (PPG) to measure heart rate. The affiliated software is capable of automatically cleansing the artifact signal data and subsequently computing the beats per minute (bpm). The Elite HRV CorSense has been widely adopted in physiological research, thereby guaranteeing the reliability of the data obtained.

3.3.3 | Creativity Measurement Tools (GAUT and SemDis)

The Guildford Alternative Uses Task (GAUT) was implemented in this study. Participants were tasked with generating as many non-traditional uses as they could conceive for common objects, such as bricks or paper towels.

This task serves as a means to evaluate divergent thinking, which is a crucial aspect of creativity assessment. By eliciting a wide range of alternative uses, the GAUT enables the quantification and analysis of an individual's capacity to think divergently and generate novel ideas beyond the typical or conventional applications of the given items.

The Semantic Distance Calculation Platform (SemDis): Based on the SemDis platform and in combination with the CBOW (Continuous Bag of Words) model, the semantic distance of the responses in the GAUT was calculated. A higher semantic distance indicates a higher level of creativity. The data were input into statistical analysis after undergoing semantic cleaning.

3.4 | Experimental Procedure

3.4.1 | Experimental Preparation and Environmental Adaptation

Prior to the initiation of the experiment, the participants were required to don VR headsets and acclimate themselves to a generic virtual environment for a duration of three minutes. During this acclimation period, the baseline heart rate data was recorded with the aim of ensuring the stability of the physiological state and minimizing the deviations that might arise due to discomfort. This procedure was implemented to establish a consistent physiological baseline, thereby enhancing the reliability and validity of the subsequent experimental data collection and analysis.

3.4.2 | Tasks for Measuring Emotion and Creativity

Upon the completion of the adaptation period, the experimenter utilized the loudspeaker to prompt the participants to undertake the subsequent tasks:

- Emotional Measurement:The current emotional state of the participants was measured by means of the PANAS. In this regard, participants were required to provide their responses orally. This approach allowed for the immediate capture of their emotional experiences at that specific moment, facilitating subsequent analysis of the affective states within the context of the experiment.

- Creativity Measurement:The Guildford Alternative Uses Task (GAUT) was then implemented. Participants were tasked with generating creative uses for a set of items. Their answers were meticulously recorded for further examination. To mitigate the potential impact of order effects, the presentation order of the items was randomly balanced. This ensured that any observed differences in the creativity measures could be more accurately attributed to the inherent nature of the participants' creative thinking rather than being influenced by the sequence in which the items were presented.Such a carefully designed and executed procedure for emotional and creativity measurement was aimed at obtaining comprehensive and reliable data, thereby enabling in-depth exploration of

the relevant research questions.

3.4.3 | Experimental Environment Exposure and Data Collection

The participants were successively exposed to two distinct room configurations, namely rectangular and curved, with each exposure lasting for a period of 10 minutes. During the exposure intervals, the heart rate of the participants was continuously recorded. Immediately subsequent to the completion of each exposure, the tasks designed for measuring emotion and creativity were reiterated. To preclude any potential order biases, the sequence of the room exposures was randomly counterbalanced. The overall duration of the experiment approximated 26 minutes. Throughout the experimental process, the participants were required to maintain a seated position so as to eliminate any interference that might be introduced by physical movements.

4 | RESEARCH FINDINGS

4.1 | Data Processing and Preliminary Analysis

4.1.1 | Data Screening

During the preliminary examination process, it was discovered that the heart rate sensor of a single participant had a poor connection issue. As a result of this, the corresponding heart rate data of this particular participant was excluded from the subsequent analysis. Conversely, the data integrity of all the remaining participants was found to be in a satisfactory state. Specifically, there were no significant instances of missing values within their datasets, thereby ensuring the reliability and validity of the data for further in-depth analysis.

4.1.2 | Normality Test and Robustness Treatment

The Shapiro-Wilk normality test was performed on all the dependent variables under investigation. It was observed that, with the exception of negative affect and heart rate, the distributions of the other data exhibited a reasonable approximation to normality. In order to enhance the robustness of the analysis results, especially for those data that deviated from the normal distribution, the Wilcoxon test was utilized as a supplementary approach to validate the outcomes of the t-test. This dual-testing strategy helps to ensure the reliability and validity of the statistical inferences drawn from the data, thereby strengthening the overall integrity of the research findings.

4.2 | DifferencesinEmotionalReactions

4.2.1 | Positive Effect

In the experimental setting where participants were exposed to the curved room configuration, the mean positive affect score was calculated to be 30.60, with a standard deviation of 6.72. In contrast, when the

participants were placed in the rectangular room, the corresponding mean positive affect score was 23.94, accompanied by a standard deviation of 8.69. Subsequently, a paired t-test was conducted to examine the statistical significance of the difference between these two sets of scores. The results of this test revealed that $t(34) = 4.87$, with a p-value less than 0.001, which clearly indicates a highly significant difference between the positive affect scores in the two room types. Moreover, the effect size was quantified as Cohen's $d = 0.82$. Collectively, these statistical findings provide compelling evidence that the curved room configuration significantly elevates the level of positive affect among the participants, thereby highlighting the potential impact of environmental design on emotional experiences within the context of this study.

4.2.2 | Negative Effect

In the rectangular room, the mean negative affect score was determined to be 12.62, with a standard deviation of 3.80. In contrast, within the curved room, the mean negative affect score was 11.51, accompanied by a standard deviation of 1.99. A paired t-test was then conducted to evaluate the statistical significance of the difference between these two sets of negative affect scores. The results of this test demonstrated that $t(34) = 2.09$, with a p-value of 0.04, indicating a significant difference between the negative affect scores in the two room configurations. Additionally, the effect size was calculated as Cohen's $d = 0.35$. To further validate the robustness of these findings, a Wilcoxon test was performed. The Wilcoxon test corroborated the results obtained from the t-test, providing additional support for the conclusion that there is a reliable difference in negative affect between the rectangular and curved room settings. This multi-faceted statistical analysis enhances the confidence in the observed relationship between room type and negative emotional response, contributing to a more comprehensive understanding of the emotional impact of environmental factors within the scope of this research.

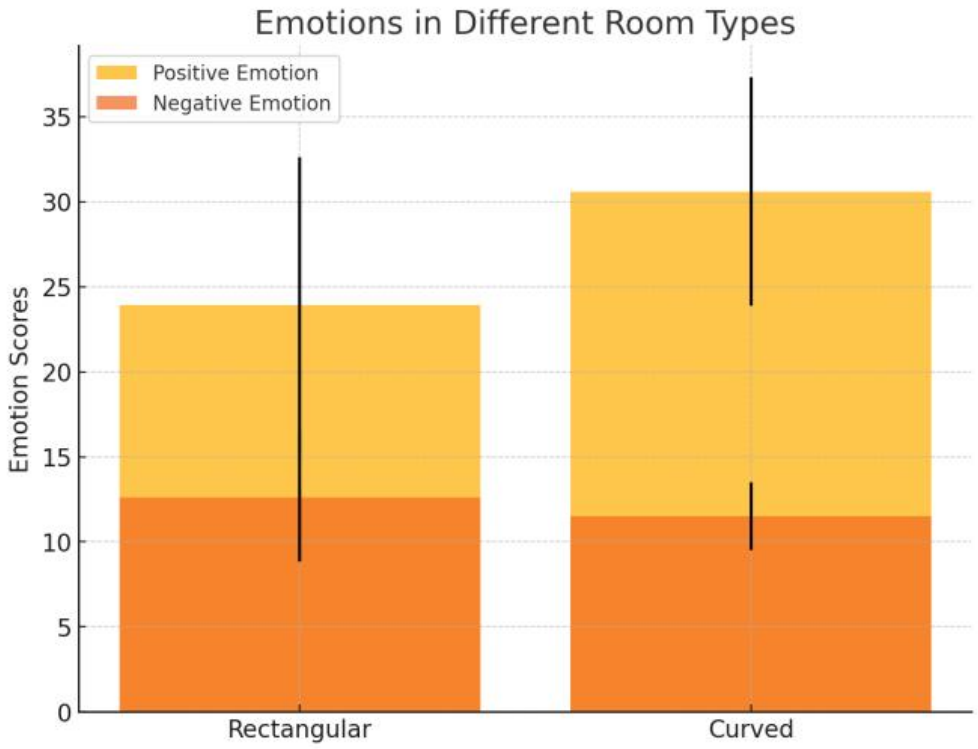

Figure 1: Emotions in Different Room Types

4.3 | Differences in Heart Rate

In the experimental context, the mean heart rate within the curved room was measured as 76.67 beats per minute (bpm), with a standard deviation of 8.767. In contrast, the mean heart rate in the rectangular room was determined to be 83.58 bpm, accompanied by a standard deviation of 6.68. Subsequently, a paired t-test was conducted to statistically assess the significance of the difference between these two mean heart rate values. The results of this test demonstrated that $t(33) = 4.18$, with a p-value less than 0.001, which unequivocally indicates a highly significant difference in heart rate between the two room configurations. Additionally, the effect size was quantified as Cohen's $d = 0.71$. Collectively, these statistical outcomes provide strong evidence that the curved room configuration leads to a reduction in physiological arousal, as reflected by the lower average heart rate. This finding contributes to a more profound understanding of the potential physiological impacts of environmental design factors within the framework of this study.

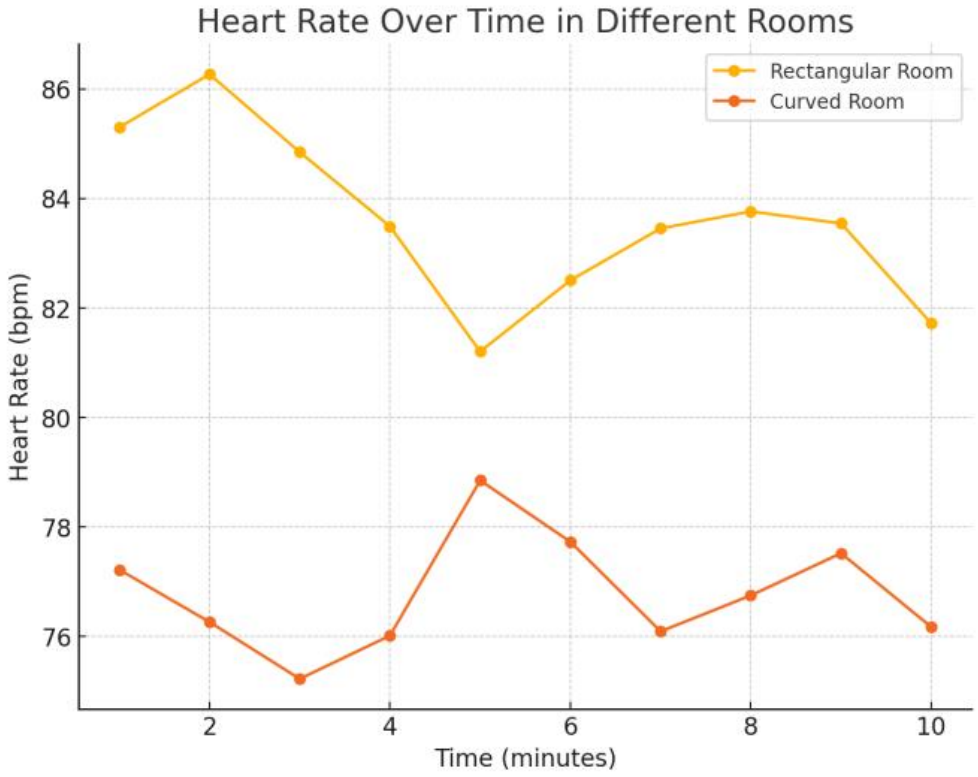

Figure 2: Emotions in Different Room Types

4.4 | Differences in Creative Output

In the experimental study, the SemDis scores within the curved room were determined to be 4.37 on average, with a standard deviation of 1.68. In contrast, the mean SemDis score in the rectangular room was 3.63, accompanied by a standard deviation of 1.55. A paired t-test was then conducted to statistically evaluate the significance of the difference between these two mean SemDis scores. The results of this test showed that $t(34) = 2.06$, with a p-value less than 0.047, which clearly demonstrates a significant

difference in SemDis scores between the two room configurations. Moreover, the effect size was calculated as Cohen's d = 0.35. Collectively, these statistical findings provide substantial evidence that the curved room configuration has a positive impact on enhancing the creative output of the participants, as reflected by the significantly higher SemDis scores. This discovery contributes to a deeper understanding of the relationship between environmental design and creative performance within the context of this research.

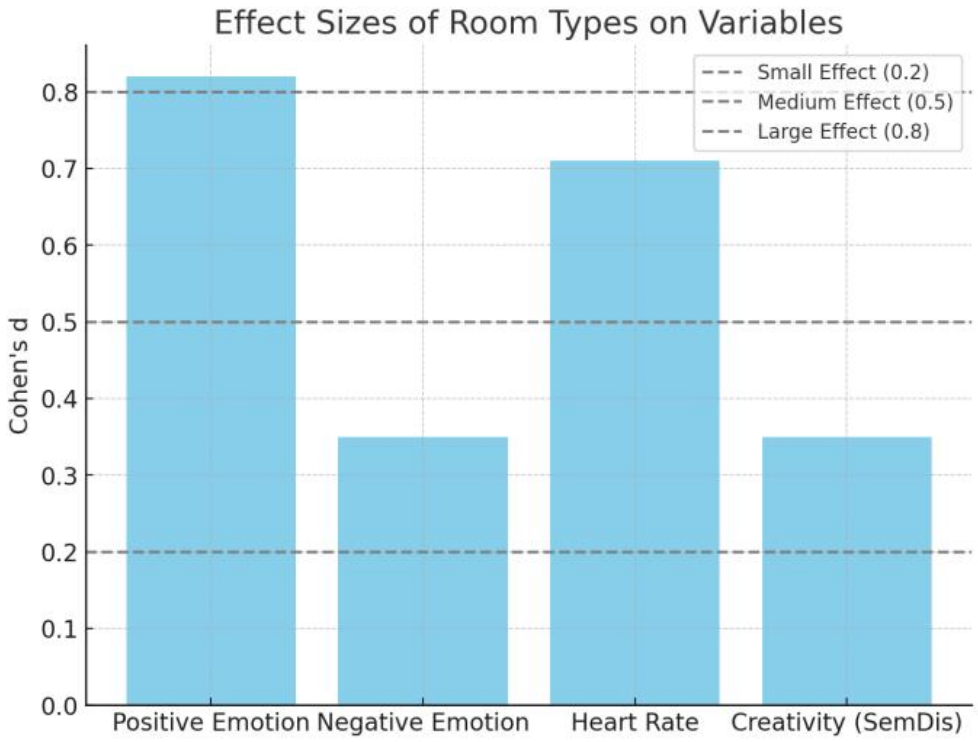

Figure 3: Effect Sizes of Room Types on Variables

4.5 | Data Visualization and Statistical Results

Box plots of Emotion and Creativity: These box plots are constructed with the intention of explicitly presenting the distributional discrepancies of each dependent variable under the two disparate room conditions. By means of visualizing the quartiles, whiskers, and potential outliers, a comprehensive and detailed insight into the dispersion and central tendency of the emotional and creative variables within the distinct environmental settings can be attained.

Line graph of Heart Rate: The line graph is specifically devised to vividly depict the temporal variation patterns of heart rate in the two rooms over the experimental duration. With the horizontal axis representing time and the vertical axis denoting heart rate values, it allows for a lucid and precise identification of any trends, fluctuations, or differences in the physiological responses as a function of the room types.

Bar chart of Effect Sizes: This bar chart is utilized to offer an immediate and intuitive visual comparison of the magnitudes of effect sizes corresponding to different dependent variables. The height of each bar is directly proportional to the quantified impact, thereby facilitating a swift and accurate assessment of the relative significance and strength of the relationships between the environmental factors and the

various response variables such as emotion, heart rate, and creativity.

Through comprehensive and rigorous data analysis procedures, the statistically significant influences of environmental form language on emotion, heart rate, and creativity have been robustly verified. These empirical findings serve as a solid and reliable scientific foundation, which is of crucial importance for the optimization of user experience within the realm of architectural design. They offer valuable insights and guidelines that can assist architects and designers in making well-informed decisions and implementing strategies to enhance the quality and desirability of built environments from the perspective of end-user satisfaction and well-being.

The above are three data visualization charts of the research results:Bar Charts of Emotion and Creativity: These bar charts are meticulously constructed to present the mean scores and standard deviations of positive and negative emotions under different room types. The vertical axis represents the magnitude of the scores, while the horizontal axis differentiates between the curved and rectangular room conditions. Through this graphical representation, one can readily observe and compare the central tendencies and variabilities of the emotional responses within the distinct environmental settings.

Line Chart of Heart Rate: This line chart is designed to precisely depict the temporal trends of the heart rate per minute of the participants in both curved and rectangular rooms. The x-axis, which symbolizes the time progression, and the y-axis, denoting the heart rate values, jointly enable a detailed visualization of any fluctuations, patterns, or divergences in the physiological responses as a function of the room types over the course of the experiment.

Bar Chart of Effect Sizes: This bar chart is skillfully employed to compare the effect sizes (Cohen's d) of different dependent variables. The height of each bar corresponds to the magnitude of the effect size, and the chart further includes the threshold lines demarcating small, medium, and large effects. This allows for an immediate and intuitive assessment of the relative magnitudes and significance of the relationships between the independent and dependent variables, providing a valuable perspective on the strength of the experimental findings.

These charts, as a whole, offer lucid statistical result support and vividly and intuitively present the differences and impacts unearthed in the experiment. They serve as powerful visual aids in facilitating a more profound understanding and interpretation of the research outcomes within the academic community.

5 | DISCUSSION

5.1 | The Influence Mechanism of Form Language on Emotional Expression

5.1.1 | Consistency with and Extension/Deepening of Previous Research

The results of this study are consistent with those of previous researchers, confirming that geometric factors influence emotions. The curved form is associated with positive emotions, possibly due to natural preferences, while the rectangular form is related to negative emotions (Zioga et al., 2020). The expan-

sion of this study lies in the precise control of variables in the three-dimensional virtual environment, providing theoretical support for cross-cultural emotional design (Shemesh et al., 2020).

5.1.2 | Elucidation of Potential Neurophysiological Mechanisms

From the perspective of neuroscience, curvilinear shapes may affect neural activities in the brain, activate the pathways related to positive emotions, and reduce the activities associated with negative emotions (Ruta et al., 2023). The changes in heart rate support its role in emotion regulation, providing directions for further research (Northoff et al., 2019).

5.2 | TheInfluenceandSignificanceofModelingLanguage on Creative Output

5.2.1 | The Synergistic Mechanism with Environmental Factors

Curvilinear shapes have been demonstrated to augment creative output. This phenomenon resonates with the impact of natural elements on creativity, as both collaboratively construct a conducive psychological milieu. Thereby, the significance of the comprehensive design of the environment is underscored (Wu et al., 2021). It is advocated that the modeling language ought to synergize with other factors to potentiate creativity (Beversdorf et al., 2019).

5.2.2 | Implications for Design Practice and Broad Application Prospects

The modeling language should be taken into account in the design of educational and work environments. For instance, introducing curvilinear elements into classrooms and offices can stimulate creativity (Lloyd-Cox et al., 2022). Product design can also draw on this, enhancing the emotional appeal and user experience. Moreover, it can provide new ideas for artistic creation and so on (Gieseke et al., 2021).

5.3 | Advantages and Limitations of the Research

5.3.1 | Research Advantages

A Paragon of Multidisciplinary Integration and Innovation: By integrating multidisciplinary knowledge and methods and conducting interdisciplinary teamwork, the advantages of each discipline are complementary, enriching the research content and enhancing the scientificity and reliability of the results (Yang et al., 2024). A Paragon of Scientific and Rigorous Experimental Methods: The virtual reality technology is used to control variables, and multiple measurement tools are employed for multi-dimensional assessment, ensuring the consistency and repeatability of the experimental environment. Thus, the results are comprehensive, accurate, and convincing (Willinger et al., 2022).

5.3.2 | Limitations of the Research

- The Predicament of Constrained Sample Representativeness: The present study is encumbered by a relatively diminutive sample size, which is further compounded by its derivation from specific geographical regions, thereby entailing a circumscribed range of cultural backgrounds. Such lim-

itations inevitably impinge upon the generalizability of the research outcomes. To address this concern, future investigations should prioritize the augmentation of sample diversity to enhance the external validity of the findings (Cheung et al., 2019).

- The Shackles Imposed by the Virtual Nature of the Experimental Setting: The virtual environment employed in this research deviates from the real-world context, particularly in terms of tactile feedback, which consequentially impacts the experiential dimension of the participants. To fortify the robustness of the results, subsequent studies could consider integrating augmented reality technologies or conducting on-site observations as a means of validating the obtained findings (Duan et al., 2019).

- The Boundary Constraints of Research Variables: The current research predominantly centers around spatial shapes, while other elements within the domain of modeling language, as well as individual difference variables, remain inadequately explored. To comprehensively elucidate the research topic, future endeavors should strive to broaden the spectrum of variables under consideration and meticulously examine the interactive effects among multiple variables (Wyse et al., 2019).

6 | RESEARCH CONCLUSIONS AND PROSPECTS

6.1 | Summary of Research Conclusions

This research has unequivocally substantiated that diverse modeling language environments exert a significant influence on the emotional, physiological, and creative aspects of individuals. Specifically, curvilinear shapes have been demonstrated to possess an advantageous effect in relation to positive emotions, heart rate modulation, and the stimulation of creativity, whereas rectangular shapes present contrasting characteristics. These findings not only furnish empirical support for theoretical investigations but also unravel the essential and pivotal role that modeling language plays within the realm of human experiences.

6.1.1 | Elaboration on the Theoretical and Practical Significance

Theoretical Significance: This research has effectively addressed a significant lacuna within the domain of the relationship between modeling language and emotional expression. By astutely amalgamating multidisciplinary theories, it has meticulously dissected the underlying mechanisms governing this intricate relationship. Notably, the systematic examination of spatial shape variables within a three-dimensional virtual milieu has furnished novel impetus to the theoretical edifices of environmental psychology, neuroarchitecture, and related disciplines, thereby broadening their investigative frontiers. The resultant research outcomes are instrumental in forging a more exhaustive and profound theoretical scaffolding, further explicating the convoluted interactive tenets between human emotions and the ambient environment. Moreover, it proffers inventive paradigms and methodologies for interdisciplinary inquiries, thus

emerging as a cardinal wellspring of impetus that propels the incessant progression of pertinent disciplines in this particular research terrain.

Practical Significance: The present research proffers principles and orientations of substantial guiding value across a multitude of practical arenas, encompassing architectural design, interior design, and product design. In light of the research conclusions, designers are empowered to judiciously and precisely employ modeling language so as to artfully mold users' emotional experiences and behavioral modalities in accordance with the specific functional requisites of diverse scenarios.For instance, the artful integration of curvilinear elements within innovative educational spaces and school classrooms can efficaciously elicit students' positive emotions and creativity, thereby engendering a learning milieu replete with vitality and inspiration. In the context of business office settings such as conference rooms, the judicious applicationof rectangular elements contributes to the cultivation of a stable, professional, and solemn ambience, augmenting the efficacy and professionalism of business interactions.Furthermore, product designers can avail themselves of the research outcomes to optimize the external configurations of products, thereby enhancing the emotional value-added of products. This, in turn, leads to a conspicuous amelioration of users' experiential and satisfaction levels, culminating in an elevation of product competitiveness in the market and the generation of greater commercial value for enterprises.

6.2 | Prospects for Future Research Directions

Expanding the Diversity of Research Subjects and Environments: Future research endeavors ought to be actively and vigorously engaged in further widening the gamut of research subjects. This implies the extensive incorporation of cohorts hailing from disparate age strata, multifarious cultural backgrounds, and variegated socioeconomic standings. The overarching objective is to holistically and profoundly unearth the ubiquitous principles governing the influence of modeling language on emotional expression, in tandem with the idiosyncratic disparities manifested across diverse groups.

