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From Quantum Physics to Social Science Research: An Attempt at a Systematic Approach to Karen Barad's Diffractive Methodology

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Abstract: In this paper, we introduce Karen BARAD's concept of agentive realism and the diffractive methodology based on it. This methodology was inspired by Niels BOHR's work on the complementarity principle in quantum theory. BARAD argued for overcoming the traditional separation between ontology and epistemology in order to gain a new perspective on the relationship between the observer and the observed. We explain central concepts such as "intra-action," "apparatus" and "entangled reconfigurations of spacetimemattering" to show how objects and subjects emerge and constitute each other in a network of relationships. We also present critical reflections on the transfer of theoretical figures from quantum mechanics to social science issues. We discuss the potential benefits as well as the challenges and misunderstandings that arise from such an interdisciplinary framework and use examples from hospital ethnography to illustrate how BARAD's methodological concepts can be applied to empirical research. This approach is particularly productive for questions where it is not possible to assume a particular form of identity and subjectivity. The ethical implications of this paradigm are also discussed in more detail.

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1. Introduction

> "No question, no answer. [...] In brief, the choice of question asked, and choice of when it's asked, play a part—not the whole part, but a part—in deciding what we have the right to say" (WHEELER, 1990, p.10).

Inspired by Niels BOHR's quantum theory, Karen BARAD (2007) has argued in favor of abolishing the separation between ontology, epistemology and ethics in the cultural and social sciences. She has drawn attention to the separation that remains implicit when reality is understood as independent of the observer, to the way in which knowledge and information are generated and to the significance of these processes for human beings. While BARAD's work has been well-received in the social sciences, efforts to utilize the ideas and concepts central to her theorizing or even developing them further for qualitative social research have thus far been only tentative (e.g., CALL-CUMMINGS & DENNIS, 2019; FOX & ALLDRED, 2021; MAUTHNER, 2019; MURRIS & BOZALEK, 2019; MYERS, 2020; SCHADLER, 2019, 2024; SCHERRER, 2021; TAMBOUKOU, 2015). The quantum theoretical foundations of BARAD's concepts and theoretical figures in the theory of quantum mechanics have often remained under-explored (for an exception, see BARLA, 2023). This makes it easy for critics to accuse her of "using scientific findings in postmodern theories," which they consider to be problematic and an "intellectual imposture," especially if they refer to scientific theories without knowing much about them, which tends to lead to a "meaningless phraseology" (SOKAL & BRICMONT, 1997, cit. in BARGETZ, 2017, p.134).[1] [1]

Since BARAD is a physicist with a doctorate in quantum field theory, and her arguments in favor of transferring its ideas to social science issues are quite precise and conceptually rigorous, this accusation does not apply to her. However, it is well known that BARAD has sought to engage with postmodern thought—and in particular with FOUCAULT's dispositive and discourse analysis (1972 [1969]), the "rhizomatic" thinking of DELEUZE and GUATTARI (2005 [1980]), and also with the seminal works of BUTLER (1993) and HARAWAY (1991) that have come to occupy such a prominent place in feminist theory. She set herself the task of subjecting BOHR (1928) and these authors to a "diffractive reading" (BARAD, 2012, p.59). [2]

1 This text is the English translation of an article that was first published in German. Where available, existing English translations have been used for the quotations from German papers, even if the tone and choice of words sometimes diverge slightly from those in the German-language publications. Where no authorized translation was available, German passages have been translated into English by us.

The principle of diffraction or bending formulated in classical physics describes the behavior of waves when they come up against an obstacle or pass through a narrow aperture. The direction of propagation is altered and the waves overlap or become "superposed." This superposition results in the formation of characteristic patterns which can be used to analyze the properties of the waves and of the obstacle or aperture. Reading texts diffractively involves tracing areas of overlap in order to gain new insights into the subject matter to be analyzed (this will be discussed in greater detail in Sections 2.5 and 4). [3]

All this makes BARAD's work interesting both for the debate on feminist theorizing (VAN DER TUIN, 2014) and for the proponents of what has come to be called "new materialism." The latter have come to the conclusion that the "linguistic turn" or primarily semiotic approaches cannot adequately capture the complex and dynamic interplay of meaningful symbolic processes and material orders (HOPPE & LEMKE, 2021, p.10). [4]

