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# The Role of Idealizations in Context-Dependent Mapping

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ABSTRACT. This paper explores the integration of Michael Strevens' concept of idealizations with my previous framework of similarity spaces and context-dependence to develop a comprehensive account of ideal explanations in scientific practice. Idealizations, which involve deliberate falsifications, play a crucial role in distinguishing between causally relevant and irrelevant factors in scientific models. Context-dependent mapping provides a structured approach to handling complementarities and context-dependent phenomena by mapping different observational contexts to distinct sets of physical laws. By combining these two ideas, I will construct an idealized context-dependent mapping structure and discuss how ideal similarity spaces within the framework of context-dependent mapping can enhance our understanding of complex scientific phenomena, especially those involving wave-particle duality and black hole complementarity. I also aim to discuss the types of idealizations that may exist within explanation and examine their relations to the mapping.

KEYWORDS: Philosophy of Physics, Scientific Explanation, Kairetic Account, Ideal Laws, Complementarities, Understanding.


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## 1. Introduction

The integration of Michael Strevens' concept of idealizations with the framework of context-dependent mapping and similarity spaces provides a novel approach to enhancing scientific explanations. Idealizations, as proposed, involve deliberate simplifications or falsifications of certain aspects of a phenomenon to highlight the core causal mechanisms critical for understanding. These idealizations are indispensable in scientific practice as they help distinguish between causally relevant and irrelevant factors, thus clarifying the essential causal relationships within a model.

However, traditional models often struggle to accommodate phenomena that exhibit dual characteristics or context-dependent behaviors, such as those observed in quantum mechanics and general relativity. The complementarity principle in quantum mechanics, for instance, posits that entities can display wave-like or particle-like properties depending on the observational context, leading to seemingly contradictory descriptions that are nonetheless necessary for a comprehensive understanding of the system[2][10]. Similarly, the reconciliation of quantum mechanics with general relativity remains an unresolved challenge due to the fundamentally different ways these theories treat space, time, and gravitational interactions[3][9][1].

By integrating idealizations with context-dependent mapping, this paper aims to address these challenges. Context-dependent mapping involves the use of similarity spaces—structured representations of different sets of physical laws applicable to distinct observational contexts. This approach allows for the creation of context-dependent explanations that remain internally consistent and free from contradictions. The mapping assigns specific laws within consistent similarity subspaces to each observational context, thus facilitating a deeper understanding of complex phenomena, such as wave-particle duality and black hole complementarity.

The significance of this integration lies in its potential to provide a more nuanced and accurate framework for scientific explanations. Ideal context-dependent mapping not only avoids contradictions by tailoring explanations to specific contexts but also enhances our ability to understand the underlying causal mechanisms across different scientific domains. By drawing on the strengths of both idealizations and context-dependent mapping, this approach offers a comprehensive account of ideal explanations that can address the complexities of modern scientific phenomena.

In the following sections, this paper will explore how idealizations lead to understanding and construct the framework for ideal context-dependent mapping.

## 2. How Idealizations Lead to Understanding

To begin, I will consider the following sense of understanding, commonly referred to as the naive view of understanding:

> To understand something, I propose that you grasp the correct explanation of that thing (Strevens 2008, 3). This is a view that is so simple and obvious that it might fittingly be called the naive view of, the connection between explanation and understanding[6][8].

Michael Strevens argues that idealizations, which involve deliberate simplifications or falsifications of certain aspects of a phenomenon, are essential in scientific explanations as they help distinguish between causally relevant and irrelevant factors. He posits that these idealizations, by omitting or distorting certain elements, highlight the core causal mechanisms that are critical for understanding a phenomenon. This approach, known as the causal difference-making approach, asserts that an explanation is effective if it accurately identifies the factors that make a difference to whether or not the phenomenon occurs.

Strevens explains that idealizations serve to flag factors that, while causally relevant, may be explanatorily irrelevant to the phenomena being studied. He notes,

> Idealizations flag factors that are causally relevant but explanatorily irrelevant to the phenomena to be explained. Though useful to the would-be understander, such flagging is only a first step. Are there any further and more advanced ways that idealized models aid understanding? Yes, I propose: the manipulation of idealized models can provide considerable insight into the reasons that some causal factors are difference-makers and others are not, which helps the understander to grasp the nature of explanatory connections and so to better grasp the explanation itself[7].