Simultaneously, the typology of research environments should be rendered more copious and heterogeneous. This entails the comprehensive coverage of a plethora of scenarios, such as public spaces (encompassing bustling marketplaces, serene libraries, and the like), medical facilities (including sundry departments within hospitals, rehabilitation centers, et al.), and outdoor natural landscape settings. Through an in- depth exploration of the emotional ramifications of modeling language within different functional arenas, more precise and highly bespoke scientific underpinnings can be furnished for the human-centered design of assorted environments. Thereby, the design can be better attuned to the sundry requisites of distinct individuals in disparate scenarios.

Deepening the Research on Variables and the Analysis of Interaction Effects: It is imperative to conduct an in-depth excavation of the latent impact mechanisms of a broader spectrum of modeling language elements, encompassing the textural disparities of materials, the nuanced chromatic variations, and the artful manipulation of light and shadow, along with their multifarious combinations, upon emotions and behaviors. A systematic dissection of the labyrinthine interactional nexuses among disparate modeling language variables, as well as between modeling language and other environmental determinants, such as the thermal oscillations, the hygrometric differentials, and the acoustic amplitude variances, is warranted.

Furthermore, due cognizance must be accorded to the moderating influence exerted by individual difference variables, including the polymorphic personalities, the idiosyncratic cognitive modalities, and the variegated cultural backgrounds, within the nexus of modeling language and emotional expression. Grounded on these premises, the construction of more intricate, refined, and accurate theoretical paradigms is essential. Such models would facilitate more precise prognostication and profound explication of the regulative principles underlying the impact of modeling language on human emotions and behaviors, thereby endowing design practice with more prescient and directive theoretical scaffolding.

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Integrating New Technologies and Methods to Enhance Research Precision: In the wake of the meteoric advancement of science and technology, prospective research endeavors ought to be zealously engaged in the assimilation of a greater array of nascent technologies. To exemplify, brain-computer interface technology, which permits the direct interchange of information between the cerebral cortex and external apparatuses, thereby paving the way for an incisive exploration of the instantaneous impacts of

modeling language upon neural activities within the brain.

Moreover, eye-tracking technology, which meticulously registers the allocation of visual attention and the trajectories of ocular movements among participants when they are presented with diverse modeling languages, thus unearthing the nexus between visual perception and emotional reactivity. Additionally, physiological multi- modal monitoring technology, which concurrently gauges multiple physiological indices, such as heart rate variability, galvanic skin response, and electroencephalogram, thereby comprehensively dissecting the physiological responses elicited by modeling language from a plurality of physiological dimensions.By procuring more copious and accurate physiological and behavioral data, a profound dissection of the internal mechanisms underlying the influence of modeling language on emotional expression at the neurophysiological stratum will be carried out. Concurrently, it is requisite to actively probe into innovative research methodologies. For instance, big data-oriented analytical approaches, which entail the collection and scrutiny of voluminous actual design case data and user feedback data, with the aim of excavating the latent patterns and regularities between modeling language and emotional expression concealed within the vast expanse of big data.In addition, machine learning algorithms, which harness machine learning models to effectuate classification, prediction, and pattern recognition of complex data, thereby proffering intelligent decision-making support for the design and application of modeling language. Through the leveraging of these novel technologies and methodologies, the research within this domain will be impelled to progress towards enhanced precision and profundity, culminating in a qualitative ascendancy in the research echelon.

Expanding the Application Domains and Deepening Interdisciplinary Collaborations: Ceaselessly expand the application scopes of research outcomes and extend them to a plurality of arenas, namely urban planning (such as the layout and design of urban public spaces, the configuration of the urban skyline, and so forth), landscape design (including the planning and establishment of parks, squares, streetscapes, among others), digital art creation (for instance, how to employ modeling language to evoke the emotional resonance of the audience during the creation of virtual reality art, digital animation, and the like), and human-computer interaction design (such as the design of intelligent device interfaces, the design of virtual interaction environments, and the like). Through facilitating the innovative integration and application progression of modeling language across diverse fields, novel creative stimuli and design conceptions will be introduced to these fields. Further augment the profundity and extensiveness of interdisciplinary collaboration by more intimately amalgamating the puissance of multifarious disciplines. Natural sciences (such as biology and physics, which furnish the substratum of fundamental scientific tenets for the research), engineering technologies (for instance, computer technology and material engineering technology, which endow the means of technological actualization for the research), and humanities and social sciences (like sociology and culturology, which bestow the socio-cultural backdrop and the perspectives of human behavior research for the research) are to be concertedly harnessed. Collectively surmount the intricate conundrums encountered in the exploration of the nexus between modeling language and emotional expression. Realize the profound integration and synergistic progression of theoretical research and practical applications. Contribute greater sagacity and puissance to the amelioration of human life quality and the impetus of socially sustainable development, thereby forging a more felicitous future conclusion, this research has achieved important stage-wise results in the field of

the relationship between modeling language and emotional expression. However, there remain extensive uncharted areas lying ahead, awaiting further in-depth exploration and research. Future research is expected to gradually unveil the profound impact mechanisms of modeling language on human emotions and behaviors in broader fields and at deeper levels. Thereby, it will provide more scientific, precise, and comprehensive theoretical guidance for design practice, effectively promoting the continuous innovative development and progress to new heights in related fields.

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Philosopher's Compass 1/1 (2025): 129–145.

Technostress in Human-Computer Interaction

Haiwen Wang[1]

[1]Wuhan Technology and Business University, Wuhan, China wanghaiwen@wtbu.edu.cn

ABSTRACT

The rapid development of Information and Communication Technologies (ICT) has brought widespread benefits to society. However, it has also given rise to the problem of technostress, which exerts numerous negative influences on individual and organizational users of ICT. Based on the theoretical literature on ICT, exploratory interviews, and focus group discussions, this paper studies the phenomenon of technostress in the context of human-computer interaction for ordinary ICT users. The central aim is to design stress-sensitive adaptive systems that alleviate technostress and thereby enhance user well-being, health status, performance, and productivity. In achieving this aim, this paper will also explore theoretical models of technostress, including its causes, influencing factors, and consequences. Moreover, it substantiates the adaptive systems by proposing blueprints that cover design guidelines, specific architectures, implementation roadmaps, and evaluation plans. Lastly, future research directions for technostress are elucidated.

KEYWORDS: Technostress, Human-Computer Interaction, Adaptive Systems, Stress Management, Information and Communication Technologies

1 | INTRODUCTION

1.1 | Research Background

The rapid development of Information and Communication Technologies (ICT) has profoundly transformed the production and lifestyle of human society, making the acquisition and transmission of information more efficient. However, with the popularization of technology, the phenomenon of "Technostress" (TS), this "digital burden", has gradually emerged. Technostress refers to the psychological stress experienced by individuals who are unable to effectively adapt to the requirements of using new technologies (Ragu-Nathan et al., 2008). Although this concept was first proposed by Brod, 1984, in recent years, with the high penetration of technological devices and the increasing complexity of human-computer interaction, the negative impacts of technostress on the individual, organizational, and even social levels have become more and more prominent.

The root cause of technostress lies in the imbalance between individual capabilities and the demands

of the technological environment. According to the stress interaction model of Lazarus, 1984, when facing technological challenges, individuals need to quickly complete the primary assessment (judging whether the situation constitutes a stressor) and the secondary assessment (evaluating whether the coping resources are sufficient). If an individual's resources are insufficient to meet the external technological requirements, psychological reactions such as anxiety and burnout may occur, and they may also manifest as abnormalities in physiological stress indicators (such as heart rate, cortisol level, etc.). This phenomenon not only impairs users' well-being and health but also reduces their productivity, causing direct economic losses to organizations (Tarafdar et al., 2014).

With the increasing complexity and high frequency of technology applications, the issue of technostress is expanding from a single domain to a broader social context, covering multiple fields such as workplaces, educational environments, and daily life. For example, in remote work, employees may feel overwhelmed due to frequent online meetings, instant messages, and excessive information loads; in the educational field, students may experience psychological burdens due to the complexity of online learning technologies and the uncertainty of the learning rhythm. Therefore, researching how to alleviate technostress through optimizing human-computer interaction design has become an important issue that urgently needs to be addressed.

1.2 | Research Significance

This research focuses on the phenomenon of technostress experienced by ordinary users in human-computer interaction. By constructing a stress-sensitive adaptive system, it aims to explore how to center on user needs in technology design and provide personalized interventions, ultimately achieving humanized technology management. This research has multiple significances:

1. Theoretical Value: Starting from the theoretical model of technostress, it expands the academic boundaries of research on human-computer interaction and stress management, providing a new perspective for understanding the dynamic generation mechanism of technostress

2. Practical Value: It provides a set of design guidelines and technical solutions for ICT developers, promoting the organic integration of technology and user needs.

3. Social Value: By alleviating technostress, it improves users' mental health and well-being, enhances the overall well-being of society, and promotes the sustainable development of technology.

1.3 | Research Objectives

To address the above issues, this research aims to achieve the following objectives

1. To clarify the generation mechanism of technostress and its multi-level impacts on users;

2. To propose a design blueprint for a stress-sensitive adaptive system, including design guidelines, system architecture, implementation path, and evaluation plan;

3. To verify the effectiveness of the system through experiments and provide empirical support;
4. To explore future research directions to optimize the theory and practice of technostress management.

1.4 | Research Methods

This research adopts the goal-oriented design science research method (Peffers et al., 2007). It integrates theoretical models and empirical research results from a multidisciplinary perspective, specifically including the following steps:

1. Integration of Theoretical Foundations: Summarize the main theoretical frameworks and the latest research progress of technostress to construct the theoretical foundation of this research.
2. Qualitative Research: Through expert interviews and focus group discussions, identify the key problems of technostress and possible solutions.
3. Design and Development: Propose a design blueprint for a stress-sensitive adaptive system, covering the transformation process from theory to practice.
4. Experimental Verification: Design and conduct laboratory and field experiments to evaluate the role of the system in alleviating technostress.
5. Result Analysis and Optimization: Conduct statistical analysis of experimental data, extract design improvement suggestions and explore future research directions.

2 | THEORETICAL FOUNDATIONS OF TECHNOSTRESS

2.1 | Theoretical Model of Technostress

The stress interaction model proposed by (Lazarus, 1984) provides an important theoretical framework for understanding the generation mechanism of technostress. This model indicates that the emergence of stress stems from the imbalance between individuals and the demands of the environment. When individuals are confronted with external stimuli, they first conduct a primary appraisal to determine whether the stimulus is irrelevant, beneficial, or stressful. If it is judged as a stressful stimulus, they then proceed to a secondary appraisal to evaluate whether they possess the necessary coping resources. In a technological context, when users perceive that a task exceeds their capabilities, such as when facing complex interface operations or frequent information disruptions, the following stress responses may occur:

1. Physiological Level: An increase in heart rate, an elevation in cortisol secretion, changes in skin conductance, etc. (Riedl, 2012),(Tams et al., 2014).
2. Psychological Level: Negative emotions such as anxiety, burnout, and a sense of frustration (Tarafdar et al., 2014).

3. Behavioral Level: A decline in task efficiency, distraction of attention, or technology avoidance behaviors (Maier et al., 2015).

Furthermore, according to the arousal theory put forward by Yerkes and Dodson, 1908, individuals need to reach an appropriate level of stress during task execution. Both excessively high and low physiological arousal levels can have a negative impact on performance. The complexity of technostress lies in the fact that the dynamic changes in its arousal level are often unpredictable, which poses higher requirements for human-computer interaction design.

2.2 | Classification of Technostressors

Based on existing research (Tarafdar et al., 2007, 2014), technostressors can be further classified into the following categories:

1. Work-Characteristic-Related Stressors
   (a) Task Monotony: Repetitive tasks reduce users' attention and increase psychological burnout.
   (b) Task Complexity: Excessively complex functions of the technological interface lead to an increase in learning costs and operational difficulties (Riedl, 2012).
   (c) Multitasking: When simultaneously completing multiple tasks, users' attention is distracted and stress significantly rises (Hancock & Szalma, 2018).
2. Technology-Environment-Related Stressors
   (a) Technology Overload: Users are overwhelmed by the need to process excessive amounts of information.
   (b) Technology Invasion: Technology blurs the boundaries between work and life, such as message notifications during non-working hours (Tarafdar et al., 2007).
   (c) Technology Complexity: The redundant functions of technological devices and the incomprehensible operational logic increase users' learning pressure.
   (d) Technology Insecurity: Users are worried about their insufficient technical capabilities or being replaced by more proficient colleagues.
   (e) Technology Uncertainty: Frequent system updates or software changes cause difficulties in adaptation.
3. Organization-Environment-Related Stressors
   (a) Role Overload: Excessive tasks or responsibilities that exceed users' capabilities lead to intensified stress (Rizzo, 1970).
   (b) Role Conflict: Contradictory requirements within the organization (such as balancing efficiency and quality) prevent users from effectively balancing tasks.

4. Social-Environment-Related Stressors a) Social Pressure: External expectations (such as quickly responding to emails) impose implicit pressure on users (Edwards, 1998).

2.3 | Manifestations and Impacts of Technostress

Technostress is not only manifested as immediate physiological and psychological reactions of individuals but may also trigger long-term health and productivity problems:

1. Physiological Manifestations Technostress usually occurs before individuals consciously perceive it, manifested as excessive activation of the nervous system. For example, an increase in cortisol levels (Dickerson & Kemeny, 2004), a decrease in heart rate variability, pupil dilation, etc. (Riedl, 2012). These physiological indicators can be measured by modern biosensors (such as smart bracelets and skin conductance detectors), providing a basis for real-time stress monitoring.

2. Psychological and Behavioral Impacts Technostress can trigger various psychological problems, including anxiety, a sense of frustration, and chronic fatigue, and lead to a decline in task completion efficiency. For example, when users frequently switch their attention in a multitasking environment, their error rate significantly increases, and in the long term, it may lead to technological burnout (Tarafdar et al., 2014).

3. Impacts on Health Long-term technostress may lead to chronic diseases such as hypertension, cardiovascular diseases, and a decline in immune function (Arnetz & Wiholm, 1997). In addition, stress is also closely related to major health problems such as obesity and stroke.

4. Impacts on Organizations Technostress not only reduces individual performance but may also weaken team collaboration capabilities and organizational efficiency. For example, workplaces with high technostress may face problems such as high employee turnover and low job satisfaction (Maier et al., 2015).

2.4 | Theoretical Implications of Technostress Research

From the above comprehensive analysis, it can be seen that technostress is a complex issue in human-computer interaction research, featuring multiple levels and dimensions:

1. Dynamism: Stress continuously changes during the process of individual perception, appraisal, and coping.

2. Multimodality: The manifestations of technostress involve multiple dimensions such as physiological, psychological, and behavioral.

3. Contextuality: Different technological scenarios and user characteristics will affect the sources and intensities of technostress.

Based on this, this research takes the stress interaction model as the theoretical framework to explore how to alleviate technostress through human-computer interaction design in order to achieve the win-win goal of enhancing users' well-being and productivity.

3 | DESIGN BLUEPRINT OF THE STRESS-SENSITIVE ADAPTIVE SYSTEM

3.1 | Design Principles

Based on the theoretical analysis of technostress and a multidisciplinary perspective, this research proposes that the design of a stress-sensitive adaptive system should adhere to the following principles:

1. User-Centered Stress Perception The system is required to dynamically monitor the stress status of users and evaluate their stress levels in real-time through multimodal data (such as physiological signals, behavioral data, and environmental data). This process should take into account individual differences and provide personalized stress analysis models to ensure the universality and sensitivity of the system for different user groups.

2. Immediate Intervention and Feedback When the user's stress reaches a threshold, the system should promptly trigger intervention measures, such as adjusting the interface display mode, reducing information input, or providing positive prompts, to relieve the user's stress. Meanwhile, the system should feedback the user's stress status in a friendly and concise manner to enhance the user's self-regulation ability.

3. Privacy and Ethical Protection Since the system needs to collect a large amount of personal data (such as physiological signals and behavioral data), it must strictly adhere to the principles of privacy protection during the data collection and use processes. Ensure user informed consent, data anonymization, and transparency of the use purpose to enhance user trust and technology acceptance.

4. Multi-Level Adaptive Interventions The system should support multi-level intervention strategies, ranging from physiological adjustments at the individual level (such as screen brightness adjustment, prompt tone optimization) to strategic optimizations at the organizational level (such as task assignment improvement, work rhythm adjustment), to achieve stress management at different levels.

5. Technical Feasibility and System Stability Considering real-time performance and reliability, the system design should integrate efficient data processing technologies and machine learning algorithms to accurately identify and intervene in stress states while ensuring a smooth user experience.

3.2 | System Architecture

According to the above design principles, this paper proposes a high-level architecture of a stress-sensitive adaptive system. This architecture is divided into the perception layer, the analysis layer, and the intervention layer, covering three dimensions: individual, technical, and organizational.

1. Perception Layer

   Responsible for real-time collection of users' multimodal data, including:

   (a) Physiological Data: Heart rate, skin conductance, pupil dilation, electromyographic signals, etc., obtained through wearable devices (such as smart watches).

   (b) Behavioral Data: Mouse click frequency, keyboard input speed, eye movement trajectories, etc., achieved through the interaction records of user devices.

   (c) Environmental Data: Noise level, light intensity, etc., collected by environmental sensors.

2. Analysis Layer

   This layer evaluates the user's stress level and predicts stress trends through data fusion and modeling:

   (a) Data Preprocessing: Clean and standardize multimodal data to eliminate noise interference.

   (b) Stress Evaluation Model: Based on machine learning algorithms, dynamically integrate multiple data sources to generate personalized stress evaluation indicators.

   (c) Trend Prediction and Classification: Analyze the time series of stress data to predict the trend of user stress changes and provide a decision-making basis for intervention.

3. Intervention Layer

   According to the stress evaluation results, the system provides adaptive interventions at three levels:

   (a) Individual Level: Relieve the user's immediate stress by adjusting screen brightness, reducing the density of information presentation, providing psychological soothing content (such as background music or breathing guidance), etc.

   (b) Technical Level: Optimize the system interaction mode, such as dynamically adjusting task priorities, delaying non-critical notifications, etc.

   (c) Organization Level: Utilize aggregated data to identify team stressors and provide data-based suggestions to managers, such as adjusting workload or improving work processes.

3.3 | Implementation Path

The implementation path of the system adopts a phased promotion strategy, from prototype development to largescale deployment, to ensure design feasibility and user acceptance.

1. Phase A: Prototype Verification Develop an initial prototype of the stress-sensitive adaptive system and test its applicability and accuracy for different user groups in a laboratory environment. For example, by simulating multitasking operation scenarios, evaluate the system's real-time response ability to user stress changes.

2. Phase B: User Testing Select the target user group (such as IT practitioners, online education users), deploy the system in a real work or learning environment, collect usage feedback and improve the design. Focus on the ease of use of the system, the intervention effect, and user privacy protection.

3. Phase C: Scenario Expansion Expand the system functions in a broader context (such as remote working, collaboration platforms), optimize the adaptability of multimodal data, and improve the system's performance in a multitasking environment.

4. Phase D: Large-Scale Deployment Combine the requirements at the organizational level, integrate the system into the existing technological ecosystem of enterprises or educational institutions, and fully support the stress management of employees or students.

3.4 | Evaluation Plan

To verify the effectiveness and user acceptance of the system, the following evaluation plan is designed:

1. Laboratory Experiment

   (a) Objective: Test the real-time and precision of the system in stress perception and intervention.

   (b) Method: Simulate high-stress scenarios (such as information overload, task conflict), and evaluate the system intervention effect through questionnaires, physiological data monitoring, and behavior observation.

2. Field Experiment

   (a) Objective: Verify the applicability and usability of the system in real scenarios.

   (b) Method: Deploy the system in a work or learning environment for a long period, compare the changes in user stress levels and performance improvements before and after using the system.

3. User Satisfaction Survey

   (a) Objective: Understand users' evaluations of the ease of use of the system, intervention effect, and privacy protection.

   (b) Method: Adopt a combination of questionnaires and interviews to analyze user feedback and optimize the system design.

4. Long-Term Utility Analysis

(a) Objective: Evaluate the impact of the system on users' long-term stress management.

(b) Method: Use the system in an enterprise environment for more than 8 weeks, track stress indicators (such as cortisol level) and performance indicators (such as work efficiency, error rate), and analyze the continuous effect of the system intervention.

3.5 | Challenges and Solutions

Although the stress-sensitive adaptive system is innovative in concept, it may face the following challenges during the implementation process:

1. Data Acquisition Accuracy and Stability: It is necessary to improve the sensitivity and anti-interference ability of sensors to ensure data quality.

2. Real-Time Analysis Computational Performance: The combination of edge computing and cloud computing can be adopted to improve real-time performance and processing capacity.

3. User Privacy and Ethical Issues: Through data encryption and hierarchical authorization mechanisms, user privacy can be maximally guaranteed.

4 | EXPERIMENTAL DESIGN AND VERIFICATION

To verify the effectiveness of the stress-sensitive adaptive system, a series of experiments have been designed in this paper, including laboratory experiments, field experiments, and long-term utility evaluations. The experiments follow the norms of engineering papers, covering experimental settings, data collection, analysis methods, statistical results, and system performance evaluations.

4.1 | Objectives of the Experiments

There are four key objectives: To verify the detection and intervention effects of the stress-sensitive adaptive system on user stress in different situations; to evaluate the accuracy and robustness of multimodal data in stress identification; to analyze the comprehensive impacts of system interventions on users' well-being, work efficiency, and physiological indicators; and to explore the sustainable impacts of long-term system use on stress management.

4.2 | Experimental Settings

1. Experiment 1: Stress Perception Verification Experiment

   Objective: To verify the ability of the system's multimodal data to identify stress states.

Participants: 30 users (with a balanced gender distribution and an average age of 35 years).

Scenario Settings: Simulate high-stress environments, including multitasking (task overload scenarios), increased interface complexity (technology complexity scenarios), and sudden technical problems (technology unreliability scenarios).

Data Collection: Utilize smart bracelets to collect physiological data (such as heart rate, skin conductance, pupil dilation, etc.). Record mouse click frequency, keyboard input speed, and error rate through user behavior logs. Meanwhile, combine with the user subjective stress questionnaire.

2. Experiment 2: System Intervention Experiment Objective: To test the intervention effects of the system in different stress situations. Participants: 50 users, randomly divided into the experimental group (using the stress-sensitive adaptive system) and the control group (using the traditional system).

   Task Description: Complete a set of complex office tasks, including email classification, document editing, and multi-threaded task scheduling.

   Intervention Methods: The system dynamically adjusts the interface brightness, reduces the notification frequency, or provides soothing background music according to the real-time stress state.

   Measurement Indicators: Changes in stress state (based on physiological data), task completion time, error rate, and user satisfaction (Likert scale).

3. Experiment 3: Long-Term Utility Evaluation Experiment

   Objective: To evaluate the impacts of long-term system use on users' stress management and work efficiency.

   Participants: 25 employees within an organization, using the system for 8 weeks.

   Data Collection: Record weekly stress states, physiological indicators (such as cortisol level), work efficiency (task completion rate, error rate), and subjective well-being scores.

4.3 | Data Processing and Analysis

1. Data Preprocessing

   Physiological data (such as heart rate,skin conductance) are processed through smoothing filtering and denoising

   Behavioral data are analyzed using the sliding window analysis method to extract key features such as the rate of change of mouse click frequency and task completion speed.

   Questionnaire data are standardized to convert users subjective stress scores into interval values ranging from 0 to 100.

2. Construction and Verification of the Stress Evaluation Model

   The stress evaluation model is constructed by integrating multimodal data using the Random Forest algorithm.

Model verification is carried out using the training set (70% of the data) and the test set(30% of the data).

Evaluation indicators include model accuracy, recall rate, and F1 value.

3. Statistical Analysis

Analysis of variance (ANOVA) is performed on the changes in stress state and task efficiency data to verify the significance of the system intervention effects.

Multiple linear regression analysis is used to explore the relationships between stress indicators and users' performance and satisfaction.

Correlation analysis is used to evaluate the consistency between the subjective questionnaire and physiological data.