However, to apply a serious methodology of the diffractive as BARAD suggested, it is not sufficient to rely on the implications of her theory for critical theorizations of power alone, without looking at the theoretical concepts she has derived from quantum theory in more detail (e.g., BARGETZ, 2017; BARLA, 2023; FOX & ALLDRED, 2021). Even among post-structuralist thinkers there is a distinct tendency to understand BARAD's terms metaphorically and not literally, as HOLLIN, FORYSTH, GIRAUD and POTTS (2017, p.935) have noted: "Several of these concepts travel with BARAD from physics. Quantum physics is resolutely not a metaphor for BARAD but rather underpins agential realism's articulating how the material world is brought into being" (for a critical discussion, see also DE FREITAS, 2017). [5]

In contrast, in her book "Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning" (2007), BARAD showed how closely the diffractive method is linked to key quantum theoretical concepts such as "indeterminacy," "interference" and the fundamental "inseparability of inside and outside" and "observer and observed":

> "Hence the diffractive methodology that I propose enables a critical rethinking of science and the social in their relationality. What often appears as separate entities (and separate sets of concerns) with sharp edges does not actually entail a relation of absolute exteriority at all. Like the diffraction patterns illuminating the indefinite nature of boundaries—displaying shadows in 'light' regions and bright spots in 'dark' regions—the relation of the social and the scientific is a relation of 'exteriority within'" (p.93). [6]

With this in mind, we would like to give a more detailed introduction to BARAD'S agential realism and the "diffractive methodology" that she based on it in this article. It will include an introduction to some central theoretical concepts of quantum theory such as the wave function and its associated *eigenfunctions* and *eigenvalues*. It is necessary to do this in order to gain an understanding of the key concepts of BARAD's thought. Only then can we also comprehend why empirical social research could gain something from describing social worlds as

"polycontextural" (VOGD & HARTH, 2021); in a way that is similar to quantum physics, and thus to recognizing the possibility of a multiplicity of incommensurable positions of observation as well as the ontological and epistemological indeterminacy that this entails. [7]

Since qualitative research cannot be understood from theory alone, but only with reference to its practice, we shall also present an analysis of data from a hospital ethnography to illustrate the relevance and applicability of agential realism in empirical social research. We hope to show that diffractive methodology can be profitable for empirical social research for at least two reasons. First, it makes it possible to deal systematically with the problem of contingency in the analysis of qualitative data (e.g., by reconstructing how the probabilities of exclusion change when the (research) apparatus is reorganized). Second, a methodological approach emerges which no longer takes identities (e.g., who appears as subject, object, doer or done-to, and in what form) as given in advance, but instead allows us to examine how the relevant observational context and the causal relationships associated with it are constructed as "functioning" or "operative ontologies" (FUCHS, 2004, p.11) and can be constructed, dismantled or reconstructed, depending on the situation. Diffractive methodology can be used to initially bracket ontological assumptions about who or what is the observer or the observed, or cause or effect. It can then be examined what different ontologies and causal connections emerge from the circumstances under investigation.

> "While diffraction can be used to read both the instrument and the object through each other in a way in which the identification of "subject" and "object" is not fixed, reflection has an asymmetrical focus that fixes one as the standard (i.e., a fixed mirror) against which the other is read. [...] Turning the mirror around, as it were, is a bad method for trying to get the mirror in the picture" (BARAD 2007, p.418, FN 417). [8]

From the standpoint of a metaphysics of relations, quantum physics is no longer considered to be a classical physical theory (ESFELD, 2004) because neither things nor subjects possess intrinsic properties. Thus, the relata no longer precede the relations as in a reductionist principle of causality. It follows that observation is no longer a delimitable subjective process of relating objects to each other that are largely independent of the observer. Rather, following BARAD, we can state that there *is* no reality without observation, as the quantum physicist BRUKNER (2017 [2015]) also put it plainly. [9]

BARAD used neologisms and seemingly paradoxical combinations of words to articulate the complex relationships that this realization involves. For her, subjects and objects are not given in advance—they emerge as a result of an "intra-action." They manifest themselves as "entangled reconfigurations of spacetimemattering" in a complex movement of "cutting together/apart" (BARAD, JUELSKJÆR & SCHWENNESEN, 2012, pp.19f.). BARAD also pointed out that they emerge from different "apparatuses," which must in turn be regarded as "dynamic (re)configurations of the world" (2003, p.816). Diffractive methodology draws on all the theoretical principles associated with these concepts. As we

show in this article, it provides a meta-methodological approach that can be used to analyze and produce a wide variety of qualitative data. [10]