By focusing on the essential causal relationships, idealizations do not impede the explanatory power of scientific models; rather, they enhance it. For example, when explaining why a cannonball and a musket ball fall at the same rate in a vacuum, scientists often ignore air resistance, an idealization that simplifies the model without compromising its explanatory power. Similarly, the ideal gas model, which assumes infinitely small molecules that do not collide, provides a powerful explanation of gases' behavior under various conditions. These simplifications allow scientists to isolate and examine the fundamental principles governing the phenomena.

Moreover, Strevens emphasizes that idealizations facilitate a deeper understanding of the causal structure of phenomena by enabling scientists to manipulate and explore different scenarios. This process involves systematically varying conditions and observing outcomes to gain insights into why certain factors are difference-makers while others are not. The manipulation of idealized models can provide considerable insight into the reasons that some causal factors are difference-makers and others are not, which helps the understander to grasp the nature of explanatory connections and so to better grasp the explanation itself. Idealizations aid understanding not only by indicating which factors are irrelevant but also by simplifying the system in a way that makes it easier to identify and understand the relevant causal relationships[7].

Strevens underscores that idealizations are indispensable tools in scientific practice, offering a clearer, more focused understanding of complex phenomena. By isolating and emphasizing the critical causal elements, scientists can effectively distinguish between relevant and irrelevant factors. This enhances the explanatory power of their models and deepens their understanding of the underlying causal mechanisms. Idealizations, therefore, serve not only as simplifications but as essential components that enable scientists to manipulate models and derive deeper insights into the causal structures of the phenomena they study. Through these idealizations, the path to understanding becomes more accessible, allowing for a more precise grasp of why and how certain events occur.

In summary, Strevens highlights the significant role of idealizations in scientific explanations. By simplifying complex systems and focusing on the most relevant causal factors, idealizations help scientists to clarify the essential mechanisms underlying various phenomena. This process enhances both the explanatory power of scientific models and the depth of understanding that scientists can achieve, making idealizations a fundamental aspect of scientific inquiry and comprehension.

From the description of idealizations, it is evident that there are a couple of different types of idealizations when it comes to explanations:

1. **Idealizations with Respect to Background and Initial Conditions**
   - Ignoring air resistance when modeling the fall of objects in a vacuum.
   - Assuming a frictionless surface when analyzing motion dynamics.
   - Setting initial velocities or positions to zero in certain physics problems.
2. **Idealizations with Respect to the Physical Laws**
   - Using Newton's laws at non-relativistic speeds without considering relativistic effects.
   - Applying Boyle's law to gases while ignoring intermolecular forces.
   - Assuming Hooke's law for springs without accounting for material limits.
3. **Idealizations with Respect to the System's Constituents**
   - Treating molecules as point particles in the ideal gas law.
   - Assuming a perfectly rational agent in economic models.
   - Representing populations as infinitely large to negate genetic drift in population genetics.

I will attempt to consider type 2 primarily in this paper. Further development may come from consideration of other types of idealizations.

## 3. Constructing the Ideal Context Dependent Mapping of Type 2

In my work on context dependence and similarity spaces, I provide a structured approach to handling complementarities and context-dependent phenomena in scientific explanations. I introduce the concept of context-dependent mapping to address the challenges posed by phenomena that exhibit different behaviors under varying observational contexts, such as those seen in quantum mechanics and general relativity. I begin by discussing the importance of addressing complementarities in scientific explanations. Traditional explanatory models often struggle to accommodate phenomena that exhibit dual characteristics, depending on the context of observation. For instance, quantum entities can display either wave-like or particle-like properties depending on the experimental setup. Complementarity posits that entities/systems can display apparently contradictory properties depending on the way they're observed or measured. These manifested properties are mutually exclusive yet equally necessary for a consistent description of the entity/system with our physical laws[4].

To handle these complementarities, I proposed the use of similarity spaces, which are structured representations of the different sets of physical laws applicable to distinct observational contexts. By mapping different contexts to specific regions within these similarity spaces, one can create context-dependent explanations that remain internally consistent and free from contradictions. It is possible to construct a mapping such that the contradictory similarity spaces can be separated into two (or more) consistent similarity subspaces. This mapping onto a similarity space will serve as an initial physical basis from which the DNP and Kairetic account can yield some higher-level phenomena[4].