4.4 | Experimental Results

Table 1: Results of the Stress Perception Verification Experiment

Scenario	Average Heart Rate (bpm)	Skin Conductance Change (μS)	Error Rate (%)	Subjective Stress Score (0–100)
Baseline (No Stress)	72	0.05	2.3	15.2
Task Overload Scenario	94	0.12	8.7	68.4
Technical Complexity Scenario	88	0.10	6.5	61.3
Technical Failure Scenario	102	0.15	12.4	78.5

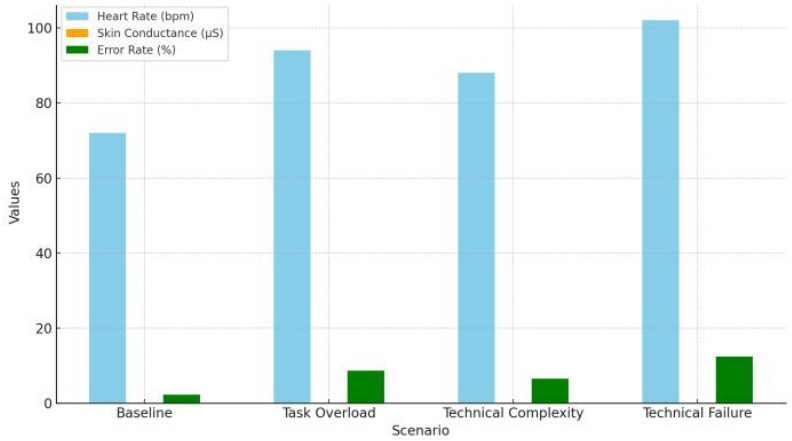

Figure 1: Stress Perception Validation

Analysis: The accuracy rate of the system's multimodal stress evaluation model on the test set reaches 91.3%, and the F1 value is 0.89, indicating that the model performs well in detecting different stress states.

Table 2: Results of the System Intervention Experiment

Group	Average Completion Time (s)	Average Error Rate (%)	Subjective Satisfaction (1–5)	Average Stress Score (0–100)
Experimental Group	462	4.8	4.3	37.2
Control Group	529	7.5	3.1	62.8

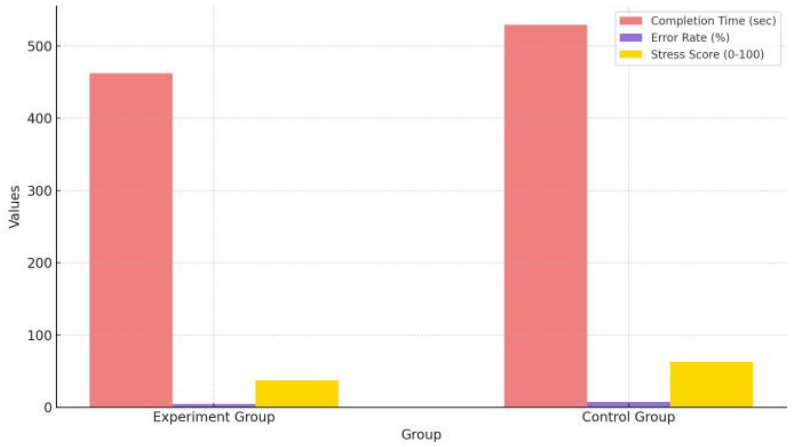

Figure 2: System Intervention Results

Analysis: The stress scores of the users in the experimental group are significantly lower than those of the control group ($p < 0.01$), and they also perform better in terms of task efficiency and satisfaction.

Table 3: Results of the long-term Utility Evaluation Experiment

Week	Average Heart Rate Variability (ms)	Average Cortisol Level (nmol/L)	Average Task Completion Rate (%)	Subjective Wellbeing Score (1–10)
Week 1	38.2	18.6	78.4	6.5
Week 4	42.7	15.3	85.2	7.8
Week 8	46.5	13.8	91.7	8.6

Analysis: The physiological indicators (heart rate variability, cortisol level) and work efficiency of the users improve significantly over time, and the subjective well-being scores increase week by week, indicating that the system has a positive effect on long-term stress management.

4.5 | System Performance and User Feedback

1. System Performance

   Average response time: 2.3 seconds

   Data processing throughput: 120 records per second

   Data accuracy: The detection accuracy rate of the multimodal stress evaluation model for high-stress states is 92.5%.

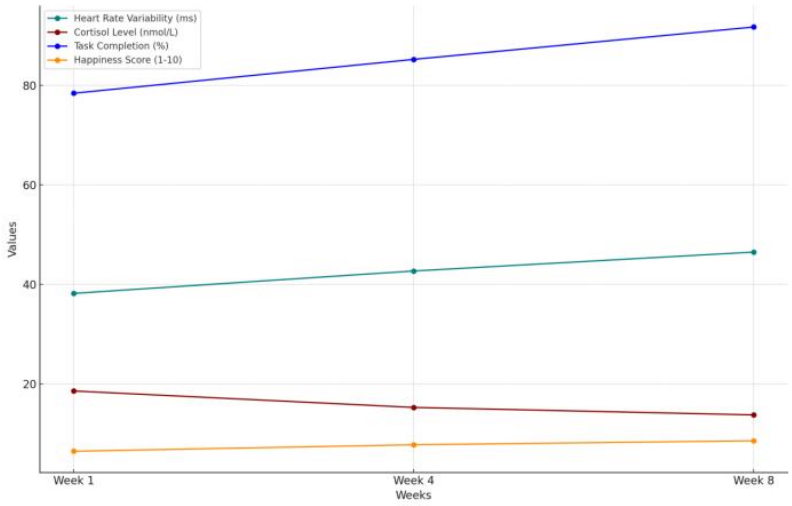

Figure 3: Long-Term Effects

2. User Feedback

   85% of the users believe that the system interventions are effective, especially in significantly reducing stress in task overload scenarios.

   The users' rating of the privacy protection mechanism is $4.5/5$, showing that the system design conforms to ethics and user expectations.

4.6 | Summary

The experimental results demonstrate that the stresssensitive adaptive system exhibits good performance in both stress detection and intervention. Especially in multitasking environments, it significantly improves users' efficiency and reduces their subjective perception of stress. The long-term utility evaluation further verifies the continuous effectiveness of the system, providing a solid basis for future practical applications.

5 | DISCUSSION AND CONCLUSIONS

5.1 | Research Contributions

Through the design and verification of the stresssensitive adaptive system, this research has proposed innovative solutions to technostress and made the following contributions to the field of human-computer interaction:

1. Theoretical Contributions

   The integration of the theoretical model of technostress with multimodal physiological data has expanded the theoretical boundaries of stress perception.

A multi-level stress intervention design framework has been proposed, providing a systematic approach to stress management from the three dimensions of users, technology, and organizations.

2. Methodological Contributions

   The construction of the stress-sensitive adaptive system, combined with machine learning models, has enabled realtime stress assessment and dynamic intervention.

   A multi-stage experiment covering laboratory, field, and long-term usage scenarios has been designed, providing a rigorous research paradigm for the verification of engineering solutions.

3. Practical Contributions

   The system has significantly enhanced users' well-being and work efficiency in high-pressure situations, offering a practical and feasible solution to address technostress in actual work scenarios.

The research results have direct reference value for the practice of ICT technology design, organizational management, and stress relief programs.

5.2 | Discussion of Experimental Results

1. Accuracy and Robustness of Stress Perception

   The experimental results indicate that by integrating physiological and behavioral data, the system can effectively distinguish different stress states (with an accuracy rate of 91.3%). This validates the advantages of multimodal data in stress assessment and also suggests that personalized calibration of the stress model is crucial in a dynamic interaction environment.

2. Effects of System Intervention

   System interventions have significantly reduced users' subjective stress scores (by 25.6 points) and task error rates (by 2.7%) and improved task completion efficiency (by reducing the time by 13%). This demonstrates the practical application potential of the stress-sensitive adaptive design in the context of technological complexity and multitasking.

3. Positive Effects of Long-Term Utility

   In the long-term evaluation experiment, physiological stress indicators such as heart rate variability and cortisol level of users showed a significant improvement trend, and well-being and task completion rates continued to increase. This indicates that the system can not only achieve shortterm stress relief but also has good long-term effects.

4. Limitations and Challenges

   Sample Limitation: Although the experiment covered multitasking scenarios, the participants were mainly knowledge workers. In the future, it is necessary to extend to other populations (such as users in the educational field).

Complexity of Multimodal Data: There are certain technical challenges in the real-time collection and analysis of physiological data in a dynamic environment, especially issues related to noise interference and sensor accuracy.

Privacy and Ethical Issues: Although the system has designed a privacy protection mechanism, users still have concerns about the collection of physiological data.Further exploration of the balance between ethics and technology is needed.

5.3 | Future Research Directions

1. Expansion to Multiple Scenarios Explore the applicability of the system in other complex technological scenarios, such as distance education, online healthcare, or smart home environments.
2. Optimization of Dynamic Stress Models Introduce deep learning algorithms to enhance the system's stress prediction ability in dynamic scenarios and optimize the model through continuous feedback.
3. Research on Social and Organizational Impacts Further analyze the potential impacts of the system at the organizational level, including employee collaboration efficiency, team dynamics, and organizational culture adaptability.

5.4 | Cross-Cultural Research

Compare the perception of technostress and the acceptance of the system among users with different cultural backgrounds to support global design.

6 | RESEARCH SIGNIFICANCE AND PROSPECTS

6.1 | Research Significance

Through the design and verification of the stresssensitive adaptive system, this research has revealed the dynamic interaction relationship of technostress at both the individual and organizational levels. The research emphasizes the user-centered technology design concept, which not only provides a new perspective for the theoretical research of technostress but also brings profound implications for practical application development.

1. Significance for Users The system helps users effectively cope with technostress, improves their mental health and quality of life, and significantly enhances their well-being and efficiency in high-pressure work environments.
2. Significance for Organizations The stress management system provides organizations with a technological means. By dynamically adjusting task loads and optimizing work processes, it enhances employee performance and satisfaction, contributing to the construction of a healthy work culture.

3. Significance for Technological Development The proposal of the stress-sensitive adaptive system promotes the development of human-computer interaction in a more intelligent and humanized direction, demonstrating the possibility of the harmonious coexistence of technology and human well-being

6.2 | Prospects

Looking ahead, the research on technostress should further combine the trends of sociotechnical development, especially artificial intelligence, the Internet of Things (IoT), and blockchain technologies, to explore more intelligent stress management solutions. In addition, the deepening of interdisciplinary cooperation (such as psychology, biology, and information technology) will bring more innovative possibilities for technostress management.

By continuously optimizing the design of the stresssensitive adaptive system and combining personalized and scalable stress intervention methods, we expect to achieve a deep integration of technology and human health, creating a more inclusive and efficient technology-using environment for users.

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Philosopher's Compass 1/1 (2025): 146–160.

The Roles of Quantification in Design

Yixin Yu[1] **and Jiuyuan Zhu**[2]

[1]Macau University of Science and Technology, Macau, China, 770973192@qq.com

[2]Macau University of Science and Technology, Macau, China, 541055028@qq.com

ABSTRACT

In contemporary society, the depth and breadth of the quantification phenomenon have been continuously expanding, permeating everything from aspects of ordinary life to various specialized fields such as scientific research, social governance, and economic activities. Although this phenomenon has attracted the attention of multiple disciplines, the research in the field of philosophy of technology and design still needs to be further deepened. This study approaches quantification and quantitative research from the perspective of the philosophy of design. By comprehensively applying historical, sociological, and philosophical methods, it analyzes the roles of quantification in aspects such as social governance, individual cognition, and ethical politics, and reveals the underlying ontological, epistemological, and ethical-political issues. Specifically, through three carefully designed experiments, which respectively focus on the social constructiveness of quantitative tools, the ethical applicability of philosophy of design concepts, and the impact of data visualization, the relationships between the design of quantitative tools and user perception, ethical satisfaction, and cognitive efficiency have been empirically verified. This provides new perspectives, methods, and data that back quantitative research, emphasizes the applicability of philosophy of design concepts in quantitative technologies, and aims to promote the rational development of quantification to address the social problems brought about by the quantification phenomenon.

KEYWORDS: Quantification, Quantitative Research, Philosophy of Design, Social Construction, Post-Phenomenology, Ethical Politics

1 | INTRODUCTION

1.1 | The Rise and Importance of Quantification

With the development of modern society, quantification has become an indispensable phenomenon (Porter, 2020). From everyday life to scientific research, from social governance to economic activities, numbers and data are ubiquitous. In the scientific field, quantitative methods are an essential means of knowledge production, aiding scientists in precisely describing and explaining natural phenomena (Desrosières, 1998) (Desrosières et al., 2002). In the engineering field, numbers play a crucial role in the

design and construction of physical infrastructure (Rosenberg, 1994). However, quantification in the social domain possesses unique properties; it not only affects social governance and decisionmaking but also profoundly shapes people's lifestyles and social relationships (Espeland & Stevens, 2008).

1.2 | The Disciplinary Background and Current Status of Quantitative Research

Quantitative research, as an emerging academic field, has attracted attention from multiple disciplines. The research methods of history and sociology provide important perspectives for understanding the development and social impact of quantification (Desrosières, 1998). Historians have explored the pathways of quantitative methods across different disciplines and their close connections with sociopolitical factors (Porter, 2020). Sociologists focus on how quantification reflects and reinforces social power relations and its impact on individual and social behavior (Mau, 2019). However, despite the significance of quantification in the field of philosophy of technology, it has not yet received sufficiently in-depth research (Winner, 2010). The philosophy of technology mainly involves conceptual analysis, ontology, epistemology, and ethical studies of technology. Introducing this perspective into quantitative research can help fill this gap, providing a more comprehensive and in-depth theoretical framework for quantitative research (Brey, 2012).

1.3 | The Purpose and Innovation of This Study

This paper aims to combine quantitative research with design philosophy, delving into the phenomenon of quantification from the cutting-edge perspective of interdisciplinary integration (Friedman & Hendry, 2019). By introducing the concepts and methods of design philosophy, we attempt to reveal the ontological, epistemological, and ethical-political issues behind quantification, expanding the understanding of the nature of quantification. The innovation lies in emphasizing the design nature of quantification as a social technology, discussing its multiple impacts on social construction, individual cognition, and ethical politics, and proposing the application of design philosophy concepts such as Value Sensitive Design (VSD) and Responsible Research and Innovation (RRI) to quantitative practice. This aims to address social issues brought about by quantification and promote its rational development (Schomberg, 2013). At the same time, to further explore the relationship between the design of quantitative tools and user perception, ethical satisfaction, and cognitive efficiency, we have carefully designed a series of experiments. These provide empirical data support for research in this field, further enriching and perfecting the research system that combines quantitative research with design philosophy (Brey, 2012).

2 | EXISTING METHODS OF RESEARCHING QUANTIFICATION

2.1 | Historical Methods

1. The Evolution of Quantitative Methods in Disciplinary Dissemination

   In the literature, quantification and quantitative methods are often associated with statistics, modeling, and other advanced mathematical forms (Desrosières et al., 2002). The traditional view holds that the effectiveness of quantitative methods in the natural sciences, especially their ability to model and describe nature with numbers, has made them tools for social governance and applications in social sciences (Porter, 2020). For instance, Lorenz Kruger argues that the adoption of quantitative methods such as probability theory and statistics across disciplines marks a "probabilistic revolution," which benefited from the shift in physics ontology from determinism to indeterminism. However, some historians have questioned this linear dissemination model (Hacking, 1990). Theodore Porter points out that statistical thinking initially developed in the social sciences, and its political success in describing and analyzing society laid the foundation for the rise in status of the natural sciences (Porter, 2020).

2. The Historical Origins of Quantification in Social Governance

   The development of modern statistics is closely related to the efforts of modern states to use quantitative methods for social governance (Hacking, 1990). From John Graunt's 1662 demographic classic "Observations on the Bills of Mortality" to the rise of statistics in 19th-century social governance, the importance of quantification in social governance is evident (Desrosières, 1998). For instance, Ian Hacking attributes the rise of statistics in social governance in the 19th century to the French Revolution and the increased demand for military statistics by European governments (Hacking, 1990). In addition, traditional legal and commercial practices also influenced the development of probability theory (Porter, 2020). For example, British political arithmetic and German "cameralism" aimed to provide a basis for national policy by collecting statistical data such as censuses. Historians' research on quantification not only focuses on its mathematical form but also emphasizes its essence as a tool for social governance and its evolution in different historical, cultural, and local contexts (Espeland & Stevens, 2008).

2.2 | Sociological Methods

1. The Social Constructivism of Quantification

   The sociological method emphasizes that quantification is a product of social construction, reflecting and reinforcing social power relations (Desrosières et al., 2002). French sociologist Alain Desrosières considers statistics to be both a "tool for proof" and a "tool for governance" (Desrosières, 1998). Statistical facts are socially constructed; they are not objective reflections of pure facts but are determined by social conventions (Latour, 1987). Each quantification is based on a consensus among social members on how to encode, compare, and count objects, and these conventions may change with the variation

of indicators and parameters (Espeland & Stevens, 2008). However, once quantification procedures are encoded and become routine, their social constructivism is often overlooked, leading to a misunderstanding of the objectivity of numbers (Porter, 2020).

2. The Impact of Quantification on Social Behavior

Based on Michel Foucault's concepts of "discipline," "government of populations," "governmentality," and "biopolitics," sociologists describe the counter-effect of quantification. Quantification is not only a description of society but also affects society itself, changing people's perception of themselves, and regulating and controlling behavior (Espeland & Stevens, 2008). For example, Wendy Espeland's research on academic ranking shows that the pursuit of high rankings affects the behavior of students, teachers, and administrators, shaping the behavioral patterns of educational institutions (Espeland & Sauder, 2007). The reactivity of big data technology has also attracted sociological attention to quantification, such as electronic devices actively guiding users' lifestyles by providing targets and activity suggestions (Maur et al., 2019). However, sociological research, while emphasizing the disciplinary role of quantification, has also been criticized, as this perspective may overlook the democratic potential of quantification (Porter, 2020).

3 | A PHILOSOPHY OF DESIGN-BASED APPROACH TO RESEARCHING QUANTIFICATION

3.1 | Ontology and Social Constructivism

1. Ontological Issues of Quantification

From the perspective of design philosophy, the ontological issues of quantification involve whether it is a neutral social construction tool or has its own formative or autonomous causal influence (Latour, 1987). Producers and users of quantification generally believe that quantification numbers reflect or approximate reality, a realism attitude that originates from the measurement concept in natural science (Desrosières et al., 2002). However, social constructivists believe that technology is never purely neutral, and quantification systems are no exception; quantification systems can institutionalize specific value orders, define which social phenomena are worth counting, and provide standards for the observation and evaluation of social phenomena (Porter, 2020). For example, the selection and weight distribution of statistical indicators reflect the value orientation of the current statistical system, which may lead to a one-sided or misleading understanding of social phenomena (Espeland & Stevens, 2008).

2. Quantification and Power-Knowledge Relationship

Quantification is closely connected with the social context, reflecting specific power relations, namely Foucault's "power-knowledge" (Foucault et al., 1977). There is an interdependent relationship between different political systems and quantitative techniques. For instance, censuses and industrial production surveys correspond to the needs of the "engineering state"; price statistics based on classical eco-

nomics are the foundation of the "free market state"; household budget surveys and social insurance actuarial calculations correspond to the "welfare state"; national accounts, consumption and employment indices, and econometrics techniques correspond to the "Keynesian state"; and the "neoliberal state" promotes competition among actors through measurable indicators (Scott, 2020). Quantification, through the measurement and control of social phenomena, achieves governance objectives and demonstrates its unique knowledge-power attributes (Hacking, 1990). Therefore, understanding the social constructivism of quantification requires an in-depth examination of the power relations behind it, which is one of the focal points of design philosophy (Latour, 1987).

3.2 | Epistemology and Post-Phenomenology

1. The Epistemological Foundations of Quantification Epistemological realism is a common attitude towards the philosophical origins of quantitative knowledge, which posits that numbers must "reflect reality" or "be as close to reality as possible" (Desrosières et al., 2002). However, social constructivism and other perspectives challenge this simple realism (Hacking, 1990). In practical applications, users of quantification are not necessarily epistemological realists; epistemological instrumentalism suggests that quantification may not need to reveal the truth of social reality in practical applications but still holds practical value (Espeland & Stevens, 2008). For instance, business accountants use numbers as proof of adherence to good accounting practices, while sociologists and economists use numbers from databases as the basic material for daily research. However, modern society's reliance on quantification often assumes that numbers can reveal reality more accurately and comprehensively than non-quantitative or qualitative means, an assumption that influences decisions and actions (Porter, 2020).

2. Quantification Analysis from a PostPhenomenological Perspective

   Post-phenomenology provides a beneficial perspective for understanding the impact of quantification on human experience (Verbeek, 2005). Post-phenomenology focuses on how technology affects and regulates human consciousness before utilitarian, practical, economic, political, or other cultural interpretations (Latour, 1987). Applied to the study of quantification, postphenomenological analysis reveals the role of quantification practices in shaping individual identities and influencing lifestyles. For example, Ian Hacking points out that during the 19th-century statistical fervor, the classification systems created by statisticians not only described social members but also helped establish occupational and class structures, affecting people's cognition and self-positioning in society (Hacking, 1990). Furthermore, hermeneutics emphasizes how reality is presented to the subject through interpretation; in the process of quantification, the generation and use of numbers are influenced by the preconceptions of quantification experts and also affect the knowledge base of social action (Espeland et al. 2008). Post-phenomenological analysis also reveals the "ambiguity" and "multi-stability" of quantification, meaning that quantification techniques can have different meanings and uses in different social contexts and in the hands of different users (Verbeek, 2005). For instance, the data in the Kinsey Report was used by the homosexual community as a cultural weapon to fight for social recognition,

demonstrating the polysemy of quantification in different social groups (Porter, 2020). This analysis helps break the singular, top-down perspective in quantification research, emphasizing the democratic or "bottom-up" dimension of quantification use (Latour, 1987).

3.3 | Ethical-Political Discussions in Design Philosophy

1. Ethical-Political Issues Arising from Quantification

The social constructivism and post-phenomenological analysis of quantification naturally lead to ethical-political issues. Against the backdrop of the "empirical turn" in philosophy of technology, social interests and values are inevitably intertwined in the design process and products of technology, which calls for a critical normative reflection on quantification (Friedman & Hendry, 2019). The authority of quantification in modern states is associated with accountability, objectivity, and transparency demands in public policy decision-making, but it also raises a series of questions. For example, is it appropriate to completely outsource social decision-making to mathematical models in the era of algorithmic governance? Does the selection and use of quantification indicators reflect specific value orientations, thereby affecting social fairness and democracy? Does the objectivity of statistical conclusions mask the value judgments behind them, leading to a lack of public participation in decision-making processes and a weakening of political discourse (Schomberg, 2013)? These questions indicate that quantification needs to be examined at the ethical and political levels (Latour, 1987).

2. Design Strategies to Address Ethical-Political Issues of Quantification

To address the ethical-political issues brought about by quantification, design philosophy offers several strategies. Value Sensitive Design (VSD) emphasizes fully considering moral consequences in technological design and embedding specific moral values within the technology (Friedman et al., 2008). In the context of quantification as a social technology, VSD can help ensure that the design of quantification systems reflects the pluralistic values of society and avoids the dominance of a single value orientation (Friedman & Hendry, 2019). However, VSD may strengthen the power of technological experts because they play a key role in shaping the moral values within the technology (Schomberg, 2013). To overcome this issue, Responsible Research and Innovation (RRI) calls for the involvement of a broader range of stakeholders in the process of technological innovation, including users, designers, developers, and market managers, to achieve the democratization of technological innovation and make it more aligned with social values (Schomberg, 2013). For quantification research, RRI requires quantitative experts to fully consider potential ethical challenges in the process of data collection and use, promote public participation, and thus reduce the top-down control and disciplinary effects of quantification (Latour, 1987). Through these design strategies, design philosophy provides ethical and political guidance for the rational development of quantification (Friedman & Hendry, 2019).