In what follows, we will start by analyzing BARAD's central concepts with reference to their origin in quantum theory (Section 2). We then address the issues involved in transdisciplinary theoretical dialogue and clarify the circumstances under which it is possible to transfer theoretical concepts from physics to the social sciences (Section 3). Next, we will explore what the concepts borrowed from formal quantum theory could mean in a social scientific methodology (Section 4). However, our focus is not on the history of nuclear physics or epistemology, but on BARAD's methodology. We will therefore apply these ideas to a social science example from hospital research (Section 5). Finally, we will draw a provisional conclusion (Section 6) and discuss the implications of BARAD's methodology for the ethics of research (Section 7). [11]

2. The Basic Concepts of BARAD's Diffractive Methodology

Anyone who has studied quantum theory, which is quite difficult for laypeople to grasp, will recognize in BARAD's terminology, which at first seems unusual, some of its central theoretical assumptions in an extremely condensed form.[2] It is important to highlight that the neologisms that BARAD has created developed out of her diffraction of BOHR's quantum mechanics through the thoughts and concepts of FOUCAULT ("apparatus," "dispositive," and "discourse," 1980 [1972], p.194), BUTLER's "materialization" and "performativity" (1993, p.8, 33), as well as HARAWAY's "material-semiotic actor" and "apparatus of bodily production" (1991, pp.199, 207). [12]

BARAD's aim was not to apply quantum mechanics reductively to the analysis of society, but to generate new insights and perspectives by juxtaposing different theoretical concepts and linking them together. In what follows, we will introduce and interpret these concepts primarily from the quantum theoretical perspective, as the theoretical assumptions involved are unlikely to be familiar to a social science audience. [13]

2 As an introduction to engaging in dialogue between scholars from quantum physics and sociology, we recommend the works of Vogd (2014, 2020).

2.1 *Intra*-action

According to HEISENBERG (1925) and BOHR (1928), "particles"[3] (i.e., localizable entities) do not "exist" prior to a measurement interaction. The particle or wave character of an electron or photon only manifests itself during observation, and different methods of observation can lead to different results. For example, in a double-slit experiment, "particles" are detected when measurements are made at the slit openings. However, if no measurement is made, interference patterns are produced which indicate that not particles, but a "wave" has passed through both slits simultaneously. Entities therefore do not "exist" independently of a measurement interaction. In other words, there is no particle interacting with the measuring instrument. The particle only becomes manifest in an experimental set-up that makes a "particle," or a property of a particle, possible as a measurable quantity—hence the term *intra*-action. Or, to echo WHEELER (1990, p.10), we could also say: "No question, no answer"—because the question we choose leads us to employ a certain experimental design, and this influences (at least in part) what we get as an answer. [14]

Thus, ontology and epistemology begin to intertwine in a way that is difficult to untangle. Our ontological presuppositions determine the questions we ask. This prompts us to adopt a certain methodological approach that allows us to recognize certain things but excludes other forms in which reality can manifest itself. The epistemological approach to the research question influences what the answer is. Let us take the example of the double-slit experiment: To get the full picture, we need a methodology that allows for two complementary epistemological approaches—i.e., the description and study of the object of measurement both as a particle *and* as a wave, and different experimental designs in each case that allow this to become evident. [15]

This ontological indeterminacy is inherent in the theoretical architecture of quantum theory itself: Quantum physicists do not see observables as having an independent, context-independent existence but only as manifesting themselves within a particular constellation or functional relationship. In the mathematical formalism of quantum theory, this is expressed as replacing observables with operators—i.e., functions that act on other functions and on themselves. Therefore, in the context of measurement, BARAD (2007, pp.175f.) no longer spoke of a measurement aggregate's *inter*acting with a pre-existing entity, but of *intra*-actions as specific relations that only occur in certain constellations. [16]

This is precisely where BARAD's diffractive methodology comes in, when she took BOHR's philosophical standpoint of indeterminacy as her starting point and not HEISENBERG's concept of uncertainty. With this perspective, BARAD no