I further illustrated this concept with examples, such as the double-slit experiment and black hole complementarity[5]. Context-dependent mapping allows for a more nuanced understanding of these complex phenomena by ensuring that the relevant physical laws are applied appropriately based on the specific observational setup. I characterize the context space and similarity subspace in the following manner: $c_i$ represents the set of contexts (as a subset of the context space C) that manifest one complementary feature: this may be the set of all accelerating frames in the Unruh effect or the set of all matter frames in the presence of a black hole. $S_i$ represents the similarity subspaces of a similarity space S. This may be the equations governing quantum field theory, black hole relativity, wave physics in quantum mechanics, etc.[4].

Note that to preserve generality, I will constantly use the index $i$ to refer to an arbitrary entity: $S_i$ is an arbitrary similarity subspace, $c_i$ is an arbitrary context element, and so forth. It is possible, then, to present the notion of an ideal similarity subset. Recall that for a set of physical laws, we can have a similarity space S as a collection of these laws grouped in a particular manner according to our needs. The elements of S are similarity subspaces, $S_i$, such that for any indicator i:

$$S'_i \in S \tag{1}$$

Let $S'_i$ denote a subset of a similarity subset $S_i$:

$$S'_i \subseteq S_i \tag{2}$$

This $S'_i$ represents the set of all idealized laws within $S_i$. We will continue with the formal treatment of the mapping itself in order to ease technical concerns regarding the transition between context-dependent mappings and the one regarding these idealized similarity subspaces. The context-dependent function $f_c$ can be said to be the following:

$$f : C \to \{S_1, S_2, ..., S_i\} \tag{3}$$

That maps a set of contexts $c_i \in C$ onto $S_i$ in the set of all similarity subspaces. I propose the ideal context-dependent mapping to take the form of a restriction on the range to be $S'_i$ instead.

$$f' : C \to \{S'_1, S'_2, ..., S'_i\} \tag{4}$$

The motivation for this mapping is as follows: consider an idealization of any law $s_h$. This would be either some new idealized law $s'_h$ or itself, $s_h$ (which suggests that it is an idealized law in itself). The natural concern at this stage of development is that since we are mapping sets of contexts $c_i \in C$ to subsets of $S_i$, there may be losses of certain domain elements $c_i$ when undergoing the map onto the range $S'_i$. This would only be possible if a similarity subspace in question, say for some k, $S'_k$, has no laws while $S_k$ does. This means that the above motivation may not hold for some laws. I claim that it does indeed hold; more specifically, for the $f'$ mapping, I assert the following proposition for an arbitrary similarity subspace $S_i$:

$P$: for any index j $s_j \in S_i$, $\exists s'_j$ such that $s'_j \in S'_i$.

In order to support $P$, let us consider the elements with ideal analogues. These may involve, for instance, the gas laws and fluid laws. These will analytically support $P$. Expressing this as a statement as $p_1$ with indices a:

$p_1$: For nonideal indices a: $s_a \in S_i$ and $s'_a \in S'_i$.

It is undoubtable that there are indeed ideal laws for laws with ideal counterparts. Recall that the types of idealization we are considering are those concerning only the physical laws. If we were ever to have a law that can not be idealized in an intuitive manner (not involved as $s_a$), then it is evident that this law would be as ideal as it gets. This isn't to say that further idealization (simplification) of this law is impossible, but rather that from a practical standpoint, it is worth considering the limitations of idealization for that law and that we then have no choice but to implement it in our similarity subspace. Hence statement $p_2$ summarizes proposition P:

$p_2$: For ideal indices m: $s_m \in S_i, S'_i$.

Here, we have assumed that indices can either denote ideal or nonideal laws. Continuing with our overall motivation for $f'$, we will denote even this unchanged law as $s'_h$ for the sake of consistency for primed laws being ideal laws. This idealization operation would naively look as follows:

$$I : S_i \to S'_i \tag{5}$$

such that

$$I(s_h) = s'_h. \tag{6}$$

The construction goes as follows: we will consider a universal idealization mapping $I_u$ such that all elements of a similarity subspace $S_i$ will undergo this idealization $I$:

$$I_u : \{S_1, S_2, ..., S'_N\} \to \{S'_1, S'_2, ..., S'_N\} \tag{7}$$

such that

$$I_u(S_i) = S'_i. \tag{8}$$

We now arrived at a mapping that takes a similarity subspace and returns an idealized subspace. It is evident that $f'$ is the following composite function:

$$I_u \circ f = f' : C \to \{S'_1, S'_2, ..., S'_N\}. \tag{9}$$

We now have a tentative formulation for idealization within sets of laws and an ideal mapping that returns an idealized similarity subset. Note that this is only a formulation for idealization of type 2: with regards to physical laws.