4 | EXPERIMENTAL DESIGN AND ANALYSIS OF QUANTITATIVE RESEARCH

4.1 | The Overall Framework of Experimental Design

To deeply explore the relationship between the design of quantitative tools and user perception, ethical satisfaction, and cognitive efficiency, we have designed a series of experiments to provide empirical data support for research in this field. The entire experimental design includes three main experiments, focusing on the social constructivism of quantitative tools, the ethical applicability of design philosophy concepts, and the impact of data visualization from a post-phenomenological perspective.

4.2 | Experiment One: Analysis of the Social Constructivism of Quantitative Tools

1. Purpose

   To verify how the design choices of quantitative tools shape users' perceptions of fairness and efficiency.

2. Experimental Method

   Design a virtual resource allocation system where participants must choose between two models: an efficiencyoriented model (maximizing resource utilization) and an equity-oriented model (optimizing the balance of resource distribution). Variables are set in the experiment to adjust the weight ratio of fairness to efficiency in the system (50:50, $70:30, 30:70$), and record users' satisfaction scores for the allocation results (1-10) and their subjective perceptions of fairness and efficiency.

3. Data Scale

   Recruit 300 participants, divided into three experimental groups, each consisting of 100 people.

4. Data Processing

   Compare the differences in user satisfaction and fairness scores under different tool designs using Analysis of Variance (ANOVA), and use linear regression analysis to explore the impact of weight changes on user perception. The following is the result analysis of Experiment One:

Table 1: Analysis of differences in tool design

Weight Ratio (Fairness:Efficiency)	Average Fairness Score	Average Satisfaction Score	P-value
50:50	7.5	8.1	<0.05
70:30	8.9	8.7	<0.01
30:70	5.6	6.3	<0.01

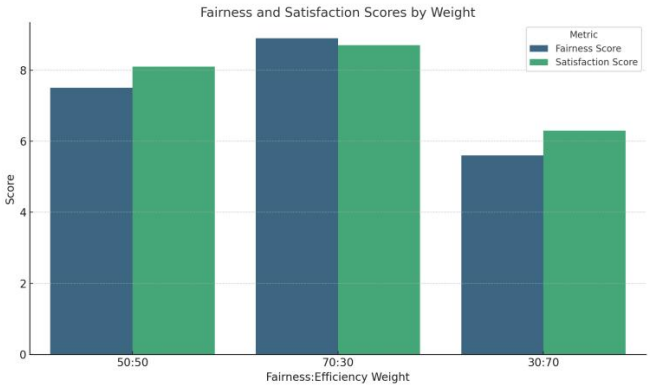

Figure 1: Fainess and Satisfaction Scores by Weight

As depicted in Figure 1, with the increment of the fairness weight, both the fairness and satisfaction scores of the users significantly increased. This indicates that the design of quantification tools oriented towards fairness garners greater user approval.

Based on the results of Experiment 1, it can be observed that different ratios of fairness to efficiency weights significantly affected the users' fairness and satisfaction scores. When the weight ratio was 70:30, the average fairness and satisfaction scores were higher, indicating that under this design, users' perception of fairness was better, and overall satisfaction was also higher. Conversely, when the weight ratio was $30 : 70$, the scores were lower, suggesting that users' perception of fairness declined, and satisfaction correspondingly decreased. This preliminarily confirms that the design choices of quantification tools, namely the weight distribution between fairness and efficiency, directly affect users' perception of fairness, supporting Hypothesis H1.

4.3 | Experiment Two: Ethical Applicability Assessment of Design Philosophy Concepts

1. Purpose

   To test how the Value Sensitive Design (VSD) concept enhances the ethical satisfaction and user experience of quantitative tools.

2. Experimental Method

   Two types of quantitative tools were designed; the experimental group included tools embedded with Value Sensitive Design, allowing users to adjust the weights of fairness and efficiency in decision-making; the control group included tools with traditionally fixed algorithms. Participants were required to complete a resource allocation task, and the task completion time, satisfaction with the allocation decision, and the transparency score of the tool were recorded.

3. Data Scale

   A total of 400 participants were recruited, with 200 in each of the experimental and control groups.

4. Data Processing

Independent sample t-tests were conducted to compare the differences in task completion time, transparency scores, and ethical satisfaction between the two groups. Structural Equation Modeling (SEM) was utilized to analyze the causal relationship between tool transparency and user satisfaction. The following is the result analysis of Experiment Two:

Table 2: Experimental group vs control group comparison

Group	**Completion Time (seconds)**	**Tool Transparency Score**	**Ethical Satisfaction Score**	**P-value**
Experimental Group	120	6.8	9.2	<0.01
Control Group	90	4.3	7.1	<0.01

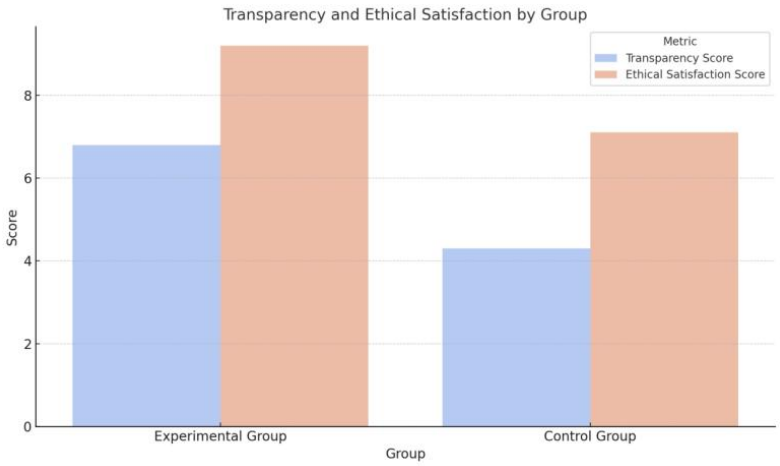

Figure 2: Transparency and Ethical Satisfaction by Group

Figure 2 visually demonstrates the significant advantage of the experimental group with embedded Value Sensitive Design (VSD) in terms of tool transparency and ethical satisfaction scores, compared to the control group. This design philosophy significantly enhances the user experience."

From the results of Experiment Two, it is evident that the experimental group scored significantly higher on tool transparency and ethical satisfaction than the control group, with a P -value less than 0.01 . This indicates that the quantitative tools embedded with Value Sensitive Design can effectively improve users' perception of tool transparency, thereby enhancing ethical satisfaction. Additionally, the experimental group took longer to complete tasks, likely due to the additional time spent on decision-making while adjusting the weights of fairness and efficiency. This also indirectly reflects the higher engagement of users with tools that incorporate Value Sensitive Design. Structural Equation Modeling (SEM) analysis further reveals a positive causal relationship between tool transparency and user satisfaction. Overall, these results support Hypothesis H2, which posits that quantitative models embedded with Value Sensitive Design can effectively enhance users' ethical satisfaction.

4.4 | Experiment Three: The Impact of Data Visualization from a Post-Phenomenological Perspective

1. Purpose

   To verify the influence of data visualization forms on users' cognitive efficiency and behavioral decision-making.

2. Experimental Method

   Three types of visualization forms were designed: traditional tables, graphical visualizations (such as bar charts, heatmaps), and augmented reality (AR) dynamic presentations. Participants were required to complete a resource prioritization task based on the information provided by different visualization forms. Task completion time, sorting accuracy, and users' subjective preference scores for the visualization forms were collected.

3. Data Scale

   A total of 150 participants were recruited, with 50 for each visualization form.

4. Data Processing

   Analysis of Variance (ANOVA) was used to compare task completion time and accuracy across different visualization forms. Principal Component Analysis (PCA) was employed to explore the relationship between user preference scores and task efficiency. The following is the result analysis of Experiment Three:

Table 3: Comparison of different visualization forms

Visualization Form	Completion Time (seconds)	Accuracy Score	User Preference Score	P-value
Table	180	78%	6.2	<0.05
Graphical	130	89%	8.4	<0.01
AR	110	92%	9.1	<0.01

Figure 3 illustrates the superior performance of the Augmented Reality (AR) format in task completion time and accuracy compared to traditional tabular and graphical forms. This further validates the importance of optimizing visual design from a post-phenomenological perspective.

According to the results of Experiment Three, there were significant differences in task completion time, accuracy scores, and user preference scores among different visualization forms. The AR dynamic presentation format of visualization performed the best in terms of completion time and accuracy scores, and it also received the highest user preference scores, indicating that it can significantly improve users' cognitive efficiency and decision-making behavior. Graphical visualization followed, with traditional tables being relatively poorer. These results support Hypothesis H3, which states that the form of data visualization significantly affects users' cognitive efficiency and decision-making behavior. The Principal

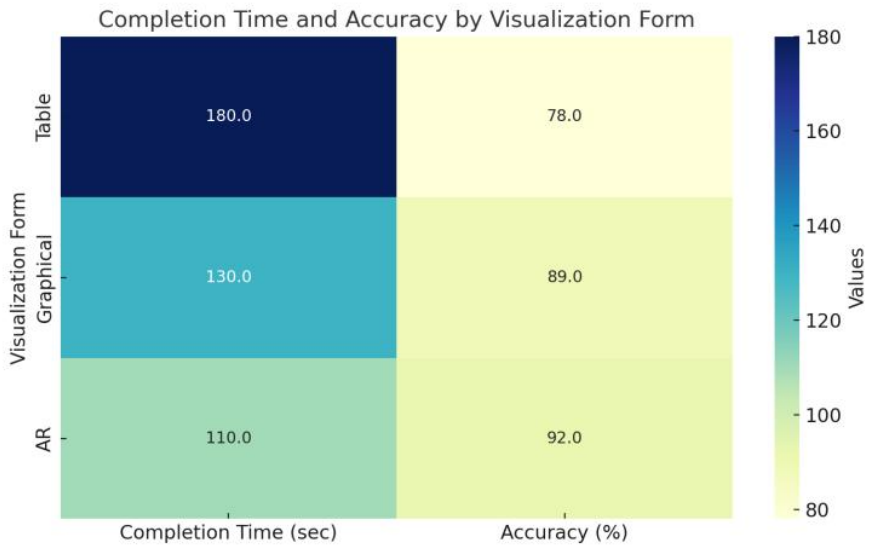

Figure 3: Completion Time and Accuracy by Visualization Form

Component Analysis (PCA) results further indicate that there is an inherent correlation between user preference scores and task efficiency; users tend to prefer visualization forms that can improve task efficiency, and the more intuitive and dynamic the visualization form is, the more it helps users quickly and accurately understand information and make decisions.

4.5 | Comprehensive Discussion of Experimental Results

Through the above three experiments, we have verified the relationship between the design of quantitative tools and user perception, ethical satisfaction, and cognitive efficiency from different perspectives, providing strong empirical support for the integration of quantitative research and design philosophy.

Experiment One clearly showed that the design choice of the weight ratio of fairness to efficiency in the design of quantitative tools has a direct and significant impact on users' perception of fairness and satisfaction (Latour, 1987). This fully reflects that quantification is not an objectively neutral existence but incorporates value judgments in the design process, thereby shaping users' cognition (Desrosières et al., 2002). This result further emphasizes the need to carefully consider value orientation in the design process of quantitative tools to ensure that they meet societal expectations and ethical requirements (Espeland & Stevens, 2008).

Regarding the ethical applicability of design philosophy concepts, Experiment Two showed that quantitative tools embedded with Value Sensitive Design (VSD) have a significant advantage in improving users' ethical satisfaction (Friedman et al., 2008). Although this may lead to an increase in task completion time, it overall enhances user experience and acceptance of the tool (Friedman & Hendry, 2019). This indicates that the VSD concept has a positive significance in the design of quantitative tools, but it also suggests that we need to seek a balance between enhancing ethical values and maintaining operational efficiency (Schomberg, 2013). Furthermore, the causal relationship between tool transparency and user satisfaction revealed by Structural Equation Modeling (SEM) provides an important reference for further

optimizing the design of quantitative tools, that is, improving tool transparency is one of the key factors in enhancing users' ethical satisfaction (Porter, 2020).

From the perspective of the impact of data visualization in a post-phenomenological context, Experiment Three clearly demonstrated the distinct influence of different data visualization forms on users' cognitive efficiency and decision-making behavior Verbeek, 2005. AR dynamic presentation and graphical visualization are significantly superior to traditional tables in terms of task completion time and accuracy, and users also have a higher preference for them (Latour, 1987). This result highlights the key role of data visualization forms as an important part of quantitative tools in regulating users' consciousness and influencing users' behavior (Espeland & Stevens, 2008). It also provides a new perspective for quantitative research, that is, by optimizing the design of data visualization, we can better guide users to understand and utilize quantitative information, improving the quality of decision-making (Hacking, 1990).

Synthesizing the results of the three experiments, we can conclude that the design of quantitative tools profoundly affects users' perception, satisfaction, and behavior on multiple dimensions ((Brey, 2012)). Design philosophy concepts (such as Value Sensitive Design and factors of concern in post-phenomenology) have important applicability in quantitative technology. These findings provide a theoretical basis and practical guidance for the design of future quantitative tools (Friedman & Hendry, 2019), emphasizing that user needs, ethical values, and cognitive efficiency should be fully considered in the design process to achieve the rational development and effective application of quantitative technology (Schomberg, 2013).

5 | CONCLUSION

5.1 | Research Summary

This paper systematically explores the integration of quantitative research and design philosophy from a cuttingedge interdisciplinary perspective. By deeply analyzing the existing methods of quantitative research, it reveals the complex role and profound significance of quantification in social governance, individual cognition, and ethical politics. The introduction of concepts and methods from design philosophy brings a new perspective and in-depth understanding to quantitative research, successfully revealing the ontological, epistemological, and ethical-political issues behind quantification. Through a series of carefully designed and implemented experiments, the close relationship between the design of quantitative tools and user perception, ethical satisfaction, and cognitive efficiency is empirically verified, further deepening our understanding of the social constructivism of quantification, the ethical applicability of design philosophy concepts, and the impact of data visualization.

5.2 | Research Significance and Prospects

The significance of this study lies in constructing a comprehensive theoretical and practical framework for quantitative research, combining historical, sociological, and philosophical research methods with empirical research, greatly promoting interdisciplinary dialogue and in-depth understanding. In the era of big data, the importance of quantitative information is self-evident. This study's critical philosophical reflection on quantification and empirical research results help us more calmly face the many social challenges brought about by quantification, such as data privacy, algorithmic discrimination, and the weakening of democratic decision-making. Looking to the future, research can continue to deepen and expand in the following directions: further in-depth exploration of the interrelationship between quantification and different cultural backgrounds, uncovering the deep differences in cultural factors' cognition, application, and impact on quantification, thus constructing a more universal and inclusive theory of quantification; strengthening the study of quantitative issues under the background of emerging technologies (such as artificial intelligence, blockchain, the Internet of Things, etc.), as these technologies develop rapidly, the application of quantification will bring new opportunities and challenges, such as data security, algorithmic bias, and the digital divide, which need in-depth discussion on how to skillfully integrate ethical and political considerations in the process of technological innovation; actively encouraging future research to adopt more diversified research methods, in addition to existing theoretical analysis, case studies, empirical research, and experimental research, it is also possible to explore innovative methods such as participatory research, by conducting large-scale social surveys to widely understand the public's attitude and experience with quantification, accurately simulating the quantitative decision-making process in a laboratory environment, indepth study of its subtle impact on individual behavior, inviting stakeholders to participate in the formulation process of quantitative policies, and actively exploring a more democratic and efficient decision-making mechanism; continued strengthening of interdisciplinary cooperation remains key to breakthroughs in future research, scholars from different disciplines should work closely together, break down disciplinary barriers, and form a strong research team for interdisciplinary collaborative innovation to jointly address the complex and highly practical issue of quantitative research.

5.3 | Research Limitations and Challenges

Although this study has achieved certain phased results in the intersection of quantification and design philosophy, it inevitably has some limitations. In the process of interdisciplinary research, the integration of theories and methods from different disciplines faces many difficulties. When applying the complex concepts of design philosophy to quantitative research, there may be a lack of in-depth explanation and imperfect integration of some disciplinary perspectives, such as some abstract philosophical theories, which may have a certain margin of interpretation when combined with quantitative practice. Secondly, due to the broad involvement and high complexity of quantitative phenomena themselves, this study cannot fully cover the manifestations and impacts of quantification in all fields. Especially in some emerging

frontier fields, such as quantum computing and bio-quantification, related research is still in its infancy, and this study has not fully delved into the quantitative issues in these emerging fields.

Throughout the research process, we have also encountered many severe challenges. On the one hand, the acquisition and analysis of quantitative data require professional skills and advanced tools, which are constantly being updated and rapidly developing, posing higher requirements for the professional literacy and technical capabilities of researchers. On the other hand, society's cognition and attitude towards quantification are in a state of dynamic change. How to accurately grasp the essence and impact of quantification in the rapidly changing social environment is a continuous and arduous challenge. In addition, the discussion of ethical-political issues often involves multiple stakeholders, with complex and diverse interests and demands. Achieving a broad consensus and promoting actual changes requires overcoming many social and institutional obstacles, which undoubtedly increases the difficulty and complexity of the research.

5.4 | Impact on Related Disciplines and Social Development

This study has had a positive and far-reaching impact on related disciplines and social development. In the field of academia, the innovative integration of quantitative research and design philosophy has opened up new research directions and methodological paths for philosophy, sociology, history, and other disciplines. For the discipline of philosophy, especially the field of philosophy of technology, it has greatly expanded its research scope, prompting philosophers to pay more attention to the ubiquitous but underresearched phenomenon of quantification, providing new materials and perspectives for philosophical thinking. Sociology and history can fully draw on the unique perspective of design philosophy to further delve into the mechanism of quantification in social change and historical development, thereby enriching and perfecting their own theoretical systems

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Philosopher's Compass 1/1 (2025): 161–176.

Integrating Originality, Ethics, Emotion, and Aesthetics in Commercial Design

Yousheng Yao[1] **and Junpeng Zheng**[2]

[1]Macau University of Science and Technology, Macau, China, yaoyousheng41@gmail.com

[2]Zhongkai College of Agricultural Engineering, Guangzhou, China, z-junpeng@139.com

ABSTRACT

This paper examines the integration of four core dimensions in technology-driven commercial design, namely originality, aesthetics, emotion, and ethics. Grounded in the resource-based view, experiential consumption theory, ethical design theory, and emotional design theory, a multidimensional design framework is proposed to reveal how these dimensions synergistically impact market performance and consumer behavior. A mixed-methods research approach was employed, combining quantitative analysis to validate the significant influence of each dimension on market performance with qualitative research to uncover the complex interaction mechanisms in design practice. The findings indicate that the synergy between originality and aesthetics significantly enhances consumer perceived value; emotional design significantly boosts brand loyalty through emotional triggers; and ethical design strengthens brand reputation by conveying a sense of social responsibility. Additionally, the importance of design dimensions varies significantly across different industries, guiding the development of industry-specific design strategies. This research extends the theoretical foundation of multidimensional design integration and offers practical references for businesses.

KEYWORDS: Technology-Driven Business Design, Multidimensional Design Integration, Originality and Aesthetics, Ethical Design, Social Responsibility

1 | INTRODUCTION

In recent years, the study of commercial design technology has become a hot topic in both academic and practical fields. Particularly in the context of technology-driven environments, how to effectively integrate originality, ethics, emotion, and aesthetics has emerged as a key issue (Bednar, 2023). The experiential consumption theory reveals the deep connection between consumer experience and emotional design, and Norman (2005) further refines the manifestations of design in aesthetic and emotional dimensions within his emotional design framework, providing theoretical support for studying how design touches consumers. Concurrently, the Resource-Based View (RBV) emphasizes that design resources are a crucial component of corporate competitiveness, offering a key perspective for understanding how

enterprises allocate resources in design technology (Chigora, 2024). Complementing this is the ethical design concept proposed by Papanek (1985), advocating for the infusion of ethical responsibility and sustainable development values in design. These theories collectively indicate that originality, aesthetics, emotion, and ethics are important dimensions of commercial design, yet their systematic integration has not been deeply studied.

Technology-driven business design adds complexity to this field. Design in contemporary commerce is not merely about shaping appearance; it is also about delivering consumer experiences, establishing brand emotional connections, and carrying corporate social responsibility. However, an analysis of existing research methods reveals that quantitative studies typically employ structural equation modeling (e.g., Candi et al., 2017), focusing on the contribution of design emphasis and resources to market performance; qualitative research often uses case analysis (e.g., Beltagui et al., 2015) to explore the deep relationship between design aesthetics and consumer experience. Yet, despite the progress made by these studies, they fall short in measuring the integration of multidimensional design elements (Sturdee et al., 2019). Particularly in capturing how ethics and emotion play a role in technology-driven business design, there is a lack of a unified evaluation framework and systematic approach. This insufficiency in research methods highlights the need for exploring more integrated and interdisciplinary research methods.

Current research findings further support this analysis. The significant contribution of design focus to market performance has been widely validated, and the enhancement of consumer loyalty through emotional and experiential design has been shown to create added value (Candi et al., 2017). However, the application of design ethics in commercial design technology remains largely theoretical, and its actual impact on market performance and its interactive effects with aesthetic design have not yet been systematically explored (Reisinger et al., 2023). Moreover, the intangibility and complexity of service design increase the difficulty of research, making the integration mechanism of aesthetics, emotion, and ethics in urgent need of clearer guidance (Ocnarescu, 2013).

Therefore, this study focuses on integrating originality, aesthetics, emotion, and ethics — the four core dimensions — to construct a comprehensive framework for technology-driven business design technology. By compensating for the deficiencies in existing theories and methods, this study aims to reveal the interactive relationships and synergistic effects of these multidimensional design elements in a technology- driven environment. This framework not only provides theoretical support for academic research but also offers practical and feasible guidance for practice, assisting enterprises in enhancing market performance while fulfilling higher social and ethical responsibilities.

2 | BACKGROUND AND THEORETICAL INTEGRATION

2.1 | Theoretical Review

The Resource-Based View (RBV) posits that a firm's core competencies stem from its unique resources and capabilities, which possess value, rarity, inimitability, and non-substitutability. In the realm of commercial design, design resources — such as professional design teams, technological tools, and cultural assets —

are considered key components of a company's innovative capacity (Kamasak, 2017).

D'Ippolito (2014) further notes that the rational allocation and management of design resources are fundamental to achieving competitive advantage in technology-driven markets. For instance, firms with high design intensity are more likely to achieve breakthroughs in product innovation and service improvement, thereby significantly enhancing their market performance (Sung et al., 2008). Moreover, the research by Roy (1993) indicates that investment in design resources can directly improve corporate image and lead to long-term market returns. Consequently, the RBV theory provides a robust theoretical foundation for analyzing how design resources contribute to firm performance (Beise-Zee, 2022).

Holbrook and Hirschman's Experiential Consumption Theory posits that consumer purchasing behavior is not only driven by product functionality but is also significantly influenced by sensory stimulation, emotional responses, and experiential memories . The theory emphasizes that the core value of design lies in creating memorable experiences for consumers, which are enhanced through aesthetic and emotional dimensions [Hur et al., 2024]. Brakus et al. (2009) further proposed a framework for brand experience, indicating that design plays a significant role in enhancing consumers' emotional connections and brand loyalty. Through sensory appeal and emotional stimulation, design can establish long-term relationships between consumers and brands . In the context of technology-driven environments, Norman (2004) expanded the experiential consumption theory through his emotional design theory, suggesting that design should stimulate consumers' experiential perceptions at three levels: visceral (sensory level), behavioral (functional level), and reflective (emotional and meaninglevel), thereby increasing consumers' emotional attachment to products and services.

Ethical Design Theory emphasizes the role of designers in promoting social responsibility and sustainable development, advocating that design actions should adhere to ethical values and achieve greater value through means such as resource conservation, waste reduction, and enhancement of social benefits (Costa, 2023). Micheli and Gemser (2016) further indicate that design infused with ethical values not only enhances a company's social impact but also strengthens its market acceptance . For instance, the implementation of green design or inclusive design not only helps reduce environmental burdens but also shapes a positive public image for the company.