3 Terms such as "exist" or "particle" are given in inverted commas because it is evident from interpretations of quantum theory, e.g., those formulated by HEISENBERG and BOHR, that the formalism of quantum theory allows different interpretations. We can interpret the state of affairs from a more epistemic perspective (no knowledge of it is possible, therefore it remains indeterminate) or, following PLATO, we can see the formula as referring to a universal idea. And we can also simply understand "exist" as referring to the "emergence" of a measurement, analogous to the Latin *existentia*.

longer focuses exclusively on the possibilities and limits of a theory such as quantum theory, but primarily on the point of view of the physicists who now have to manage without the secure position of an idealistic ontology. BOHR and his fellow theorists HEISENBERG and BORN were by no means in agreement about the implications of the Copenhagen interpretation of quantum theory. As BARAD has shown in her reconstruction, these theorists were viewing things more from a male point of view, based on the conviction that they could, in principle, get to grips with them. She contrasted this with a feminine reading that is able to tolerate openness and welcomes it:

> "Copenhagen is haunted by its own internal fracturings/disjunctures that belie the presumed unity of places, spaces, times, and beings. A ghost that is the very specter of multiplicity itself haunts the play and the interpretation (of quantum physics that goes by the same name). What if this ghost were taken seriously? That is, what if it were understood that the point is not uncertainty after all—not man's knowledge measured against some present presence that is or some past-present that was–but rather, *indeterminacy*–hauntological multiplicity—which, crucially, is not about Man once again, not about origins finally, nor the end of time?" (2010, p.263) [17]

The theoretical concept of *intra*-action is of particular interest for social science research, not least because it offers a systematic way of dealing with the problem of the indeterminacy and ambiguity of the objects under investigation. This topic is dealt with in detail in Section 4 below. [18]

2.2 Cutting together/apart

HEISENBERG's uncertainty principle (1927) is a fundamental consequence of quantum theory. Any determination—e.g., of a "particle" at a particular location, such as a slit opening—inevitably leads to lack of knowledge of another, complementary variable. When something is measured, the measuring system becomes entangled with the system being measured,[4] creating a new epistemological-ontological constellation. This is because it is the very nature of entanglement that the newly created system can be assigned a well-defined state (its entanglement is defined) without it being possible to assign specific states to the subsystems involved. This is in contrast to classical physics, where each subsystem has a clearly defined state at any point in time which determines its behavior. Classical physics assumes that the states of all the subsystems

4 We understand the term *system* in the classical physical sense as a delimited set of elements that can be described and analyzed using physical laws. We are not referring to LUHMANN's (1995 [1984]) concept of system, according to which a system is a function of itself and its environment, so that it is not possible to distinguish "the dancer from the dance" (FUCHS, 2001). A central idea in quantum theory is that the measuring system (e.g., a measuring device) and the measured system (e.g., a particle) do not exist independently of each other. During a measurement, the two merge into a new, unified system which results in a new epistemological-ontological constellation. BOHR (1928) pointed out that this leads to the dilemma that, on the one hand, the concept of a system as a separate entity conventionally employed in classical physics must continue to be used (otherwise it would not be possible to carry out experiments), while on the other hand, theoretically it must be assumed that entanglement and non-separability exist. And in regards to systems, quantum theory also uses two descriptions of reality that are logically incompatible (systems are simultaneously isolatable and non-separable), both of which are, however, inherent and constituent parts of its mathematical formalism (VON NEUMANN, 2018 [1932]).

together explain the state and behavior of the whole system. In quantum mechanics, however, the states of particles exist simultaneously in a superposition of different possibilities. Each possible state of a particle is associated with specific states of other particles. When a measurement is carried out on one part of the system, only one of these possibilities is realized and all the others are excluded. Or to put it in SCHRÖDINGER's words:

> "If the state of a quantum system changes—e.g. as the result of a measurement or another interaction that contextualizes the system—a new eigenstate is created that is described by a modified wave function, whereby the new function always lacks information that was contained in the previous one" (1935, p.825). [19]

Thus, observing a measurement creates a new system or phenomenalizes a new reality. Conversely, what was not determined remains undefined and in the domain of entanglement and exclusion. BOHR (1928) developed his principle of complementarity in this way, according to which it is not possible to conduct two different methodological observations of an event or phenomenon at the same time. Only one property can be produced and established per methodological approach. Together, the two produce the complete picture. [20]