The ultimate thought behind the idealized context-dependent mapping $f'$ is that we can allow for the benefits of these ideal explanations mentioned above to be utilized within standalone explanations (explanations involving models of each factor within another model) in a versatile manner. Dealing with complementarities in quantum mechanics and general relativity can be imperative to the consistency of an explanation as they are almost universally involved: the wave-particle duality, for instance, exists on a particle-basis[5]. This means that complementarity is involved in every particle of a considered system. It is a feature of all matter at the subatomic scale.

It is arguable that there is a need to reconcile the tension between relativistic and quantum physics at the subatomic scale as well. There have been attempts to reconcile them in the form of complementarities. This is the significance of the context-dependent mapping. The proposed solutions to contradictions in our physical theories, being in the form of complementarities, can be attended to through mappings onto sets of consistent, noncontradictory laws. In the following section, I discuss in further detail the benefits of an ideal context-dependent mapping.

## 4. The Prominence of Type 1 Idealization in $f_c$ mapping

When dealing with context-dependent mappings, a selected context set $c_i$ will be mapped onto $S_i$ based on our understanding of the nature of the types of experiments and phenomena tied closely to $c_i$. The possible thought is that the $f_c$ mapping is inherently a type 1 idealized mapping in the sense that the choice of range for $f_c$ depends on the class of manifested outcome of the complementarity. For example, consider the multiple-slit scenario $c_{mesh}$ where we have an interference pattern[5]. We may use the context of the experiment (reference, the energies, and momenta of each particle involved, etc.) to prescribe that $c_{mesh} \in c_{wave}$ and map onto the wave-like laws $S_{wave}$ to certain photons. This is because we have observed similar effects with similar setups to produce wave-like effects, and hence construct the set $c_{wave}$. These setups are in no way the exact same: there is a degree of assumption that the behaviors of each mesh and laser will behave similarly to provide the manifested complementarity outcome. That is to say that the $f_c$ mapping is not situation-specific in the sense that the context itself is sufficient in determining the mapping outcome. Rather, it is the case that it assigns a set of laws $S_i$ to any involved piece of the system based on the class of dual phenomena (particle or wave, matter frame or observer frame, accelerating frame or rest frame) that we have observed in the past, alongside the assumption that the particles that are relatively involved in similar manners to experiments in the past would manifest the same features as before.

Without this assumption, allocating the similarity subspace to the context of any particle (or set of particles) in relation to other factors in a system is difficult, as any explanandum would then require almost an identical setup for observation.

## 5. Type 3 Idealization is the Range of $f_c$

Suppose we have the context-dependent mapping $f_c$ that maps a set of particles prone to dual phenomena onto a set of laws involving only one aspect. The premise of this mapping is to represent the complementarities through this mapping; however, it may be argued that type 3 idealization (regarding the constituents of the system) may be what the resulting range (of $S_i$) is. I do not deny this interpretation of similarity subspaces as an idealization of the already manifested complementarity feature, yet it may prove useful to retain nonetheless the thought that although it may be an idealization in that sense, there is another sense in which we are preserving the representation of complementarities through $f_c$. Namely, the sets of particles that are involved with complementarities do manifest only one feature (hence one set of laws in the range $S_i$), yet they have, in other contexts $c_i$, the potential to manifest another set of laws $S_j$. This closely aligns with our current conception of complementarities and is, at the very least, not a misrepresentation.

I do grant that the idealization of type 3 may exist in the sense of the particle only having one set of laws to abide by within a causal model; however, the $f_c$ mapping does not deny the possibility for the other feature to manifest itself in the future (in another context)[5]. When thought of in this manner, the similarity spaces are idealizations as we are using one set of laws over another (when the identity of the matter in question incorporates both aspects). This does not undermine, however, the representative qualities of $f_c$. It simply points towards the idea that idealizations may exist in some form within the range of the mapping. In the following section, I will discuss idealizations alongside the notion of understanding.