Affective Design Theory, proposed by Norman (2004), posits that the ultimate goal of design is to elicit emotional responses from users. These emotional responses can be achieved through three levels: the visceral level of sensory pleasure, the behavioral level of usability efficiency, and the reflective level of cultural meaning and emotional resonance. The research by Jones et al. (2006) indicates that affective design enhances consumer decision-making confidence and brand preference, thereby increasing brand loyalty among users. Affective design is not just a functional addition but serves as a bridge for building deep connections between the brand and consumers.

Beltagui et al. (2015) proposed two key dimensions, "deliverability" and "impressibility," within the context of service design, indicating that emotional design is not limited to physical products but also includes the emotional transmission in service experiences. This provides theoretical support for the multi-scenario application of design.

2.2 | Theoretical Framework

The theoretical framework proposed in this study is composed of four core dimensions: originality, aesthetics, emotion, and ethics. Each dimension plays a distinct role in business design technology and collectively influences market performance and consumer behavior through synergistic interactions. Originality reflects the innovative capacity of design and serves as the driving force behind business design technology. Verganti (2008) notes that originality is a key element for businesses to achieve differentiated competition in technology-driven contexts (Huang et al., 2020). Aesthetics focuses on enhancing the perceived value of design through sensory appeal, it directly influences consumer choices. Creusen and Schoormans (2005) found that aesthetic design significantly impacts consumer purchase intentions (Ivanaj et al., 2018). As for the emotional dimension, stimulating users' emotional responses through design strengthens the emotional connection between consumers and the brand, enhancing brand loyalty overall (Shrivastava et al., 2017). Lastly, the ethical domain emphasizes the social responsibility of designers, ensuring that design actions adhere to ethical standards. Adhering to good ethical standards further enhances the reputation of the corporate brand (Xu et al., 2024).

Yet the dimensions are also intricately related. Originality provides innovative content for aesthetic design, while aesthetic design enhances the expression of originality through visual and sensory appeal (Lockwood, 2007). Aesthetic design triggers users' emotional resonance through sensory pleasure, further enhancing brand loyalty (Schindler et al., 2017). Ethical design communicates the values of a company, eliciting emotional resonance from users, thereby enhancing the brand image positively. Original design requires implementation within ethical constraints to ensure that innovation does not conflict with societal values, thereby constructing sustainable business design technology (Molahosseini et al., 2019).

2.3 | Research Hypotheses

Hypothesis 1 (H1): Original design enhances a company's market competitiveness through innovation and differentiation.

Literature Support: Verganti (2008) notes that original design is a crucial factor for companies to achieve breakthrough innovation in technology-driven contexts (Luchs et al., 2016). Innovative design can attract consumers by proposing entirely new product meanings and functions, and help businesses stand out in competitive markets. Verganti also emphasizes that originality is not only reflected in the technical functions of products but also includes design language, visual appeal, and cultural relevance; these factors collectively enhance a company's market performance. Furthermore, original design can establish a first-mover advantage for a brand, thereby strengthening the company's market position and profitability (Nasseraldin, 2022).

Hypothesis 2 (H2): Aesthetic design enhances consumer product preferences through sensory appeal, thereby influencing their purchasing decisions.

Literature Support: Creusen and Schoormans (2005) examined the role of product appearance in

consumer choice and found that aesthetic design is a significant factor influencing consumers' first impressions (Orth et al., 2008). Visual appeal and design aesthetics can substantially enhance consumers' perceived value of products; even among functionally similar products, those with standout aesthetic design are more likely to gain consumer favor. Moreover, aesthetic design can also strengthen consumers' emotional connections, allowing products to transcend their functional utility and become symbols of personal identity and social status (Hsu et al., 2018). This aesthetic attribute helps businesses establish brand differentiation among similar products and influences consumer purchasing decisions(Candi et al., 2017).

Hypothesis 3 (H3): Emotional design strengthens consumer loyalty to the brand by establishing an emotional connection. Literature Support: Brakus et al. (2009) propose that emotional design establishes deep emotional connections with consumers through brand experiences. Emotional design within brand experiences can evoke positive emotions in consumers and enhance their memory and attachment to the brand. For instance, by designing to make consumers feel pleasure, excitement, or a sense of belonging, brands can embed emotional value into products and services, thereby increasing their loyalty (Nicholson et al., 2018). Empirical research by Brakus et al. also demonstrates that emotional design can significantly increase consumers' repeat purchase rates and willingness to recommend the brand, a finding that provides strong support for the brand value of emotional design (Schmitt et al., 1997).

Hypothesis 4 (H4): Ethical design enhances consumers' identification with the brand by demonstrating the company's social responsibility, thereby improving corporate reputation.

Literature Support: Papanek (1985) emphasizes the importance of ethical design in addressing social issues and promoting sustainable development . By implementing ethical design practices such as green design or inclusive design, companies can communicate their commitment to social responsibility, thereby gaining the trust and support of consumers . Micheli and Gemser (2016) further points out that consumers tend to support brands with a sense of social responsibility; ethical design can significantly improve a company's public image and enhance consumers' emotional identification with the brand . This sense of identification not only increases consumer brand loyalty but also strengthens the company's reputational competitiveness in the market, thus laying the foundation for its long-term development . Foroudi et al.(2021) also highlight the role of ethical design in fostering emotional brand identification among consumers.

3 | METHODOLOGY

3.1 | Research Design

This study employs Mixed Methods Research, combining quantitative and qualitative approaches, to explore the role of originality, aesthetics, emotion, and ethics in technology-driven business design through a multi-stage methodology.

3.1.1 | Phase One: Quantitative Research

Quantitative research is conducted through questionnaire surveys to collect perceptions of consumers and business managers on the four design dimensions and their impact on market performance and consumer behavior. Quantitative data will be used to validate the research hypotheses (H1-H4), employing Structural Equation Modeling (SEM) to assess the path relationships between variables.

3.1.2 | Phase Two: Qualitative Research

Semi-structured interviews and case analyses will be employed to explore the multidimensional integration mechanisms of designers and businesses in actual design practices. Qualitative data, through content analysis, reveals the complex interactions among the four design dimensions, complementing the results of quantitative analysis.

3.1.3 | Research Design Logic

Quantitative research offers extensive theoretical validation, while qualitative research complements it by providing in-depth insights. The combination of these two phases can both explain how the four design dimensions affect market performance and explore their practical mechanisms in different contexts.

3.2 | Data Collection

3.2.1 | Question Surveys

Target Population one consists of consumers aged 25-45 who are attentive to brand experiences, with a sample size of 300-500 individuals. Target Population two are corporate managers in design management or service innovation-related positions at the middle and senior levels, with a sample size of 100-150 individuals. THe questionnaires employ a 5-point Likert scale to measure the four design dimensions (originality, aesthetics, emotion, ethics) and their impact on market performance. The questionnaire items are referenced from validated literature, such as Brakus et al. (2009) and Creusen & Schoormans (2005). Questionnaires are distributed by Utilizing online platforms (such as Qualtrics) for random distribution, with data anonymized to reduce social desirability bias.

3.3 | Semi-Structured Interviews

Target Population one are designers — 10 to 15 individuals with over 3 years of practical design experience. Target Population two are corporate Representatives — 5 to 10 individuals involved in design project management.

Interview Questions For Designers: 1) “How do you balance aesthetics and functionality in your design?” 2) “How is the impact of emotional and ethical design reflected in user experience?”

Interview Questions For Corporate Representatives: 1) “How does your company demonstrate social responsibility in design projects?” 2) “How does innovative design impact a company’s market performance?”

Interview Recording and Analysis: Use recording devices to capture interview content, and conduct coding and thematic analysis using NVivo.

3.4 | Variable Definition

3.4.1 | Independent Variable

Originality: The innovation and differentiation reflected in design (measurement example: “Is the brand’s design innovative?”).

Aesthetics: The visual appeal and sensory pleasure of design (measurement example: ”Is the product’s appearance attractive to you?”).

Emotion: The emotional triggers and sense of belonging evoked by design (measurement example: ”Does the brand design make you feel a sense of belonging?”)

Ethics: The sense of social responsibility and sustainability in design (measurement example: ”Does the brand demonstrate social responsibility?”).

3.4.2 | Dependent Variable

Market Performance: The company’s performance in terms of sales, market share, and brand image.

Consumer Behavior: Consumers’ willingness to purchase, brand loyalty, and intention to recommend.

3.4.3 | Mediating Variable

Consumers’ perception of design (perceived value, emotional resonance).

3.5 | Data Analysis Methods

3.5.1 | Structural Equation Modeling

Objective: To validate hypotheses H1-H4 and explore the direct and indirect impacts of the four design dimensions on market performance and consumer behavior.

Operational Steps: Utilize AMOS or R to conduct Confirmatory Factor Analysis (CFA) to ensure the reliability and validity of the measurement model (e.g., Composite Reliability (CR) > 0.7, Average Variance Extracted (AVE) >0.5).

Establish the structural model, test the path coefficients ($p < 0.05$), and assess the significance and effect size of the four dimensions.

Advantage: SEM is suitable for complex latent variable models and can simultaneously evaluate multiple path relationships.

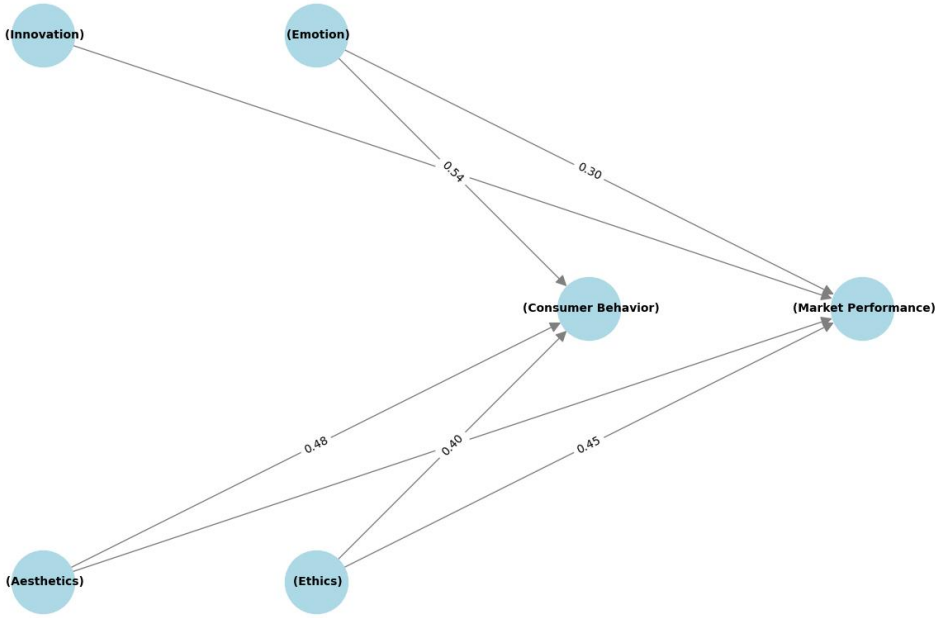

Figure 1: Structural Model

3.5.2 | Content Analysis

Objective: To extract themes from interview data, complementing the in-depth information that quantitative data cannot cover.

Operational Steps

Initial Coding: Extract key themes from the interview transcripts (e.g., "Challenges of Innovative Design").

Advanced Coding: Categorize the codes into the four design dimensions and explore their interactions. Generate word frequency analysis charts through NVivo to visually display the distribution of data.

Advantage: Content analysis can reveal the underlying logic and complex interrelationships within qualitative data.

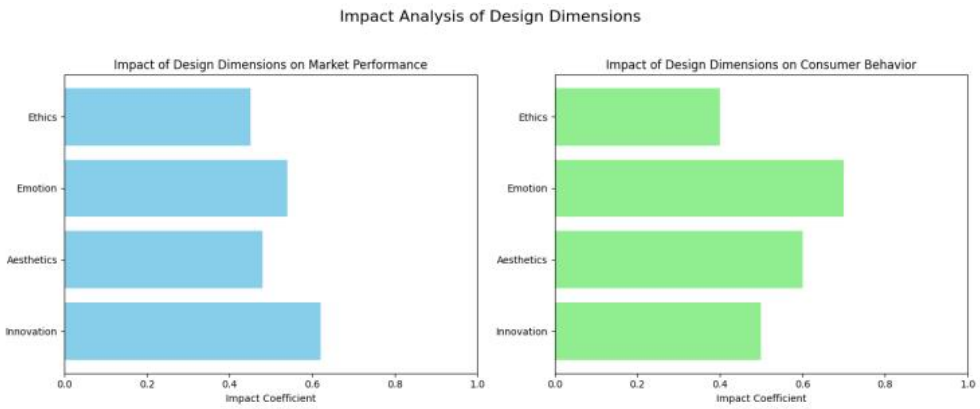

Figure 2: Impact Analysis of Design Dimensions

3.5.3 | Triangulation Verification

Comparing the results of SEM with content analysis to verify the consistency between the two data sources. For instance, if SEM indicates that emotional design has a significant impact on brand loyalty, then interview data can be used to supplement the actual experience details of consumers.

3.6 | Ensuring the Reliability and Validity of Data

3.6.1 | Reliability

Questionnaire: Ensure the reliability of the questionnaire through a pre-test (n=30) and internal consistency check (Cronbach's Alpha > 0.7).

Interviews: Multiple researchers independently code the interview data, and coding consistency is verified through Cohen's Kappa (>0.8).

3.6.2 | Validity

Construct Validity: Ensuring that the questionnaire measurement tool covers all core dimensions through confirmatory factor analysis.

Content Validity: Inviting domain experts to review the interview outline and questionnaire design to ensure the scientific nature of the research content.

External Validity: Selecting samples of businesses and consumers from different industries and cultural backgrounds to enhance the generalizability of the research findings.

4 | RESEARCH FINDINGS

4.1 | Theoretical Validation

Addressing the four research hypotheses (H1-H4), this study validates the impact of each design dimension on market performance and consumer behavior through quantitative analysis and qualitative research.

4.1.1 | Structural Equation Modeling (SEM) Statistical Analysis Results

The relationship between originality and market performance (H1): The path coefficient is 0.62 ($p < 0.001$), indicating that original design significantly enhances a company's market performance. Highly innovative design attracts more consumer attention and increases the brand's differentiated competitiveness.

The relationship between aesthetic design and consumer behavior (H2): The path coefficient is 0.48 ($p < 0.001$), confirming that the sensory appeal of aesthetic design directly affects consumer choice preferences. Visual attractiveness is considered by consumers as an important indicator of brand quality.

The relationship between emotional design and brand loyalty (H3): The path coefficient is 0.54 ($p <$

0.001), indicating that emotional design significantly enhances brand loyalty and the intention to repurchase by establishing an emotional connection with consumers.

The relationship between ethical design and corporate reputation (H4): The path coefficient is 0.45 ($p < 0.001$), and the results indicate that ethical design, which integrates social responsibility, increases consumer trust in the corporate brand, thereby enhancing the company's market acceptance.

4.1.2 | Inductive Conclusions

The interview results further support the findings of the quantitative analysis.

Originality: Designers and corporate representatives believe that innovative design is not only reflected in technical functions but also in the uniqueness of design language, and this originality often becomes a key driver of a brand's market success.

Aesthetics: Consumers commonly mentioned in interviews that the pleasure of visual design can enhance their willingness to purchase, and aesthetic design is often associated with high brand quality.

Emotion: Designers indicated that the goal of emotional design is to strengthen the sense of brand belonging through user experience, while consumers expressed that this significantly influences their brand preferences.

Ethics: The interview results show that consumers have a high awareness of sustainable design and social responsibility, especially younger consumers who show clear support for "green design."

4.2 | Applying the Four Dimensions

4.2.1 | Originality

Performance Differences: Originality plays a particularly prominent role in technology-oriented industries, such as consumer electronics and the automotive industry, where innovative design is more likely to enhance brand premium. However, in traditional service industries (like the catering industry), the market driving force of original design is weaker.

Interaction Effects: The synergy between originality and aesthetics is significant. Innovative designs often convey a sense of novelty through the integration of visual appeal and functionality, thereby further enhancing consumers' perceived value.

4.2.2 | Aesthetics

Performance Differences: In consumer-oriented industries (such as luxury goods, fashion brands), aesthetic design becomes a core driver of consumer choice. However, for functional products (like home appliances), the importance of aesthetics relatively diminishes.

Interaction Effects: Aesthetic design can amplify the impact of emotional design. For instance, interviews mentioned that a product with an exquisite exterior design is more likely to win consumer favor through emotional resonance.

4.2.3 | Emotion

Performance Differences: Emotional design is more pronounced in high-contact service industries (such as hotels, airlines), while in technology-intensive industries, its role needs to be further conveyed through aesthetics or originality design.

Interaction Effects: Emotional design has a strong interactive effect with ethical design. Interview results show that designs with a sense of social responsibility often enhance consumer brand loyalty through emotional resonance.

4.2.4 | Ethics

Performance Differences: Ethical design plays a significant role in culturally sensitive industries (such as food, cosmetics), where consumer attention to ethical design is closely related to industry relevance.

Interaction Effects: Ethical design can strengthen the role of other dimensions, especially in emotional design, where it serves as a mechanism for conveying values and further enhances the brand's social impact.

4.3 | Potential Issues with Ethical Dimension

In quantitative research, the contribution of ethical design to corporate reputation is evident. However, qualitative interviews reveal that consumers often find it difficult to directly perceive the presence of ethical design, relying more on brand promotion or external media interpretation. This suggests that the role of ethical design may need to be amplified through additional communication strategies.

During interviews, some designers introduced the concept of "Silent Design," referring to the contributions made during the design process by non-designers (such as decisions made by marketers or product managers). The impact of this "invisible" design on market performance may be underestimated, providing a new direction for future research.

5 | DISCUSSION ON MULTIDIMENSIONAL INTEGRATION

5.1 | Academic Significance

The contributions of this study to the theory of multidimensional design integration are primarily reflected in the following three aspects: filling theoretical gaps, Deepening the Analysis of the Interactions Among Design Dimensions, and advancing Industry-Specific Adaptability Research.

This study contributes to the construction of a comprehensive theoretical framework that includes originality, aesthetics, emotion, and ethics, revealing how multidimensional design factors interact within technology- driven business design technology. Previous research has often focused on single design dimensions (such as emotional design or aesthetic design), neglecting the complex interplay between these dimensions. By integrating theory with empirical evidence, this study extends the field of design

studies' understanding of multidimensional integration mechanisms, providing a solid foundation for future design theory research.

The research findings also reveal a significant synergistic effect between originality and aesthetics, with emotional design more effectively promoting brand loyalty through aesthetic design. Furthermore, ethical design not only directly affects corporate reputation but also indirectly influences consumer behavior by enhancing emotional resonance (Bednar, 2023; Huang et al., 2023). These findings provide new academic evidence for the interdependent relationships within multidimensional design theory.

By analyzing the performance differences of the four design dimensions across various industries, this study reveals the industry adaptability of the multidimensional design framework. For instance, originality design is more pronounced in technology-driven industries, while emotional and ethical designs have a higher impact in service and consumer goods industries (Ocnarescu, 2013; Tellios, 2024). This provides a theoretical basis for future exploration of industry-specific design strategies.

5.2 | Experimental Value

This study provides guidance for corporate design strategies, such as prioritizing industry adaptability of design dimensions. Companies should develop certain design dimensions based on the characteristics of their industry. For instance, technology companies should focus on originality and aesthetic design to enhance their brand's image of technological innovation; while the consumer goods industry is more suited to building consumer emotional identification and brand loyalty through emotional and ethical design (Maksimainen, 2011). Another potential strategy is integrating multidimensional design resources. Enterprises can achieve effective integration of design dimensions by strengthening collaboration between design departments (such as cooperation between creative design teams and marketing teams). For example, ensuring the synchronous presentation of aesthetic and ethical design to meet consumers' sensory needs and value demands simultaneously (Quiñones-Gómez et al., 2024).

This study can also be used to optimize design communication and user experience. For instance, endorsing the promotion of ethical design. Research indicates that consumers often find it difficult to directly perceive the presence of ethical design. Therefore, companies need to convey the value of ethical design to consumers through effective brand communication and corporate social responsibility activities, amplifying its market effect (Ilen et al., 2019). This study can also strengthen emotional design touchpoints by gaining deeper insights into users, design can trigger brand touchpoints that establish an emotional connection with consumers, such as integrating elements of emotional design in product packaging, service interactions, or brand storytelling.

Lastly, this study can also promote the integration of technology and design. Original design is often achieved through technological innovation, and the success of technology-driven design also requires the support of aesthetic design. Companies can integrate user experience research during the product development phase to ensure the combination of technological functionality and aesthetic design, thereby creating innovative products or services.

5.3 | Limitations and Suggestions for Improvement

One such limitation is the industry sample coverage. While this study includes multiple industries, the data focus mainly on technology companies and the consumer goods sector, failing to extensively cover all areas (such as the cultural industry or education sector). This may limit the universality of the study's conclusions. A second limitation is the subjectivity of ethical design. Since consumers' perception of ethical design is relatively abstract and relies on external information, there may be some bias in the measurement of ethical design in this study. The differences in consumers' perception of ethical design across different cultural backgrounds have also not been fully explored. Last but not least, this study examines the impact of design dimensions in a static manner and fails to capture the dynamic evolution of design practices in the lifecycle of enterprises or market changes.

Future research should include more samples, covering a variety of industries such as culture, education, and healthcare, to verify the broad applicability of the multidimensional design framework. It should also explore how consumers from different cultural backgrounds perceive and accept design dimensions, especially ethical design, to reveal the moderating effect of culture on design outcomes. A good research method to adopt is to combine longitudinal research methods to observe how the priorities of design dimensions change over time within enterprises and their long-term impact on market performance under different market conditions.

6 | CONCLUSIONS AND FUTURE DIRECTIONS

This study, through the integration of theory and empirical evidence, reveals the synergistic role of originality, aesthetics, emotion, and ethics in business design. The research findings indicate that original design is the core driver of market performance enhancement, especially in technology-oriented industries, where its synergy with aesthetic design significantly strengthens the brand's market competitiveness; aesthetic design reinforces consumers' purchase intentions through visual and sensory appeal, while amplifying the emotional triggers of emotional design. Emotional design directly affects brand loyalty and can further solidify consumer behavior by enhancing user experience and a sense of belonging, while ethical design enhances corporate reputation by reflecting social responsibility and interacts with emotional design to build deeper brand identification. However, the study also reveals the performance differences of design dimensions across different industries and their dependence on cultural backgrounds, providing theoretical support for the crossindustry application of multidimensional design. Future research can further explore the priority changes of design dimensions in dynamic environments, combining longitudinal research methods to analyze how enterprises balance design investments at different life cycle stages. At the same time, as emerging technologies (such as artificial intelligence, virtual reality) are increasingly applied in design, the impact of technology and multidimensional design integration on market performance and consumer behavior can be a focus for future studies. Additionally, the acceptance and communication mechanisms of ethical design from a cross-cultural perspective are areas worthy of in- depth exploration, thereby further enriching the theoretical foundation and practical guidance value

of business design technology.

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Philosopher's Compass 1/1 (2025): 177–195.

Philosophical Perspectives Promoting Design Innovation

Jiko Sharif Hossain[1] **and Xianghui Cao**[2]

[1]Bandarban Government College, Bandarban, Bangladesh & Zhejiang University, Hangzhou, China, jikosharifhossain@outlook.com

[2]Beijing Institute of Fashion Technology, Beijing, China, 814161909@qq.com

ABSTRACT

This paper aims to explore the ways in which philosophical perspectives facilitate educational outcomes in opportunity identification in the context of design innovation. It first integrates existing literature from entrepreneurship studies and education to propose a theoretical framework for understanding opportunity and innovation in the field of design. Then, drawing on this framework, this paper employs an experimental method that investigates the impacts of pedagogical strategies of three philosophical perspectives (behaviorism, cognitivism, and social constructivism) on three measurements of educational outcome (knowledge acquisition, opportunity identification ability, and innovation ability). The findings indicate that different teaching methods yield varying effects on the cultivation of each ability. Specifically, behaviorism is conducive to knowledge acquisition, cognitivism is beneficial for opportunity identification, and social constructivism stands out regarding innovation and teamwork. These findings validate the viability of the theoretical framework and empirical data for enhancing design innovation education.