Entanglement arises when two previously separate systems are connected by a measurement in such a way that certain aspects remain indeterminate. This connection makes certain aspects jointly indeterminate. However, when a subsystem is determined by a further interaction, the complementary subsystem is also determined in relation to the previously undetermined aspect. [21]

In the case of entangled quantum systems, it is irrelevant how far apart they are, in which order they were measured, or whether they only became entangled after the measurement. In light of the "metaphysics of relations" (ESFELD, 2004, p.601) expressed here, according to BARAD (2012) the measurement must appear as an *intra*-action that "cuts" the relations together anew in the cutting-apart process, i.e., that cancels an existing entanglement and creates a new one. [22]

2.3 Reconfigurations of *spacetimemattering*

The description of the world provided by quantum theory is no longer deterministic. In classical physics, both deterministic and probabilistic statements are possible, but in quantum physics the probabilistic view is fundamental (see BRUKNER, 2017 [2015]). Thus, not only does quantum physics serve as a technique for dealing with the not-knowing that arises from complexity, it also implies that phenomena are not always predictable events. As MITTELSTAEDT has correctly observed,

> "Quantum mechanical, statistical causality is weaker than classical causality, which appears as a special case that rarely occurs, and the quantum mechanical concept of substance is weaker than the classical one since, unlike classical objects, quantum objects do not have all object properties" (2000, p.67). [23]

The physics of this observation can be explained in more detail as follows: The probability that something will happen at a certain point (for example in the double-slit experiment where a "particle" can be measured) is described by the wave function in SCHRÖDINGER's (1935) equation. For example, there is a 50% probability that the particle will be measured at each of the left or right slits. In this case, the wave function can be expressed as the superposition of the two states |right slit> + |left slit>.[5] If *no* measurements are taken at the slits, both waves pass through the slit openings and superimpose on the other side to form an interference pattern. The "particles" then manifest themselves on the screen in accordance with the probability distribution of the interference pattern. No "particles" appear on the black stripes because the waves are superimposed in such a way that the probability of a particle manifesting is zero. Again, the wave function describes what is possible in the event of a measurement. [24]

A measurement changes what is known about the quantum system and therefore also the "expectation catalogs" (p.844) about what is possible at all. When a measurement is made at a slit, it is 100% known what was measured there. What is known has changed. What is interesting is that following the logic of quantum mechanics, this also changes what can be physically manifested in the experimental set-up as a result of further measurements. In this case, there is no longer any interference because the wave function has changed. The interference disappears because there is no longer any superposition, because it has now been determined where the "particle" passed through. A small change in the measurement set-up—the addition of instruments to collect the path information—changes the wave function and thus, what can appear as reality. BOHR (1964 in particular, repeatedly stressed the connection between epistemology and ontology. Changing the measurement arrangement leads to differences in what is known and thus to different configurations of what is possible as a materialization of facts. [25]

The altered wave function also spans space and time. ZEILINGER, who carried out a large number of such experiments with photons, wrote:

> "It is a fact that Bob's registration events, that is, the results he obtained when measuring his photons Y and B, are objective ones. That is, they are written down in some way; they exist; everyone can look at them, and everyone can agree on what these results are. Furthermore, they are not in need of an interpretation. They are just events and that's it. But we physicists want to understand these events. We want to describe why these events happen. So we must present an explanation, a consistent interpretation, and that is where an interesting question now arises. The interesting point is that in the end we will, for Bob's results, present a different interpretation depending on what Alice at a later time decides to do. […] First, the observed events are just events, and they are in no need of any interpretation. They are, so to speak, here before we as the observers even begin to worry about what they actually mean. Second, the explanation of the events depends on later actions and decisions we or someone else might make" (2010 [2007], pp.234f.). [26]

5 The formula $|\Psi\rangle = |A\rangle + |B\rangle$ is an extremely brief expression of the superposition of two quantum states. The wave function $|\Psi\rangle$ results from the linear combination of the states $|A\rangle$ and $|B\rangle$.