## 6. Understanding Through Ideal Context-Dependence

I claim that the laws in $S_i'$ facilitate the sense of understanding discussed in section 2. It may be sufficient to point towards Strevens' thoughts regarding the acquisition of understanding itself. I present the following thought: the structure of context-dependent mapping avoids various contradictions that may arise when even considering idealized laws. In the past, I have argued that similarity subspaces pertaining to complementarities have contradictory laws[4]. Ideal similarity subspaces, containing either elements already idealizations in $S_i$ or the idealized versions of the non-ideal law, also contain contradictions with each other (given the laws are grouped up in a manner that attempts to address a complementarity). This is evident from the thought that idealized laws must contain the principles of each theory: quantum mechanics principles must be obeyed in an ideal case for $S_{quantum}$ and the same for relativity $S_{relativity}$. The root of complementarities and paradoxes is that we have disagreeing principles of quantum mechanics and relativity. This entails that even if we are considering the ideal versions of each formalism, we are nonetheless left with two conflicting theories built upon two conflicting principles: we can not rid the similarity subspace $S_{quantum}$ of quantum-like behavior through idealization. Similarly, it is not possible for our relativistic theory to be quantized through idealization. For the information paradox, information will be conserved in quantum mechanics and will not be conserved in general relativity. Ideal interference patterns will not be compatible with ideally scattering particles. Ideal accelerations will nonetheless generate the Unruh effect, and ideal vacuum laws will not. It is not just the specific laws that contradict each other but the ideal ones as well. To this day, the unification between these complementarities and disagreeing theories is debated. Accordingly, the arguments made for understanding before hold for this case as well:

> [The mapping] elucidates difference-making...and becomes a mechanism within the DNP/Kairetic accounts. Moreover, since the mapping assigns a particular law within a consistent similarity subspace to each particle, there are no apparent contradictions within any of

the kernels[5].

Accordingly, I will offer a set of thoughts with regard to the arguments for the facilitation of understanding within the context-dependent mapping extending to the idealized counterpart. Ideal explanations, as discussed in Section 2, provide insight into the reasons that some factors within a model are difference-makers. The context-dependent mapping serves to represent the manifested feature as well as to depict the feature that is not manifested but can still be involved: if the degree to which that feature is manifested (or not) changes, it will have an effect on whether the event occurred or not [5]. Ultimately, I hold the stance that ideal context-dependent mapping contains the benefits (when it comes to understanding) of both ideal explanations and context-dependence. As discussed earlier, I mentioned the persistence of contradictions through the process of idealization. If this is the case, then my argument for non-ideal context-dependent mappings providing understanding also persists[5]. One can consider the steps taken for non-ideal mappings and determine that the root of these benefits in understanding derives from the consistency and accommodation of complementarities that the mapping offers. Continuing with the extension, one must select between one of the following factors and sacrifice the other:

- A “correct” explanation in the sense of representing the current physical theories and determining difference-makers
- The notion of understanding, as discussed prior.

In addition, the reasons Strevens offers towards idealizations in explanations must extend to this mapping as well, since the laws involved in each kernel of the Kairetic account’s standalone explanation will involve those ideal laws.

The idealized laws will point towards difference-makers in the explanation, while the context-dependent mapping will flag the difference-makers involved in complementarities and avoid inconsistencies in the entailment structure of DNP or related accounts involved in a standalone explanation. This goes beyond having a mechanism that avoids contradictions; it is a method of depicting difference-makers that may exist outside of the relevant idealized laws that we implement in describing that phenomenon.

## 7. Conclusion

In this paper, I have explored the integration of Michael Strevens' concept of idealizations with my framework of context-dependent mapping and similarity spaces. By combining these ideas, I developed a comprehensive account of ideal explanations that effectively address the complexities and complementarities observed in modern scientific phenomena.

Idealizations, through deliberate simplifications or falsifications, help isolate the core causal mechanisms essential for understanding, while context-dependent mapping ensures that explanations remain consistent across different observational contexts. This integrated approach allows for a deeper grasp of complex phenomena, such as wave-particle duality and black hole complementarity, by applying the appropriate physical laws to each specific context.

The significance of this integrated framework lies in its ability to enhance both the explanatory power and the practical applicability of scientific models. By avoiding contradictions and tailoring explanations to specific contexts, ideal context-dependent mapping offers a nuanced method for understanding the underlying causal mechanisms and difference-makers across various phenomena.

Beyond the framework itself, all three distinct types of idealization are closely related to the $f_c$ mapping. In some interpretations, $f_c$ embodies certain senses of idealization, further pointing towards the value of idealizations in facilitating understanding. It is worth further considering to what extent these idealizations play a role in context-dependent mapping under various complementarities. In addition, it may also be useful to discuss the degree of idealizations in our laws, even those we do not instinctively deem to be idealized laws, as well as the roles of assumptions in explanation.

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