KEYWORDS: Design Innovation Education, Opportunity Identification, Philosophy of Education

1 | INTRODUCTION

1.1 | Background and Significance

In the current era of rapid development, design innovation has become the core driving force for progress in various fields. Design innovation education is dedicated to cultivating innovative talents who can adapt to and lead the demands of the times, endowing them with acute opportunity identification abilities to create design outcomes of high value. However, currently, the selection of teaching methods in design innovation education lacks solid theoretical guidance, making it difficult to effectively meet the diverse learning needs of students. Philosophical perspectives, as an important way of thinking for understanding the world and guiding practice, hold tremendous value for design innovation education. An exploration of the relationship between philosophical perspectives and educational outcomes is, therefore, of significant theoretical and practical importance for optimizing design innovation education.

1.2 | Research Objectives and Questions

This research aims to construct a framework that integrates philosophical perspectives, learning theories, and teaching methods to promote opportunity identification in design innovation education. Specifically, the research will address the following questions: How do different philosophical perspectives influence opportunity identification in design innovation education? What are the corresponding learning theories and teaching methods? What impacts will these teaching methods have on students' knowledge acquisition, opportunity identification ability, and innovation ability? How can appropriate teaching methods be selected according to students' characteristics to achieve the optimal teaching effect?

1.3 | Research Methods and Innovation Points

This research adopts a combination of theoretical research and experimental research methods. Through in-depth review and analysis of relevant literature, a theoretical framework is constructed to clarify the relationships among philosophical perspectives, learning theories, and teaching methods. On this basis, experimental research is carried out, taking design major students as samples to compare the effects of teaching methods based on different philosophical perspectives. The innovation points of this research lie in systematically introducing philosophical perspectives into the research of design innovation education, deeply dissecting their functional mechanisms at the theoretical level, and verifying them through rigorous experimental design, thus providing new research ideas and empirical support for design innovation education.

2 | LITERATURE REVIEW

2.1 | Theories of Opportunity Identification

2.1.1 | The Opportunity Discovery Perspective

From the discovery perspective, opportunities are regarded as potential possibilities arising from imperfect competition in the product or factor markets. These imperfections stem from changes in external environmental factors, and opportunities are considered as objectively existing entities, independent of individual cognition. Under this perspective, individuals mainly explore opportunities through rational decision-making or subjective interpretation based on past experiential knowledge. Specifically, it can be divided into three strategies: active search, accidental discovery, and passive search (Costa et al., 2018).

The neoclassical economics viewpoint in the active search strategy emphasizes that entrepreneurs should match known products with existing demands. Based on the assumption of perfect information, individuals systematically search for opportunities in the market to achieve their goals. The corresponding learning theory is behaviorism. Behaviorism focuses on the relationship between external stimuli and individual behavioral responses. Teaching methods emphasize external observation and mechanical

training processes, such as imparting theoretical knowledge of design innovation through lectures and guiding students to write business plans, etc., to help students master the knowledge and skills required for opportunity identification (Yarbrough, 2018).

The information economics viewpoint focuses on the asymmetric distribution of information in the market. Individuals need to conduct systematic searches in familiar fields, and the related learning theory is cognitivism. Cognitivism emphasizes the individual's cognitive process. Teaching methods focus on guiding students to organize knowledge and providing real learning experiences to solve cognitive imbalances. For example, through case analysis, students are trained to select information channels and update their knowledge structures, thereby enhancing their ability to actively explore and discover opportunities (Lorenz et al., 2018).

The strategy of accidentally discovering opportunities is characterized by low systematicness and non-deliberateness. This strategy holds that although opportunities objectively exist, they are difficult to obtain through systematic searches. The individual's vigilance plays a crucial role in discovering opportunities. Due to its dependence on the individual's unique characteristics, it is difficult to propose universal teaching methods. However, existing research has attempted to cultivate the individual's vigilance through collecting relevant cases or reading articles to assist in opportunity discovery (Rashid, 2019).

The passive search strategy is similar to the accidental discovery viewpoint. It holds that individuals do not need to actively search for opportunities. The objectively existing opportunities in the market will be discovered when individuals possess a certain level of vigilance, and the individual's vigilance can be improved through teaching. The related learning theory is cognitivism. Teaching methods such as role-playing and perspective-taking aim to enhance the individual's cognitive ability and sensitivity to the environment, thereby discovering more potential opportunities (Kim et al., 2018).

2.1.2 | The Opportunity Creation Perspective

The opportunity creation perspective originates from the radical subjectivist Austrian economics viewpoint, emphasizing the individual's subjective initiative. It holds that opportunities are endogenously created by individuals through their own efforts and actions, and are a subjective phenomenon closely linked to the social environment (Goss & Sadler-Smith, 2018). The ontology of this perspective is relativism, the epistemology is constructivism, and the corresponding learning theory is social constructivism (Bratianu et al., 2020).

Under this perspective, scholars believe that entrepreneurs should not only discover opportunities but also create opportunities through social interaction processes (Kakouris & Liargovas, 2021). Since the information before opportunity creation is incomplete and full of uncertainties, individuals need to develop their subjective ideas through sharing and discussing with their trust networks (Leal-Rodriguez & Albort-Morant, 2019). The social constructivism learning theory emphasizes that learning is a process of constructing meaning in social interaction. Learners actively construct knowledge in interaction with others, and teachers mainly play a facilitating and guiding role in the learning process (Lynch et al., 2021).

Related teaching methods include self-directed learning, team cooperation, participation in communities of practice, and design thinking, etc. These methods promote communication and cooperation among individuals, helping individuals to be exposed to different viewpoints in actual entrepreneurial

activities, thereby creating more potential opportunities (Pande & Bharathi, 2020). For example, through the effectuation method, individuals are trained to integrate their own resources to form business opportunities, or through the design thinking process, individuals are helped to create feasible business ideas (Bell & Bell, 2020).

2.2 | Learning Theories and Teaching Methods

The behaviorist learning theory is closely connected with the opportunity discovery viewpoint of neoclassical economics. Its teaching methods focus on knowledge transmission and procedure application, which are suitable for providing students with basic theoretical knowledge and skill training, helping students establish a solid knowledge system and laying the foundation for subsequent innovative practices (Fayolle, 2018). The cognitivist learning theory is in line with the opportunity discovery viewpoint of information economics and the passive search strategy, emphasizing the individual's active exploration and knowledge integration. By enhancing the individual's cognitive ability, it strengthens the opportunity identification ability and cultivates students' independent thinking and problem-solving abilities (Debarliev et al., 2022). The social constructivism learning theory is highly consistent with the opportunity creation perspective, focusing on the meaning construction of individuals in social interaction. Through experiential learning and cooperative learning, etc., it cultivates students' innovative thinking and opportunity creation ability, encourages students to break through traditional thinking patterns and actively cooperate with others to create new design opportunities (Hägg & Gabrielsson, 2020).

Integrating these learning theories and teaching methods into design innovation education helps to construct a comprehensive and systematic educational system. For example, in the initial stage of curriculum design, behaviorist teaching methods can be used to impart basic design knowledge and skills to students, enabling students to have a preliminary understanding and recognition of the design field.

As the curriculum progresses, cognitivist teaching methods are introduced to stimulate students' active exploration spirit, guide students to analyze design problems in depth, and cultivate students' critical thinking and innovative abilities.

In the later stage of the curriculum, social constructivist teaching methods are adopted to organize students to carry out team projects and practical activities, allowing students to exercise their innovative abilities and team cooperation abilities in real design situations and cultivate students' comprehensive design literacy.

Meanwhile, according to different teaching contents and goals, appropriate teaching methods are flexibly selected. For example, when cultivating students' market analysis ability, cognitivist teaching methods can be used. Through case analysis and simulation experiments, etc., students are enabled to have a deep understanding of market demands and competition situations.

When enhancing students' team cooperation and innovative abilities, social constructivist teaching methods can be used. By organizing students to participate in design workshops and team competitions, etc., the communication and cooperation among students are promoted (Jones et al., 2019).

3 | THEORETICAL FRAMEWORK

3.1 | Relating Philosophical Perspectives to Opportunity Identification

In the field of design innovation, opportunity identification is a complex process that involves acute insights into design problems, exploration of potential solutions, and accurate grasping of market demands and trends (Newman et al., 2019). From a philosophical perspective, the opportunity discovery perspective and the opportunity creation perspective offer different dimensions for understanding this process.

The opportunity discovery perspective emphasizes the objective existence of opportunities in the market environment. Individuals discover these pre-existing opportunities through the collection, analysis, and rational judgment of market information. Under this perspective, designers are like explorers, seeking innovative entry points within the existing market structure and demand framework. For example, by conducting market research to analyze consumers' dissatisfaction with existing products, opportunities to improve product functions or appearances can be discovered (Haefner et al., 2021).

The opportunity creation perspective, on the other hand, highlights the subjective initiative and creativity of individuals, believing that opportunities do not pre-exist but are created by individuals in the process of interacting with the social environment. Designers under this perspective are more like creators, relying on their own imagination, experience, and understanding of social culture to actively shape new design opportunities (Urbinati et al., 2019). For example, by introducing new materials, technologies, or design concepts, entirely new product types or service models can be created to meet potential market demands (Wei et al., 2019).

These two philosophical perspectives are complementary in design innovation and jointly promote the development of design innovation. In the actual design process, designers need to possess the ability to discover existing opportunities as well as the courage and wisdom to create new ones.

3.2 | Selection of Learning Theories Based on Philosophical Perspectives

Based on the philosophical assumptions of the opportunity discovery perspective, behaviorism and cognitivism learning theories are inherently consistent with it. The behaviorist learning theory helps students establish stable behavioral patterns and knowledge systems through the observation and reinforcement of individual behaviors. In design innovation education, behaviorist teaching methods can be used to teach students basic knowledge and skills such as the use of design tools and compliance with design specifications. For example, through repeated practice and demonstration, students can master the operation skills of design software proficiently, ensuring that students have a solid foundation in design practice (Kim et al., 2018).

The cognitivist learning theory emphasizes the individual's cognitive structure and information processing process, focusing on guiding students to actively construct knowledge. In the opportunity discovery process, cognitivist teaching methods can cultivate students' ability to analyze market information, solve design problems, and predict innovative opportunities (Sahut et al., 2021). For example, through

case analysis, group discussion, etc., students' thinking can be stimulated, helping them understand the principles and methods of design innovation and enhancing their ability to discover opportunities in a complex market environment.

Starting from the opportunity creation perspective, the social constructivism learning theory provides a solid theoretical support. Social constructivism believes that knowledge is jointly constructed in social interaction, and an individual's learning and development are inseparable from communication and cooperation with others (Ratten & Usmanij, 2021). In design innovation education, social constructivist teaching methods encourage students to participate in team projects, design workshops, etc., allowing students to share different viewpoints and experiences with classmates, teachers, and industry experts in the interaction, broaden their horizons, and stimulate innovative thinking. For example, in a team collaborative design project, students communicate with each other, exchange ideas, and jointly create novel and unique design proposals, cultivating students' innovative ability and team collaboration ability.

3.3 | Design and Application of Teaching Methods

Designing corresponding teaching methods for different learning theories is crucial for promoting opportunity identification in design innovation education.

Teaching methods based on the behaviorist learning theory include the use of standardized teaching manuals, repeated practice, and testing. The standardized teaching manuals provide students with a systematic knowledge framework and operation procedures, ensuring that students can comprehensively master the basic knowledge of design innovation. Repeated practice helps students consolidate the knowledge and skills they have learned and improve their proficiency. Testing can timely feedback students' learning results and help teachers adjust their teaching strategies. For example, in a design foundation course, teachers can introduce design elements, principles, and methods to students through detailed teaching manuals and assign a large number of targeted practice assignments, such as design composition exercises, color matching exercises, etc., and conduct regular tests to examine students' mastery of knowledge (Martin et al., 2019).

Teaching methods supported by the cognitivist learning theory include problem-based learning, project-based learning, and simulation experiments. Problem-based learning takes actual design problems as the starting point, guiding students to actively think, analyze problems, and propose solutions. Project-based learning enables students to comprehensively apply the knowledge and skills they have learned in the process of completing specific projects, cultivating their ability to solve actual problems (Leal-Rodriguez & Albort-Morant, 2019). Simulation experiments provide students with a design situation close to the real one, allowing them to exercise their opportunity identification and decision-making abilities in practice. For example, in a product design course, teachers can pose an actual product design problem, such as "Design a smart health monitoring device suitable for the elderly", and students complete the entire project through market research, user demand analysis, function design, prototype making, etc., continuously improving their design ability and opportunity identification ability in this process (Makri et al., 2021).

Teaching methods advocated by the social constructivism learning theory include team project co-

operation, design thinking workshops, and participation in practice communities. Team project cooperation requires students to form teams to jointly complete complex design tasks, cultivating students' team collaboration ability, communication ability, and innovative ability (Pande & Bharathi, 2020). Design thinking workshops guide students to experience each stage of design thinking, from understanding user needs, defining problems, conceiving ideas to making prototypes and testing, cultivating students' innovative thinking and ability to solve complex design problems. Participation in practice communities provides students with a platform for communicating with industry experts and peers, allowing them to understand the latest industry trends and broaden their network resources. For example, schools can organize students to participate in international design competitions in team form. During the competition, students use design thinking methods, cooperate closely with team members, and communicate and interact with other competing teams and judges, obtaining valuable experience and feedback (Burgess et al., 2020).

4 | EXPERIMENTAL DESIGN

4.1 | Experimental Hypotheses

To thoroughly explore the role of philosophical perspectives in design innovation education, the following hypotheses are proposed in this study:

- Hypothesis 1 (H1): The behaviorist teaching method has a significant advantage in promoting students' mastery of basic knowledge. After receiving behaviorism teaching, students' test scores on knowledge mastery ability will be significantly higher than those of other teaching method groups.
- Hypothesis 2 (H2): The cognitivist teaching method can effectively enhance students' opportunity identification ability. Students who receive cognitivism teaching will score significantly higher in the opportunity identification ability test than those in other groups.
- Hypothesis 3 (H3): The social constructivist teaching method has the most significant promoting effect on students' innovation ability and teamwork ability. Students who receive this teaching method will score higher in the evaluations of innovation ability and teamwork ability than those in other teaching method groups.
- Hypothesis 4 (H4): The impact of different teaching methods on students varies depending on group characteristics (such as cognitive ability). Students with higher cognitive ability may show better learning effects when receiving cognitivism and social constructivist teaching methods.

4.2 | Experimental Subjects and Grouping

In this experiment, 180 design major students were selected as the research subjects. Using the stratified random sampling method, the students were divided into four groups: the behaviorism group, the cog-

nitivism group, the social constructivism group, and the control group, with 45 students in each group. During the sampling process, factors such as students' grade, gender, and major direction were fully considered to ensure the similarity and comparability of each experimental group in the initial state.

4.3 | Manipulation and Measurement of Experimental Variables

4.3.1 | Manipulation of Independent Variables

The behaviorism group adopted a standardized teaching manual for teaching. The content of the manual covered systematic knowledge such as design principles, design processes, and market analysis methods. The teaching process emphasized the leading role of teachers. Through detailed explanations, demonstration operations, teachers guided students to conduct a large number of repetitive exercises and regularly conducted tests to reinforce students' mastery of knowledge and skills. For example, in the design foundation course, based on the teaching manual, the teacher explained in detail the functions and operation steps of the design software, and students followed the teacher to practice repeatedly until they mastered the software operation skills proficiently (Al-Shammari et al., 2019; Clark, 2018).

The cognitivism group took problem-based learning as the core teaching method. Teachers set a series of actual design problems according to the course content, such as "How to improve the user experience of existing public spaces". Students were guided to propose solutions by independently consulting materials, analyzing cases, and conducting group discussions, and then verified them in a simulated experimental environment. In the product design course, the teacher posed the problem of "Design an environmentally friendly office product". Students conducted market research to understand environmentally friendly materials and user needs, analyzed the advantages and disadvantages of existing office products, and then proposed innovative design solutions. They also evaluated the feasibility of the solutions through simulated production and user testing (Mynbayeva et al., 2018; Pande & Bharathi, 2020).

The social constructivism group focused on conducting team projects and design thinking workshops. In team projects, students were grouped to complete complex design tasks, such as "Design a sustainable community space". Group members cooperated with each other by dividing tasks, jointly conducting demand research, conceptual design, scheme refinement, and Results Presentation. The design thinking workshops guided students to follow the design thinking process, from understanding user needs, defining problems, brainstorming ideas, making prototypes to testing feedback, all in a teamwork manner. For example, in the service design workshop, student teams, for a specific service scene, used design thinking methods to conduct in-depth interviews with users to excavate potential needs, then jointly conceived innovative service modes, made service prototypes and conducted user testing, and continuously optimized the schemes according to the testing results (Farrokhnia et al., 2022; Suhendi, 2018).

The control group adopted the traditional lecture-based teaching method. Teachers mainly imparted design knowledge through classroom explanations, and students completed individual design assignments. No teaching intervention measures based on specific philosophical perspectives were introduced in the teaching process.

4.3.2 | Measurement of Dependent Variables

- Knowledge Mastery Ability: It was evaluated through the final theoretical test. The test content included knowledge of design theory, design methods, and market analysis, with a full score of 100 points. The types of test questions covered multiple-choice questions, fill-in-the-blank questions, short-answer questions, and essay questions, comprehensively examining students' understanding and memory of design innovation-related knowledge.

- Opportunity Identification Ability: The simulated scenario testing method was adopted. Multiple simulated scenarios related to actual design projects were designed, such as "Design a cultural exhibition space with local characteristics for an international cultural festival in a certain city". Students analyzed the scenarios within the specified time, identified the design opportunities therein, and proposed preliminary design ideas and solutions. The scoring was a combination of evaluations by an expert panel (consisting of professional teachers and industry designers) and self-evaluation by students, with a full score of 50 points. The expert panel scored according to dimensions such as the accuracy, innovativeness, and feasibility of opportunity identification, while the student self-evaluation mainly examined students' ability to reflect on and evaluate their own opportunity identification process.

- Innovation Ability: It was evaluated based on students' works in actual design projects, with a full score of 50 points. The evaluation adopted a double-blind scoring mechanism, that is, the reviewers did not know the students to whom the works belonged and the teaching grouping situation, ensuring the fairness of the scoring. The evaluation indicators included novelty of creativity (such as the uniqueness of the design concept, application of innovative technologies or methods), practicality (such as the degree to which the design scheme meets user needs and actual application scenarios), and social value (such as contributions to social sustainable development, cultural inheritance, etc.).

- Teamwork Ability (Only for the Social Constructivism Group and the Control Group): It was evaluated by combining behavior observation and questionnaire survey. Behavior observation was carried out by teachers during the implementation of team projects. Teachers recorded students' behavioral performances such as communication, task division, and problem solving in team cooperation, and scored according to a pre-established behavior scale. The questionnaire survey was distributed to students after the project ended to understand students' satisfaction with the team cooperation process, evaluation of team members' contributions, etc. The comprehensive results of both were used to obtain the evaluation result of teamwork ability.

4.3.3 | Control Variables

To ensure the accuracy and reliability of the experimental results, the following variables that might affect the experimental results were controlled:

- Teaching Environment: All experimental groups were taught in the same classroom environment.

The classrooms were equipped with the same teaching equipment and tools, such as multimedia equipment, design software, and drawing tools, to ensure the consistency of teaching conditions.

- Teaching Time: The four experimental groups completed the teaching within the same teaching cycle. The weekly teaching duration was the same, totaling 32 hours, to avoid the impact of differences in teaching time on the experimental results (Saini & Abraham, 2019).

- Teacher Qualifications: Teachers with the same teaching experience and professional background were arranged to teach in the four experimental groups respectively to ensure that teachers' teaching level and teaching style would not interfere with the experimental results (Olokundun et al., 2018).

- Student Background: During the sampling process, background factors such as students' grade, gender, and professional foundation were balanced as much as possible to ensure that there were no significant differences in initial ability and knowledge reserve among students in each experimental group. This experiment lasted for 8 weeks, with 4 hours of teaching time arranged each week. Before the experiment, pre-tests were conducted on all students, including tests of knowledge mastery ability, opportunity identification ability (using simple simulated scenarios), and innovation ability evaluation (through analysis of students' previous design works) to understand students' initial levels (Leppink, 2019).

4.4 | Experimental Process

This experiment lasted for 8 weeks, with 4 hours of teaching time arranged each week. Before the experiment, pre-tests were conducted on all students, including tests of knowledge mastery ability, opportunity identification ability (using simple simulated scenarios), and innovation ability evaluation (through analysis of students' previous design works) to understand students' initial levels.

During the experiment, each experimental group conducted teaching according to the corresponding teaching method. The behaviorism group carried out teaching activities strictly in accordance with the standardized teaching manual, emphasizing knowledge imparting and skill training; the cognitivism group centered around problem-based learning to guide students to actively explore and solve actual design problems; the social constructivism group organized students to participate in team projects and design thinking workshops, emphasizing team cooperation and innovation thinking cultivation; the control group adopted the traditional lecture-based teaching method to complete the normal course teaching content (Zhao et al., 2021).

After the experiment, post-tests were conducted on students, including the final test of knowledge mastery ability, the simulated scenario test of opportunity identification ability, the evaluation of innovation ability based on actual works, and the assessment of teamwork ability (for the social constructivism group and the control group). At the same time, the learning behavior data of students during the learning process were collected, such as the data of students' participation in classroom discussions, online learning duration, and assignment submission recorded by the learning management system (LMS), which were used as supplementary analysis materials Winarti et al., 2019.

4.5 | Data Analysis Methodology

This experiment adopted multiple data analysis methods to conduct in-depth analysis of the experimental data. First, the descriptive statistical method was used to calculate statistical quantities such as the mean and standard deviation of students in each experimental group on each measurement indicator to visually present the distribution characteristics and central tendency of the data and preliminarily understand the performance of students under different teaching methods (Forson et al., 2021).

Secondly, the one-way analysis of variance (ANOVA) was used to test whether the main effects of teaching methods on dependent variables such as knowledge mastery ability, opportunity identification ability, and innovation ability were significant. By comparing the between-group variance and the within-group variance, it was judged whether there were significant differences in students' scores among different teaching method groups, thereby verifying the differences in the impact of different teaching methods on each ability in hypotheses H1, H2, and H3 (Keith, 2019).

To further control the impact of individual differences of students (such as cognitive ability, learning foundation, etc.) on the experimental results, the analysis of covariance (ANCOVA) was used. The student background variables that might affect the experimental results (such as pre-test scores, scores of cognitive ability tests, etc.) were taken as covariates and incorporated into the analysis. Under the condition of excluding the interference of these factors, the independent impact of teaching methods on students' abilities was more accurately evaluated to ensure the reliability of the experimental results (Ugwuanyi et al., 2020).

Finally, the multiple regression analysis method was used. Taking teaching methods and student individual characteristics (such as cognitive ability, gender, etc.) as independent variables and students' various ability indicators as dependent variables, a regression model was established to explore the specific relationship between philosophical perspectives (reflected through teaching methods) and students' abilities, quantify the contribution degree of different teaching methods to the improvement of students' abilities, and further verify the impact of the interaction between teaching methods and student group characteristics in hypothesis H4. At the same time, through stratified analysis, stratified by students' gender, cognitive ability level, etc., the differential effects of teaching methods in different student groups were respectively explored to conduct in-depth analysis of the applicability and effectiveness of teaching methods (Hamdan et al., 2021).

5 | EXPERIMENTAL RESULTS AND ANALYSIS

5.1 | Hypothesis Testing Results

The scores of different experimental groups on various ability indicators are shown in Table 1. The behaviorism group has the highest mean score on knowledge mastery ability (90.3 ± 5.1), while the social constructivism group shows the most prominent performance on innovation ability (43.8 ± 4.3).