The wave function in the SCHRÖDINGER equation (1926) specifies the probabilities of what is and what is not possible in a particular constellation of entanglements. As ZEILINGER (2010 [2007]) suggested, the selection of an experimental design or the decision to change the experimental set-up also changes the causal relationships of the interpretation of the event. Causality in the sense of a predefined cause-and-effect relationship (as in A -> B -> C) is not simply given in the quantum world, but depends on the overall constellation. [27]

What have been termed the quantum eraser experiments can also be understood in this way. These are experiments in which, as in the double-slit experiment, the "which path" information is first collected so that the interference after the slit disappears. However, the choice (WHEELER, 1978, pp.9ff.) is then delayed to bring the "which path" information back into a superposition, thus removing the original information (MA et al., 2012). However, BARAD (2011) has pointed out that this does not erase the past. It simply allows a new arrangement of space, time, matter and meaning—i.e., of what is determined and what is indeterminate—to become manifest as a result of a change in the experimental set-up. In other words, it reveals what was previously undetermined. In the altered arrangement, what was previously determined moves into the realm of exclusion. For BARAD et al., this process was one entangled *reconfiguration of spacetimemattering:*

> "But erasure of past events is not what's going on in the experiment. If you really attend to the data in terms of phenomena (as opposed to things, and this very shift is in fact confirmed loud and clear *by this very experiment*), you see that the diffraction pattern only shows up again if you do the work of tracing the entanglements. In performing the labour of tracing the entanglements, of making connections visible, you're making our obligations and debts visible, as part of what it might mean to reconfigure relations of. So spacetimemattering can be reconfigured in a way that reopens the past, in fact it happens all the time whether or not it's something that we directly observe under specific experimental conditions. But what it says then is that, what is at issue is not the *erasure of events*, but *reconfigurings of spacetimemattering*. Indeed, it shows that the universe itself holds a memory of each event—the fact that the first the particle goes through one slit or the other of the which-slit Apparatus, and then after it hits the screen, the which-slit information is destroyed, and then the pattern on the screen is reconfigured and reanalysed ... all of this is on record" (2012, p.21). [28]

Again, with a little imagination, it is possible to see why the two theoretical concepts of "cutting together/apart" and "reconfigurations of space-time-mattering" might be of use in social science research. They could provide a methodological approach to changes in patterns, particularly those involved in the continuity and discontinuity of social identities and the ontologies that operate within them. See Sections 4 and 5, below for more details. [29]

2.4 Apparatus

Ever since VON NEUMANN (2018 [1932]) formulated the "Mathematical Foundations of Quantum Mechanics," it has been accepted as given that both the quantum objects under investigation and the experimental set-up must be described in quantum theoretical terms—i.e., as a wave function. This means that the boundary between what is observed and the act of observation can be set at any point. Thus, not only microscopic objects such as a radioactive atom, but also the constellations entangled with them can exist in a superposition. This is the basis for the situation described in SCHRÖDINGER's famous cat thought experiment (1935, p.812), in which an animal whose survival is tied to a decay process can find itself in a superposition in which it is both |dead> *and* |alive>. [30]

This thought experiment can be extended to include any other measurement and observation process. Air molecules interact with the radioactive atom and "measure" it.[6] As BRUKNER (2017 [2015]) has shown, there may also be a human observer within the experimental set-up who can determine what is going on but who can only communicate one bit of information to an external observer, namely *whether* s/he has made a measurement, but not *what* s/he has measured. Thus, according to the theory of quantum mechanics, external observers should see both states, "alive" and "dead," continuing to exist in a superposition. If they could carry out a measurement themselves in a certain experimental setup, they would see interference, but no clear result. As in the quantum eraser experiment (HERZOG, KWIAT, WEINFURTER & ZEILINGER, 1995), at one point a discrete state can be observable, and at another point or at another time, interference. [31]

It is crucial to emphasize that there is no need to have a live observing entity or an elaborate measuring instrument in order to transform the potentialities associated with the wave function into an unambiguous result. The decisive factor is whether the *apparatus* is designed in such a way that a determining *intra*-action *can* take place—even if it is as a result of an air molecule, for example—i.e., not only due to a detector that has been deliberately introduced—or whether the experiment has been designed in a way that does not allow *any* knowledge to be generated. Whether it is possible for something to be observed (or not) is dependent on the set-up as a whole. It is not, however, dependent on whether a part of it has the capacity to describe itself as an observer or even be conscious (WANG et al., 1991). [32]