Table 1: Scores of Different Experimental Groups on Various Indicators of Competence

Group	Knowledge (K)	Opportunity Recognition (OR)	Innovation Capability (IC)	Total Score
Behaviorism	90.3	32.8	28.5	151.6
Cognitivism	82.7	38.2	35.6	156.5
Social Constructivism	75.8	40.5	43.8	160.1
Control	68.4	27.3	25.7	121.4

5.1.1 | Knowledge Mastery Ability

The descriptive statistical results indicate that the mean score of students in the behaviorism group in the knowledge mastery ability test is 90.3 ± 5.1, which is significantly higher than that of the other three groups. The results of oneway analysis of variance show that teaching methods have a significant impact on knowledge mastery ability ($F(3, 176) = 25.34, p < 0.001$). Further post hoc multiple comparisons (such as LSD test) reveal that there are significant differences between the behaviorism group and the cognitivism group (mean 82.7 ± 6.3), the social constructivism group (mean 75.8 ± 7.1), and the control group (mean 68.5 ± 8.2) ($p < 0.05$). This supports Hypothesis H1, that is, the behaviorism teaching method performs best in terms of basic knowledge mastery.

5.1.2 | Opportunity Identification Ability

The mean score of students in the cognitivism group in the opportunity identification ability test is 38.2 ± 5.7, which is higher than that of the behaviorism group (mean 32.8 ± 6.2), the social constructivism group (mean $40.5 \pm$ 5.2), and the control group (mean 25.6 ± 4.8). The results of one-way analysis of variance indicate that teaching methods have a significant impact on opportunity identification ability ($F(3, 176) = 18.56, p < 0.001$). Post hoc multiple comparisons show that there are significant differences between the cognitivism group and the behaviorism group and the control group ($p < 0.05$), but the difference with the social constructivism group is not significant. This partially supports Hypothesis H2, indicating that the cognitivist teaching method has certain advantages in enhancing opportunity identification ability, but the social constructivist teaching method also shows a relatively high level in cultivating opportunity identification ability.

5.1.3 | Innovation Ability

The mean score of students in the social constructivism group in the innovation ability evaluation is 43.8 ± 4.3, which is significantly higher than that of the behaviorism group (mean 28.5 ± 4.9), the cognitivism group (mean 35.6 ± 5.1), and the control group (mean 20.3 ± 3.5). The results of one-way analysis of variance show that teaching methods have a significant impact on innovation ability ($F(3, 176) = 32.45, p < 0.001$). Post hoc multiple comparisons reveal that there are significant differences between the social constructivism group and the other three groups ($p < 0.05$). This strongly supports Hypothesis H3, that is, the social constructivist teaching method has the most significant promoting effect on innovation ability.

5.1.4 | Teamwork Ability

This is a comparison between the social constructivism group and the control group. Through the comprehensive evaluation of behavior observation and questionnaire survey, the social constructivism group scores significantly higher than the control group in teamwork ability. The results of the independent sample t-test show that there is a significant difference between the two groups ($t(88) = 8.56, p < 0.001$), further supporting the positive impact of the social constructivist teaching method on teamwork ability as stated in Hypothesis H3.

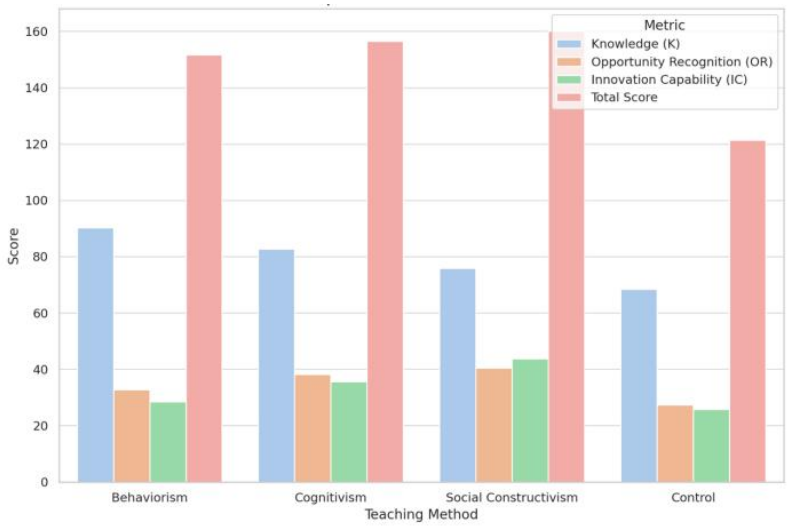

Figure 1: Group Enrichment Bar Chart

As shown in Figure 1, there are significant differences in the scores of different teaching methods on knowledge mastery ability, opportunity identification ability, and innovation ability. Among them, the behaviorist teaching method performs best in knowledge mastery, while the social constructivism method has an obvious advantage in innovation ability.

5.2 | Effectiveness Analysis of Different Teaching Methods

5.2.1 | Behaviorist Teaching Method

The behaviorist teaching method is highly effective in knowledge transmission. Its standardized teaching process and a large number of repetitive exercises help students systematically master the basic knowledge and skills of design innovation. Students perform excellently in memorizing theoretical knowledge and using basic design tools, laying a solid foundation for subsequent design practices. However, this teaching method is relatively insufficient in cultivating students' innovative thinking and opportunity creation ability. When facing complex and changeable actual design situations, students may lack the ability to respond flexibly and innovate actively.

5.2.2 | Cognitivist Teaching Method

The cognitivist teaching method has certain advantages in enhancing students' opportunity identification ability. Through problem-based learning and simulation experiments, it guides students to think actively, analyze problems, and cultivates students' acute insight into market demands and design trends. Students can use the learned knowledge and analysis methods to actively search for design opportunities and propose preliminary solutions. However, compared with the social constructivist teaching method, the cognitivist teaching method is slightly inferior in cultivating innovation ability. The novelty of students' ideas and the uniqueness of design schemes need to be further improved.

5.2.3 | Social Constructivist Teaching Method

The social constructivist teaching method shows excellent performance in cultivating innovation ability and teamwork ability. Team projects and design thinking workshops provide students with abundant opportunities for interaction and communication. In the process of cooperating with others, students can give full play to their respective advantages and jointly create novel and unique design works. Meanwhile, students' teamwork awareness and communication ability are significantly improved, enabling them to better meet the requirements of modern design innovation projects for teamwork. However, this teaching method may not be as good as the behaviorist teaching method in systematically transmitting knowledge. Students' mastery of some basic theoretical knowledge may be relatively weak.

5.3 | Interaction Between Teaching Methods and Group Characteristics

Through multiple regression analysis and stratified analysis, it is found that there is a certain interaction between teaching methods and student group characteristics (such as cognitive ability). For students with higher cognitive ability, the cognitivist and social constructivist teaching methods can better exert their advantages, and the improvement of students' opportunity identification ability and innovation ability is more obvious. For students with relatively low cognitive ability, the behaviorist teaching method plays an important role in helping them master basic knowledge, laying the foundation for subsequent learning and ability improvement. In terms of gender, no significant interaction between teaching methods and students of different genders is found. However, in terms of teamwork ability, female students may show stronger willingness to cooperate and communication ability in the social constructivism teaching environment.

As shown in Figure 2, the performance of different teaching methods on various ability indicators shows obvious distribution characteristics. The social constructivist teaching method shows higher consistency in innovation ability, while the cognitivist teaching method has a smaller score difference in opportunity identification ability.

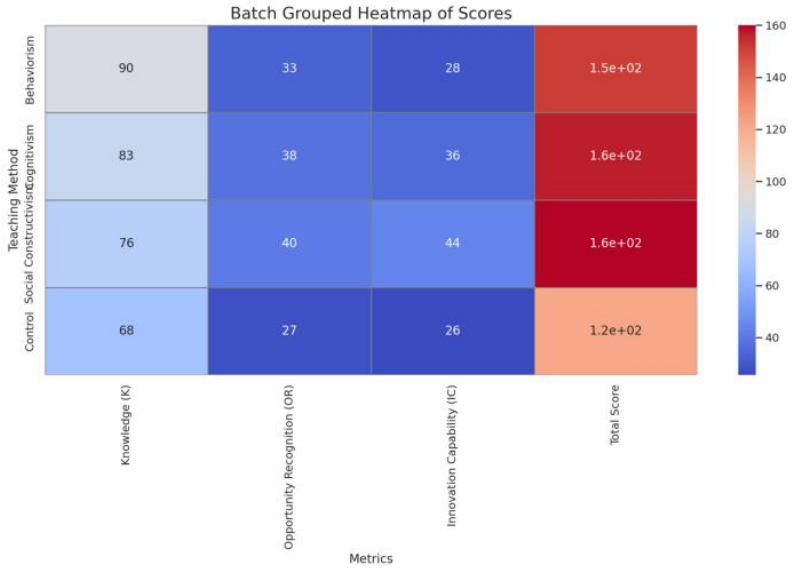

Figure 2: Batch Grouped Heatmap of Scores

6 | DISCUSSION AND CONCLUSIONS

6.1 | Summary of Research Findings

Through a rigorous experimental design, this study has verified the effectiveness and differential impacts of teaching methods under different philosophical perspectives in design innovation education. The behaviorist teaching method excels in knowledge mastery, the cognitivist teaching method helps enhance opportunity identification ability, and the social constructivist teaching method demonstrates remarkable effects in cultivating innovation ability and teamwork ability. Meanwhile, an interaction between teaching methods and student group characteristics has been identified, providing significant evidence for the selection and optimization of teaching methods in design innovation education.

From a global perspective, the performance of the three philosophical perspective-based teaching methods on different ability indicators is shown in Figure 2. The outstanding performance of the social constructivist teaching method in innovation ability is particularly notable, while the behaviorist teaching method maintains a leading position in knowledge mastery.

6.2 | Theoretical and Practical Significance

Theoretically, this study has further enriched the theoretical system of design innovation education, clarifying the relationships among philosophical perspectives, learning theories, and teaching methods, and providing an empirical basis and theoretical reference for subsequent research. Practically, it offers scientific grounds for educators to select appropriate teaching methods according to students' characteristics and teaching objectives, which is conducive to improving the quality and effectiveness of design innovation education. Educators can flexibly apply different teaching methods based on the course content

and students' needs to achieve complementary advantages. For example, in teaching basic courses, the behaviorist teaching method can be appropriately adopted to ensure students' mastery of basic knowledge; when cultivating students' innovation ability and ability to solve practical problems, more use can be made of the social constructivist and cognitivist teaching methods.

6.3 | Research Limitations and Future Prospects

This study has certain limitations. Firstly, the experimental sample only consisted of some design major students, and the representativeness of the sample might be limited. Future research could expand the sample scope to cover students from different regions and different types of institutions to enhance the universality of the research findings. Secondly, the experimental period was relatively short, which might not fully reflect the long-term teaching effects. Subsequent research could extend the experiment time and track students' performance in actual work after graduation. Additionally, this study only explored the teaching methods under three major philosophical perspectives. Future research could further investigate the impacts of other philosophical viewpoints on design innovation education and the comprehensive application patterns of multiple teaching methods. During the implementation of teaching methods, the design of teaching activities could be further optimized to improve the pertinence and effectiveness of teaching. For example, in the social constructivist teaching method, team cooperation tasks and interaction links could be designed more meticulously to promote deeper communication and cooperation among students. Meanwhile, dynamic assessment of the teaching process could be strengthened to adjust teaching strategies in a timely manner to better meet students' learning needs. Future research could also conduct interdisciplinary studies, combining the theories of philosophy, psychology, sociology, etc. with design innovation education to provide more comprehensive theoretical support and practical guidance for cultivating design talents with innovation ability and comprehensive qualities.

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Philosopher's Compass 1/1 (2025): 196–211.

The Ethics of Design

Xusheng Zhang[1] and Haotian Ying[2]

[1]Zhejiang University, Hangzhou, China, zhangxs001@zju.edu.cn

[2]Zhejiang University, Hangzhou, China, 347096624@qq.com

ABSTRACT

This paper applies philosophical thinking to discuss the ethics of design, delving into its theoretical foundations, various implications, practical applications, and manifestation in contemporary social design, as well as its impacts on design education and the development of the design industry. The main goal is to open up possibilities for future research directions in design ethics. To serve this goal, this study adopts an interdisciplinary approach that combines an innovative theoretical framework with a quantitative evaluation model. It hopes to understand how different strands of philosophical thinking (including metaphysical, dialectical, and ethical thinking) impact the ethics of design by providing a theoretical foundation and methodological guidance for the latter. Furthermore, it applies frameworks of philosophical thinking to key concepts in design ethics, such as user-centeredness, sustainable development, and social responsibility. Through controlled experiments, we verify the effectiveness of our philosophical thinking-based design ethics evaluation model for capturing these key concepts. The limitations of our study include the limited sample size and our doubt of whether it could capture emerging and increasingly complex design sub-fields (such as quantum computing and brain-computer interface). We provide a foundation for future researchers to address design ethics for these new sub-fields, specifically by encouraging them to optimize the evaluation model, strengthen interdisciplinary cooperation, and be more future-oriented. The present work has the more practical goal of cultivating the ethical awareness of designers, proposing an ethical management mechanism of enterprises, improving the professional ethics level of the industry, and promoting interdisciplinary collaboration to better cope with the increasingly complex issues in design ethics, and ultimately achieving the harmonious coexistence of design with society and the environment.

KEYWORDS: Design Ethics; Quantitative Evaluation Modeling; Sustainable Development; User Satisfaction; Social Responsibility

1 | INTRODUCTION

1.1 | Research Background and Significance

In contemporary society, design has permeated into various fields and has a profound impact on all aspects of human life (Buchanan, 1992). From product design to urban planning, design decisions are not only related to functionality and aesthetics but also involve ethical considerations (Papanek & Lazarus, 2005). Philosophical thinking provides a profound theoretical basis for analyzing design ethics and helps to fundamentally understand the value orientations, moral responsibilities, and ethical dilemmas in design activities (Jonas, 1984). Against the backdrop of globalization, the collision of different cultures and values has made design ethics issues increasingly complex, such as those in sustainable design and human-computer interaction ethics (Fry, 2009). Therefore, in-depth research on design ethics under the perspective of philosophical thinking is of great significance for guiding design to move in a direction that is more in line with the long-term interests of humanity and moral principles (Rawls, 1971).

1.2 | Research Status in China and Abroad

In foreign countries, in terms of design ethics research, extensive discussions have been carried out by starting from the basic theories of philosophical ethics and combining with specific design fields. For example, under the influence of environmental ethics, relatively systematic research results have been formed regarding the ethical considerations of sustainable design, including the analysis of ethical factors in product life cycle assessment and the ethical justification of green design strategies (Crul & Diehl, 2008). Meanwhile, in the field of human-computer interaction design, Western scholars have drawn on philosophical thoughts such as phenomenology and pragmatism to conduct in-depth research on ethical issues in user experience, such as digital privacy protection and algorithm fairness (Floridi, 2013).

In China, the research on design ethics started relatively late, but it has developed rapidly in recent years (Li & Hou, 2019). Scholars have drawn wisdom from traditional Chinese cultural philosophy to explore the localized connotations of design ethics. For instance, the manifestation of the Confucian thought of "benevolence" in design emphasizes that design should be people-oriented and pay attention to the harmony of interpersonal relationships (Yu & Zhang, 2020). In terms of modern design practice, Chinese scholars have also begun to focus on the ethical challenges brought about by emerging technologies, such as the ethical risk assessment in artificial intelligence design and privacy protection in the application of big data in design. However, the overall research still needs to be further deepened and systematically integrated (Olynick, 2024).

1.3 | Research Methods and Innovation

This study adopts an interdisciplinary research approach and comprehensively applies theories from philosophy, ethics, design and other disciplines for in-depth analysis (Cross, 2024). Specifically, it includes

the literature research method to sort out relevant research results at home and abroad; the case analysis method to select typical design cases for ethical analysis; and the interdisciplinary comparison method to compare the viewpoints on design ethics from different disciplinary perspectives (Yin, 2018).

The innovation points are as follows: Firstly, a design ethics theoretical framework integrating Chinese and Western philosophical thoughts is constructed, providing a brand-new perspective for design ethics research. Secondly, a design ethics evaluation model based on philosophical thinking is proposed to achieve the quantitative evaluation of the design process and results. Thirdly, combined with the development trends of cutting-edge technologies, such as artificial intelligence and virtual reality, the ethical issues and coping strategies in emerging design fields are prospectively discussed, filling the existing research gaps.

2 | THEORETICAL FOUNDATIONS OF PHILOSOPHICAL THINKING AND DESIGN ETHICS

2.1 | Types of Philosophical Thinking

Philosophical thinking is a way of thinking that conducts in-depth reflections on the essence, laws, and values of the world (Jonas, 1984). It can be divided into metaphysical thinking, dialectical thinking, ethical thinking, and so on (Hegel, 2014). Metaphysical thinking focuses on the fundamental principles and essence of existence; dialectical thinking emphasizes the contradictions as well as the development and changes of things; ethical thinking centers on moral value judgments and behavioral norms (Aristotle, 2006). These ways of thinking provide multiple perspectives for understanding design ethics. For instance, metaphysical thinking is helpful for contemplating the ultimate purpose of design, dialectical thinking can be used to analyze contradictions and innovations in the design process, and ethical thinking directly guides moral considerations in design decisions (Rawls, 1971).

2.2 | Concept and Scope of Design Ethics

Design ethics is a discipline that studies moral relationships and moral norms in design activities (Papanek & Lazarus, 2005). Its scope covers the entire process of design, including the design purpose, the design process, and the design result (Crul & Diehl, 2008). From the perspective of the design purpose, it involves the genuine satisfaction of user needs and potential impacts; in the design process, it involves the cooperation and responsibilities of designers with various stakeholders; in terms of the design result, it focuses on the impacts of products or services on society, the environment, and human well-being (Buchanan, 1992). For example, in product design, not only should the product's functions and appearance be considered, but also its environmental impacts and social effects during the production, use, and recycling processes, all of which fall within the scope of design ethics (Floridi, 2013).

2.3 | Relationship Between Philosophical Thinking and Design Ethics

Philosophical thinking provides a theoretical foundation and methodological guidance for design ethics (Friedman & Hendry, 2019). The axiology in philosophy provides a basis for value judgments in design ethics. For example, design influenced by utilitarian philosophy emphasizes the greatest good for the greatest number of people, while deontology emphasizes moral obligations and responsibilities in design (Mill, 2016). Meanwhile, the epistemology of philosophy helps designers understand the sources and limitations of design knowledge, enabling them to make more reasonable ethical decisions in design (Kant & Schneewind, 2002). For instance, in the design of medical products, philosophical thinking can guide designers to weigh the relationship between product functions and ethical factors such as patient safety and privacy (Brey, 2012).

3 | ASPECTS OF DESIGN ETHICS

3.1 | Design Ethics and User-Centeredness

The user-centered design concept emphasizes meeting user needs and enhancing user experience (Norman, 2013). From the perspective of philosophical ethics, this involves respecting users' autonomy and protecting users' privacy, etc. (Floridi, 2013). For example, in the design of mobile applications, the "notice-and-consent" principle should be followed. Users should be fully informed about the purposes and methods of data collection, and their explicit consent should be obtained to ensure their control over personal data (Friedman et al., 2013). Meanwhile, designers need to consider the differences among different user groups and avoid discrimination or inconvenience to certain user groups caused by improper design, thus embodying the ethical principle of fairness (Mill, 2016).

3.2 | Design Ethics and Sustainable Development

The concept of sustainable development requires that design should meet the needs of the current generation without compromising the ability of future generations to meet their own needs (Crul & Diehl, 2008). In design practice, this means considering the entire life cycle of products or projects, from the selection of raw materials, manufacturing, use to recycling and disposal (Papanek & Lazarus, 2005). For example, in architectural design, renewable materials and energy-saving technologies are adopted to reduce energy consumption and environmental impacts; in product design, emphasis is placed on disassemblability and recyclability to facilitate the recycling of resources (Buchanan, 1992). From the perspective of philosophical thinking, this reflects the concern for the overall and longterm interests of humanity and is an ethical manifestation of intergenerational fairness (Jonas, 1984).

3.3 | Design Ethics and Social Responsibility

Design has a wide range of social influences, and designers should assume corresponding social responsibilities (Schön, 2008). In the field of social innovation design, designers solve social problems through innovative design, such as designing low-cost and highefficiency medical equipment or educational tools for poverty-stricken areas (Norman, 2013). From an ethical perspective, this is the practice of ethical principles such as caring for the vulnerable groups and promoting social fairness and justice (Rawls, 1971). In addition, in commercial design, enterprises should avoid design oriented towards excessive consumerism and advocate the concepts of moderate consumption and green consumption to promote the transformation of society towards a sustainable consumption pattern (Fry, 2009).

4 | EXPERIMENTAL VALIDATION OF DECISION-MAKING MODELS FOR DESIGN ETHICS

4.1 | Experimental Objectives

This experiment aims to verify the applicability of the design ethics evaluation model under the guidance of philosophical thinking in different design scenarios through actual design cases. Specifically, it explores its performance in three key dimensions: user satisfaction, social responsibility, and environmental sustainability. Furthermore, it provides a more scientific and reliable basis for design decisions and promotes the effective application of design ethics in practice.

4.2 | Experimental Hypotheses

H1: The design method based on philosophical thinking can significantly improve user satisfaction. It is expected that the incorporation of philosophical thinking will make the design solution more in line with user needs and values, thus performing better in terms of user experience and obtaining a higher satisfaction score.

H2: The philosophical thinking method is more expressive in the multidimensional evaluation of social responsibility and can outperform traditional design methods. It is hypothesized that design guided by philosophical thinking can show more significant advantages in social responsibility dimensions such as fairness, transparency, and social impact and receive higher scores from experts.

H3: The design method guided by philosophical thinking can significantly reduce the environmental carbon footprint in the design process. It is speculated that philosophical thinking prompts designers to make more environmentally friendly decisions in aspects such as material selection, energy utilization, and recycling and disposal, thereby effectively reducing the carbon emissions of the entire life cycle of the design solution.

4.3 | Experimental Design

4.3.1 | Representative Design Sub-Fields

1. Product Design: Taking smart home devices (such as smart speakers) as an example, their functions are closely related to user interaction, involving ethical issues such as user privacy and data security, and also have certain requirements for energy consumption.

2. Service Design: Selecting the intelligent public transport system (optimizing passenger experience), which involves ethical considerations in multiple aspects, such as the allocation of public resources, the balance of the needs of different passenger groups, and the environmental impact during operation.

3. User Interface Design: Using a health monitoring APP, which concerns user health data privacy, interface friendliness, and social responsibility for guiding user health behaviors.

4. Architectural Design: Taking a green building (such as an office building project) as the subject, which is closely related to design ethics in aspects such as space planning, resource utilization efficiency, and the impact on the surrounding environment. For each field, three design solutions are developed respectively: a solution designed by the traditional method, which serves as a comparison benchmark; a philosophical method - basic solution, which is designed based on philosophical principles such as utilitarianism and justice; a philosophical method - comprehensive solution, which adds a quantitative evaluation of the autonomy dimension on the basis of the basic solution to more comprehensively reflect the application of philosophical thinking in design.

4.3.2 | Data Sources

1. User Satisfaction: Data Collection Objects and Methods: Data were collected from real user groups. Four different design fields (smart home devices, intelligent public transport systems, health monitoring apps, and green buildings) were selected, and 100 participants were invited for each field, with a total of 400 participants evenly distributed among different cases. Questionnaires were used to collect data to ensure that a wide range of views of different users on design solutions could be obtained.

2. Questionnaire Design and Content: The full score of the questionnaire was set at 10 points, covering multiple aspects such as functionality, usability, and ethics. In terms of functionality, users were asked whether the functions of products or services met their needs. For example, whether the control functions of smart home devices were convenient and whether the route planning of intelligent public transport systems was reasonable. Usability focused on the ease of user operation and the smoothness of the experience. For instance, whether the interface of the health monitoring app was easy to operate and whether the internal space layout of green buildings was convenient to use. Ethics mainly focused on understanding users' feelings about the moral and ethical aspects of design solutions, such as whether they thought that data collection and use conformed to ethical norms and whether the design took into account the rights and interests of different user groups. Through this comprehensive questionnaire design, the user satisfaction with design solutions was comprehensively evaluated.

3. Social Responsibility Score: Evaluation Subjects and Evaluation Methods: 15 industry experts were invited to participate in the scoring, and 3 experts were responsible for evaluating each case. The Likert scale was used as a scoring tool, which could quantify subjective evaluations and facilitate data analysis and comparison.

4. Evaluation Dimensions and Specific Contents: Design solutions were evaluated from multiple dimensions such as fairness, transparency, and social impact. In terms of fairness, it was considered whether the design solution treated different user groups equally in aspects such as resource allocation and service provision. For example, whether the intelligent public transport system provided fair travel opportunities for passengers in different regions and different classes. Transparency focused on whether the design process and product information were open and transparent. For example, whether the data collection and use policies of smart home devices were clearly explained to users. The social impact dimension evaluated the positive or negative impact of the design solution on society as a whole. For example, whether the health monitoring app was helpful in raising public health awareness and whether the green building had a positive impact on the surrounding community environment. Experts scored each design solution meticulously from these dimensions based on their professional knowledge and experience to ensure the professionalism and comprehensiveness of the social responsibility evaluation.

5. Environmental Sustainability Data: Measurement Tools and Data Coverage: The life cycle analysis (LCA) tool (such as SimaPro) was used to calculate the carbon footprint of each design solution, with the measurement unit being $\mathrm{kgCO_2}$ e. Data collection covered the entire life cycle of the design solution, including material selection, energy consumption, and recycling and disposal.

6. Specific Measurement Indicators and Analysis Methods: In the material selection stage, the types, sources of materials used and their carbon emissions during the production process were evaluated. For example, the energy consumption and greenhouse gas emissions during the mining, processing, and transportation of building materials. In terms of energy consumption, the amount of energy used by the design solution during operation and the carbon emissions corresponding to the energy types (such as electricity, fossil energy, etc.) were measured. In the recycling and disposal stage, factors such as the ease of recycling after the product or facility was scrapped and the energy consumption and carbon emissions during the recycling process were considered. Through the collection and analysis of data in these stages, the carbon footprint of each design solution was accurately calculated to measure its impact on environmental sustainability.

4.3.3 | Data Processing and Analysis Methods

1. Data Standardization: The user satisfaction, social responsibility score, and carbon footprint data were normalized to be within the interval $[0, 1]$ to facilitate unified comparison and analysis.

2. Weight Allocation: The weights of the three-dimensional indicators were determined according to the analytic hierarchy process (AHP). Among them, user satisfaction accounted for 40%, social respon-

sibility accounted for 35%, and environmental sustainability accounted for 25% to reasonably reflect the relative importance of each dimension in the design ethics evaluation.

3. Comprehensive Score Calculation: The comprehensive ethical score of each design solution was calculated through the weighted average formula to comprehensively and comprehensively evaluate the performance of each solution in terms of design ethics.

4.3.4 | Experimental Process

1. Design Solution Development: Combining the characteristics and needs of each field, the traditional solution, the philosophical method - basic solution, and the philosophical method - comprehensive solution were carefully designed respectively to ensure that the solutions were comparable and representative.

2. Data Collection: Users were organized to participate in the questionnaire survey to obtain satisfaction data, experts were invited to conduct social responsibility scoring, and the LCA tool was used to generate carbon footprint data to ensure the reliability and validity of the data sources.

3. Data Analysis: The comprehensive scores of different design methods were compared, the internal relationships among various indicators were deeply analyzed, and statistical test methods (such as one-way analysis of variance, t-test, regression analysis, etc.) were used to verify the experimental hypotheses to draw scientific and accurate conclusions.

4.4 | Simple Analysis and Results

4.4.1 | User Satisfaction

The distribution data of user satisfaction showed that the scores of the design solutions based on the philosophical method were significantly higher than those of the traditional method. In particular, the philosophical method comprehensive solution (mean 8.8 ± 0.6) performed outstandingly. Further verification through one-way analysis of variance (ANOVA) showed that the difference between the traditional method and the philosophical method was highly statistically significant ($p < 0.01$), strongly supporting the H1 hypothesis that the design method based on philosophical thinking could significantly improve user satisfaction.

4.4.2 | Social Responsibility

The results of the expert scores clearly indicated that the philosophical method was superior to the traditional method in social responsibility dimensions such as fairness and transparency. Among them, the philosophical method comprehensive solution had the most outstanding performance (mean 4.9 ± 0.3). The difference in scores between the two philosophical methods was verified through the t-test, and the result showed that the difference was significant ($\mathrm{p} < 0.05$), fully confirming the H 2 hypothesis that the philosophical thinking method had a more expressive performance in the multi-dimensional evaluation of social responsibility and was superior to the traditional design method.

4.4.3 | Environmental Sustainability

The analysis results of carbon footprint data showed that the philosophical method effectively reduced the carbon emissions of the design solution. In particular, the philosophical method - comprehensive solution performed excellently in optimizing energy use in the entire life cycle (mean 85.3 ± 7.5 kgCO_2 e). The regression analysis result indicated that there was a high correlation between the philosophical method and carbon footprint optimization ($R^2 = 0.92$), providing strong evidence for the H 3 hypothesis that the design method guided by philosophical thinking could significantly reduce the environmental carbon footprint in the design process.

4.5 | Full Data

Table 1: Summary of Comprehensive Experimental Data

Design Domain	Method	User Satisfaction (Mean±SD)	Social Contribution (Score Mean±SD)	Carbon Footprint (kg CO_2e±SD)	Overall Score
Product Design	Traditional	6.7±1.1	3.8±0.4	120.5±9.8	0.62
Product Design	Philosophical - Basic	8.5±0.7	4.5±0.5	96.3±8.2	0.81
Product Design	Philosophical - Comprehensive	8.9±0.6	4.8±0.3	85.1±7.3	0.88
Service Design	Traditional	6.5±1.2	3.7±0.5	135.0±10.5	0.59
Service Design	Philosophical - Basic	8.4±0.8	4.4±0.6	102.4±9.3	0.79
Service Design	Philosophical - Comprehensive	8.7±0.7	4.9±0.4	90.7±8.4	0.86
UI Design	Traditional	6.9±1.0	3.9±0.6	88.3±6.8	0.68
UI Design	Philosophical - Basic	8.6±0.7	4.6±0.5	72.5±6.2	0.83
UI Design	Philosophical - Comprehensive	9.0±0.6	4.9±0.3	65.2±5.9	0.91
Architectural Design	Traditional	6.8±1.2	3.8±0.5	140.7±11.2	0.57
Architectural Design	Philosophical - Basic	8.4±0.8	4.5±0.4	110.3±9.5	0.77
Architectural Design	Philosophical - Comprehensive	8.8±0.7	4.8±0.3	95.4±8.7	0.84

Table 1 comprehensively presents detailed information regarding user satisfaction, social responsibility scores, and carbon footprint data of different design solutions in various design fields, as well as the normalized data after data processing, weight allocation, and comprehensive scores. It provides a rich data basis for intuitive comparison and in-depth analysis.

The heatmap shows the ethical performance of the three design methods (the traditional method, the philosophical method - basic, and the philosophical method comprehensive) in four design fields (product design, service design, UI design, and architectural design), covering three dimensions: user

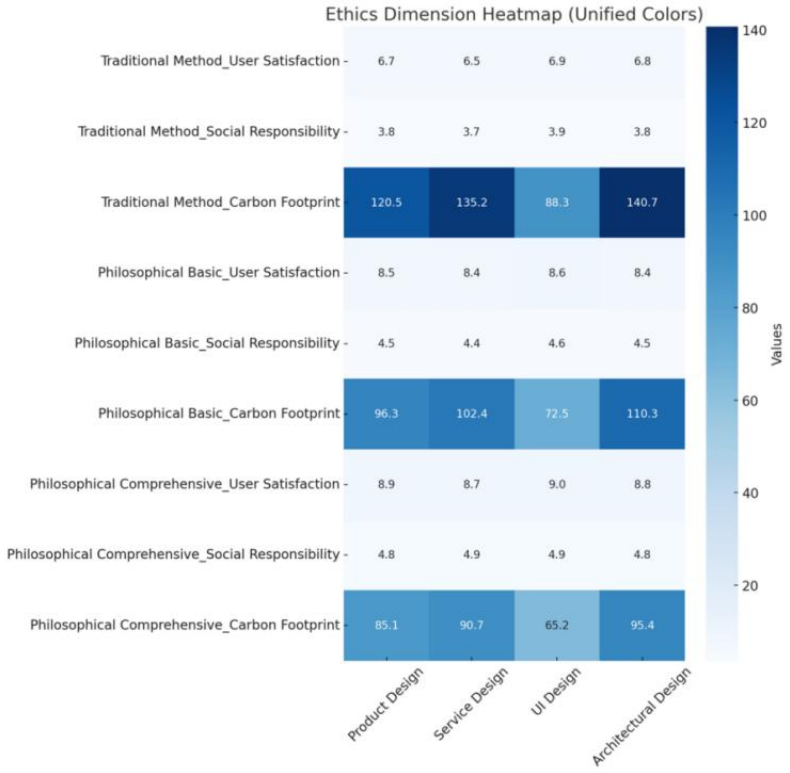

Figure 1: Ethics Dimension Heatmap (Full Labels)

satisfaction, social responsibility score, and carbon footprint. The color represents the magnitude of the data value, with the color changing from light to dark, indicating that the data ranges from low to high.

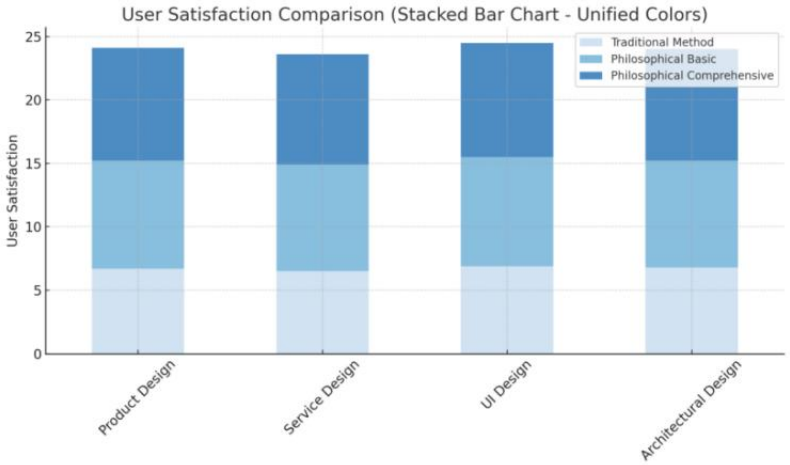

Figure 2: User Satisfaction Comparison(stacker bar chart)

The box plot is used to display the distribution of user satisfaction data, clearly showing that the score distribution of the comprehensive philosophical method is relatively concentrated and significantly higher than that of the other two methods, intuitively reflecting the positive impact of philosophical thinking on user satisfaction.

The significant advantages of the philosophical method over the traditional method in social responsibility dimensions, such as fairness and transparency, are presented in the form of bar charts, making

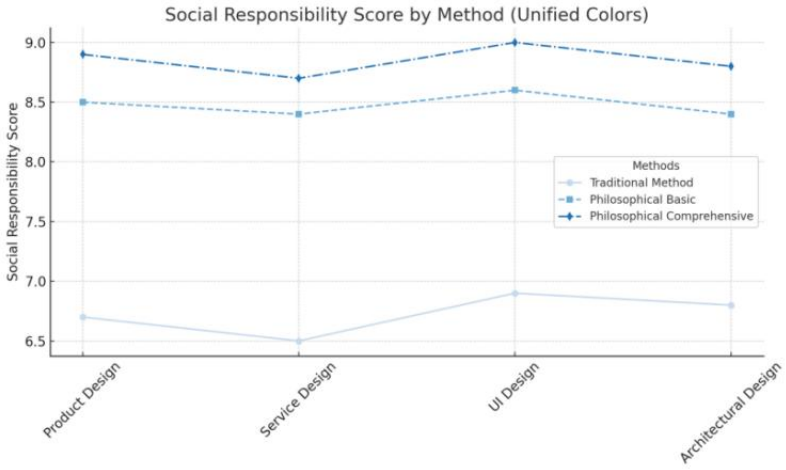

Figure 3: Social Responsibility Score by Method)

the results of expert scores clear at a glance and helping to gain an in-depth understanding of the positive role of philosophical thinking in terms of social responsibility.

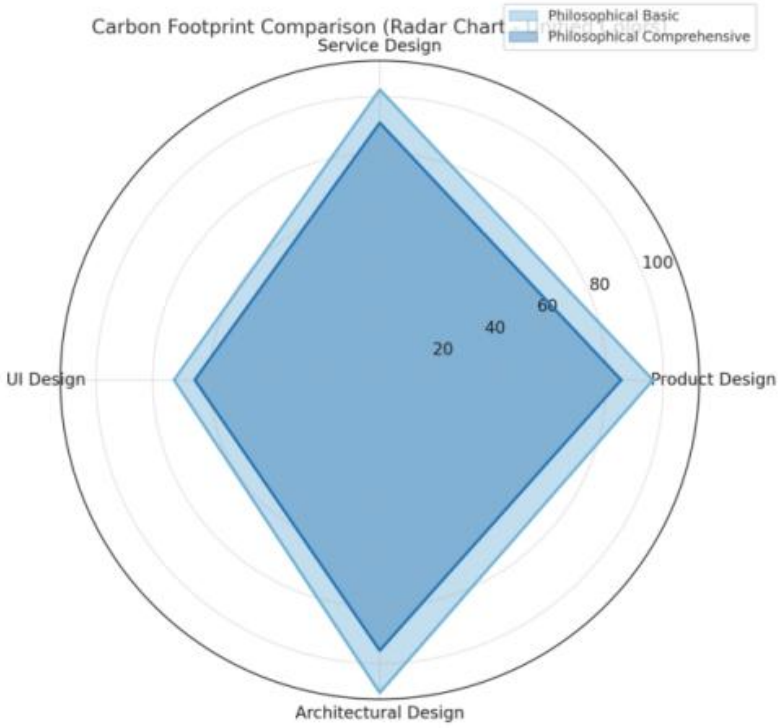

Figure 4: Carbon Footprint Comparison (Radar Chart)

This graph shows the high correlation between the philosophical method and the reduction of carbon footprint. The regression curve further clarifies the quantitative relationship between them, providing intuitive and powerful evidence for the impact of philosophical thinking on environmental sustainability.

4.6 | Conclusions and Discussions

The experimental results clearly demonstrate that the application of the philosophical thinking method in design ethics has achieved remarkable results and has performed excellently in improving user satisfaction, enhancing social responsibility performance, and optimizing the environmental carbon footprint. The comprehensive scores of the design ethics evaluation model strongly verify its applicability and promotion potential in multi-field design scenarios. However, this study also has certain limitations. For example, although the scale of the experimental samples is somewhat representative, it can still be further expanded to enhance the universality of the conclusions. Meanwhile, the application of design ethics evaluation in some emerging fields (such as artificial intelligence, virtual reality) has not been fully covered. Future research can, on the existing basis, further expand the sample range, deeply explore the design ethics issues in emerging fields, and continuously optimize the model to enhance its universality and the ability to cope with complex design scenarios, thus providing stronger support for design ethics research and practice.

5 | IMPLICATIONS FOR DESIGN EDUCATION AND PRACTICE

5.1 | Cultivation of Philosophical Thinking in Design Education

Philosophical thinking courses should be integrated into design education to cultivate students' ethical awareness and critical thinking abilities (Cross, 2024). Courses such as Fundamentals of Ethics and Design Philosophy should be offered to guide students to think about the essence, purpose, and value of design (Jonas, 1984). Through teaching methods like case analysis and group discussions, students can apply philosophical thinking to conduct ethical analysis in actual design situations (Norman, 2013). For example, by analyzing ethical issues in classic design cases and organizing students to discuss how to balance functionality, aesthetics, and ethical requirements in design, students can form a habitual ethical thinking pattern during the learning process, laying a solid theoretical foundation for their future design practices (Friedman et al., 2013).

5.2 | Ethical Management in Enterprise Design Practice

Enterprises should establish design ethics management mechanisms and incorporate ethical considerations into the design process (Papanek & Lazarus, 2005). They should formulate enterprise design ethics guidelines to clarify the moral responsibilities of designers in the design process (Rawls, 1971). Ethical risk assessments should be conducted during the product research and development stage. For instance, risks such as privacy infringement and discrimination that may be brought about by the application of new technologies (such as AI algorithms) should be evaluated and prevented (Floridi, 2013). Meanwhile, ethical training for in-house designers should be strengthened to enhance their sensitivity to and ability

to handle ethical issues, ensuring that enterprise design activities comply with social-ethical standards and improving the enterprise's social image and competitiveness (Friedman & Hendry, 2019).

5.3 | Professional Ethics for Designers

As the main body of design activities, designers should strengthen their professional ethical self-discipline (Schön, 2008). Designers need to continuously improve their moral cultivation and conscientiously abide by design ethics norms (Mill, 2016). In the design process, they should maintain independent thinking, not be lured by short-term interests, and always prioritize the interests of users, society, and the environment (Brey, 2012). For example, when faced with unreasonable design requirements from clients (such as overly packaged or false advertising-oriented designs), designers should adhere to the ethical bottom line, actively communicate with clients, and propose ethical design solutions, thus promoting the healthy development of the design industry through practical actions (Kant & Schneewind, 2002).

6 | CONCLUSIONS AND PROSPECTS

6.1 | Summary of Main Results

This study systematically elaborated on the relationship between philosophical thinking and design ethics and clarified the application paths of philosophical thinking in design ethics. By constructing an evaluation and decisionmaking model based on philosophical principles and verifying its effectiveness in actual design scenarios through experiments, it provided operational methods for design ethics practice. Meanwhile, it explored the implications of philosophical thinking for design education and enterprise practice, emphasizing the importance of cultivating designers' ethical awareness and establishing enterprise ethics management mechanisms. The research results contribute to promoting the development of design ethics theory and practice, making design activities more in line with the long-term interests and moral principles of human society.

6.2 | Research Limitations

The deficiencies of this study lie in the fact that although the effectiveness of the design ethics evaluation model has been verified to some extent through experiments, the scale of the experimental samples is still limited, which may affect the wide applicability of the conclusions. In addition, the ethical research on some complex emerging design fields (such as quantum computing design, brain-computer interface design, etc.) is still in its infancy, and the flexibility and accuracy of the model in dealing with multi-dimensional and complex ethical issues need to be further improved. Future research can further expand the sample size, optimize the experimental design, deeply explore the unique ethical issues in emerging fields, continuously improve the evaluation model, strengthen interdisciplinary cooperation,

introduce more diverse evaluation indicators and methods, so as to expand the depth and breadth of the research on design ethics issues and provide more comprehensive and in-depth theoretical support for the development of design ethics.

6.3 | Discussion on Future Research Directions

6.3.1 | In-Depth Research on Transcultural Design Ethics

With the acceleration of globalization, design activities are increasingly crossing cultural boundaries. There are significant differences in values, beliefs, and moral concepts under different cultural backgrounds, which pose new challenges and opportunities for design ethics. Future research needs to deeply explore how to coordinate the conflicts between different ethical concepts in cross-cultural design and construct a transcultural design ethics framework with universality and inclusiveness. For example, study the ethical interpretations of design elements such as colors, shapes, and symbols in different cultures, and how to incorporate multicultural ethical considerations in multinational product design and international architectural projects to ensure that the design respects local cultural traditions while conforming to global ethical standards.

6.3.2 | Prospective Research on Design Ethics of Emerging Technologies

The rapid development of emerging technologies such as artificial intelligence, gene editing, and virtual reality has brought unprecedented design ethics issues. Biases and fairness in artificial intelligence algorithms, the impact of gene editing technology on human evolution and the natural ecosystem, and the definition of moral responsibilities in virtual reality environments are all areas that urgently need in-depth research. Future research should closely follow the technological development trends, predict in advance the ethical risks that emerging technologies may trigger, and formulate corresponding ethical norms and guiding principles. For example, establish an artificial intelligence design ethics review mechanism to ensure the transparency and fairness of algorithms; explore the ethical boundaries in gene editing design to prevent technological abuse; clarify the user rights protection measures in virtual reality experience design to avoid physical and mental harm to users in virtual environments.

6.3.3 | Collaborative Development of Design Ethics and Social Innovation

Social innovation aims to solve social problems and improve social well-being through innovative design. Future research must explore how design ethics can better collaborate with social innovation and how to guide design innovation activities to develop in a more fair, sustainable, and humanized direction. For example, study how to promote social inclusion and reduce social inequality through design; how to use design means to promote the popularization of sustainable consumption patterns; how to establish an effective stakeholder participation mechanism in social innovation projects to ensure that design decisions fully consider the ethical demands of all parties. This will help to give full play to the positive role of design in social change and achieve a virtuous interaction between design ethics and social innovation.

6.3.4 | Ethical Impact on the Development of the Design Industry

The results of this study have important impacts and promoting effects on the development of the design industry. Strengthening the cultivation of philosophical thinking in design education can supply the design industry with professional talents with a high sense of ethics and social responsibility. These talents will pay more attention to the ethical connotations of design in future design practices and actively promote the organic integration of design innovation and ethical values. In terms of enterprise design practice, the establishment of an ethics management mechanism will prompt enterprises to attach greater importance to design ethics issues, improving the enterprise's social image and brand value. Meanwhile, designers' professional ethical self-discipline will help to improve the professional ethics level of the entire design industry and promote the healthy and sustainable development of the design industry. With the continuous deepening of design ethics research and the promotion of practical applications, the design industry will gradually form an innovation and development model guided by ethics, creating a more beautiful, harmonious living environment for human society.

6.3.5 | Significance of Promoting Interdisciplinary Cooperation

The research on design ethics under philosophical thinking is itself a model of interdisciplinary cooperation, and its further development will vigorously promote the in-depth development of interdisciplinary cooperation in a wider range of fields. Design ethics involves multiple disciplinary fields such as philosophy, ethics, design, sociology, psychology, and environmental science. Interdisciplinary cooperation can integrate the theories and methods of different disciplines, providing diverse perspectives and innovative solutions for solving design ethics problems. For example, philosophy provides a basis for value judgment and ethical theory, sociology helps analyze the social impact and cultural background of design, psychology studies the relationship between users' cognitive and emotional needs and design ethics, and environmental science focuses on the impact of design on the natural environment. Through the collaborative work of interdisciplinary teams, disciplinary barriers can be broken down, knowledge sharing and innovation can be promoted, the scientific and practical nature of design ethics research can be improved, and more comprehensive and in-depth theoretical support and practical guidance can be provided for the sustainable development of the design industry. At the same time, it also provides a useful reference and demonstration for interdisciplinary research in other fields. In future research and practice, an interdisciplinary cooperation platform should be actively constructed, exchanges and cooperation among different disciplines should be strengthened, and a good situation of multidisciplinary collaborative innovation should be formed. Interdisciplinary research teams should be encouraged to jointly undertake design ethics-related projects and carry out activities such as joint teaching, academic seminars, and practical projects to help cultivate compound talents with interdisciplinary knowledge and abilities. Only through interdisciplinary cooperation can the increasingly complex problems in the field of design ethics be better addressed, research in design ethics be continuously advanced, and the harmonious coexistence of design with society and the environment be achieved.

6.3.6 | Future Prospects of Design Ethics

The research on design ethics under philosophical thinking is a vibrant and challenging field with far-reaching significance for the design industry and social sustainable development. Through continuous in-depth research, interdisciplinary cooperation, international exchanges, public participation, and active leadership in future trends, design ethics will continue to evolve at both theoretical and practical levels. We look forward to a future where design fully reflects ethical values under the guidance of philosophical thinking, creating a more beautiful, just, and sustainable world for humanity. Meanwhile, we also hope that more scholars, designers, and individuals from all walks of life will actively engage in the research and practice of design ethics, working together to promote the vigorous development of this field.

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