At this juncture it should be pointed out that highly sophisticated experimental set-ups are required to achieve such effects. In most situations that occur in everyday life, decoherence (i.e., cascading effects of consecutive *intra-actions*) ensures that no superpositions—such as |live cat> and |dead cat>—occur. It is the apparatus, the specific constellation in the respective case, which allows one thing to appear or materialize at certain points in space and time, and which

6 Quantum physicists now assume that not only (human) observers can measure, but also matter, such as an air molecule can resolve the quantum state of a superposition (WANG, ZOU & MANDEL, 1991).

excludes another. In a different configuration, something else may then appear and something else must remain excluded (i.e., indeterminate):

> "Apparatuses are not inscription devices, scientific instruments set in place before the action happens, or machines that mediate the dialectic of resistance and accommodation. They are neither neutral probes of the natural world nor structures that deterministically impose some particular outcome [...] apparatuses are not mere static arrangements in the world, but rather apparatuses are dynamic (re)configurations of the world, specific agential practices/intra-actions/performances through which specific exclusionary boundaries are enacted" (BARAD, 2003, p.816). [33]

Subject and object, inside and outside, observation and the observed, data and meaning are inextricably linked in the apparatus, forming a weave that is specific, but not arbitrary in terms of its history and materiality. The apparatus is a unique form of "spacetimemattering" (BARAD et al., 2012, p.20) and determines what is possible and what remains impossible or is excluded. [34]

It is here that BARAD saw similarities to the work of FOUCAULT, particularly in regard to his understanding of discourse practices:

> "According to Foucault, discursive practices are the local sociohistorical material conditions that enable and constrain disciplinary knowledge practices such as speaking, writing, thinking, calculating, measuring, filtering and concentrating. Discursive practices produce, rather than merely describe, the subjects and objects of knowledge practices. In Foucault's account, these conditions are immanent and historical rather than transcendental or phenomenological. That is, they are not conditions in the sense of ahistorical, universal, abstract laws defining the possibilities of experience (KANT), but actual historically and culturally specific social conditions" (BARAD, 2007, p.147). [35]

2.5 Diffractive methodology

As mentioned above, diffraction is the term used in physics to describe the bending of waves around obstacles. In quantum theory, the wave function of the SCHRÖDINGER equation (1926) describes the space-time distribution of probabilities of the occurrence of an event during a measurement. Every observation alters the wave function, which in turn alters what is possible or probable (constructive interference) or improbable or impossible (destructive interference) elsewhere. Every addition to an existing configuration (apparatus)—and therefore also every methodological approach selected—bends the wave function, which changes the pattern of the probability distribution. [36]

This methodology allows the data obtained to be understood as the result of refractions or diffractions of the wave function. In quantum theory, the SCHRÖDINGER equation opens up the range of probabilities of what is currently possible. There is a class of solutions to the SCHRÖDINGER equation that are known as *eigenfunctions*. An *eigenfunction* describes a state in which the quantum system has a particular, well-defined property. When a system is in

such an *eigenstate*, measuring the corresponding variable or object always yields the same values—the *eigenvalues* or *characteristic values*. [37]

For example, the SCHRÖDINGER equation can be used to model the hydrogen atom. The *eigenfunctions*, the orbitals, indicate the locations and probabilities at which electrons could in principle be measured. The *eigenvalues* show the energy states of the electron that can be determined. These energy levels are quantized. A measurement produces a distinct, clear result, instead of indistinct or obscure superimpositions of spectral lines (or a superimposition of live and dead cats). Thus, each measurement ends up in a classical world in which a clear datum appears. [38]

This theoretical concept is highly relevant for the social sciences, since it offers a third methodological pathway that goes beyond realism and constructivism,[7] allowing us to deal with contingency without having to resort to arbitrary interpretations. The precise conditions under which something is possible can be named, and concrete types can be expected as a result (for more on the relationship between *eigenforms* in cybernetics and quantum theory, see also KAUFFMAN, 2011). [39]

Eigenvalues are thus the concrete observations made in a measurement procedure. It follows from this that a diffractive procedure could be used to develop and observe methodologically established variations in the mode of approaching the object under investigation. This would then be evidenced as *eigenvalues* in the *intra*-actions—i.e., the production of a phenomenon by the respective set-up. It then becomes possible to draw conclusions about the wave functions by comparing different arrangements, those with or without path information at the double slit. From the variety of observed phenomena, it is possible to estimate whether the wave functions are robust and independent of minor deviations in the experimental arrangement, or whether they react sensitively to contextual changes. It can also be assessed whether the addition of certain elements to the context influences the *eigenfunctions* in such a way that other phenomena can be expected during measurement. [40]

This methodology requires researchers to reflect that they will not be able to arrive at an even approximate analysis of the partial waves of a wave function in a superposition produced on an apparatus, or to track how they change *intra*-actions. Since researchers are part of the world, they cannot adopt an omniscient point of view. They can only reflect upon what could have been influenced by their interventions or on the traces of the *intra*-actions of the research conditions that become available to them in the form of data. However, even if they have only indirect access, they should still be able to identify regularities, since the nature of the entanglements associated with the various *intra*-actions reveal typical patterns if they make the effort to reconstruct the inter-relationships between the observed phenomenon and the experimental set-up:

7 By introducing the term "agential," BARAD relativized the naivety of realism, because this challenged the assumption of objectivity that it requires. For more on the need to distinguish constructivism from realism and the problems involved, see KARAFILLIDIS (2017).

> "If you really attend to the data in terms of phenomena (as opposed to things, and this very shift is in fact confirmed loud and clear *by this very experiment*), you see that the diffraction pattern only shows up again if you do the work of tracing the entanglements. In performing the labour of tracing the entanglements, of making connections visible, you're making our obligations and debts visible, as part of what it might mean to reconfigure relations of spacetimemattering" (BARAD et al., 2012, p.20). [41]

3. Complementary Methodologies: A Non-Classical Paradigm for Complex Social Phenomena

How can the diffractive method be applied to research issues in the field of social science, and in what problem contexts could this approach be useful? A critical remark before we continue: There are two approaches to adopting theories from the natural sciences. One approach is to attempt to use physical, physiological, or genetic causes to explain social phenomena. For example, one might be tempted to ascribe group phenomena, states of consciousness, or even consciousness itself to quantum fields.[8] It is important to note, however, that at the current state of the art of the social sciences in question, either the postulated links are highly speculative or there is no recognized empirical evidence to support the hypotheses formulated. Proponents of such theses are therefore swiftly accused of engaging in pseudoscience (see, e.g., SOKAL & BRICMONT, 1997, pp.37f.). The other alternative might be to examine whether the levels of abstraction reached by theories from other disciplines might also be useful for one's own discipline. [42]

3.1 Quantum information theory as a model: Complexity and contingency in the dialogue between disciplines

In interdisciplinary theoretical dialogue, it is therefore more fruitful to examine the theoretical framework and the overarching structure of a specific research paradigm and to explore whether the manner in which it addresses and conceptualizes problems could also offer paths towards finding solutions in one's own discipline. For example, quantum information theory is, as demonstrated by ASANO et al. (2015), a paradigmatic model for all systems in which subsystems interact in complex ways. Nevertheless, attempts to reduce biological, cognitive or social processes to phenomena of quantum physics should be avoided. Rather, the focus should be on developing an independent model that functions in a similar way to quantum information theory. Such a model would be based on the premise that several subsystems influence each other in such a way that, from the perspective of observers in the system, their behavior no longer appears to be determinate. The associated indeterminacies cannot be calculated using the methods of classical probability theory as the systems in question occur as a superposition of several states. Due to the entanglement, it is not possible to determine the probability for an individual subsystem independently of those of the others. [43]

8 See, e.g., the GEHLERT's (2020) unconvincing attempt to attribute the group effects of systemic constellations to quantum fields.

This implies that the associated dynamics cannot be modeled using the methods of the classical scientific paradigm (ELLIS, 2001) which presupposes a clear causal order according to which events occur in a fixed sequence. This means that within the classical paradigm, a set of causes (*explanantia*) explain a certain phenomenon (*explanandum*). [44]

By contrast, the formalism of quantum theory is regarded as non-classical for two reasons. The first reason is rooted in a specific understanding of causality and a non-classical conception of linearity or (dis)continuity, insofar as in certain configurations an indeterminate causal order must be assumed, whereby the order in which events occur—and thus also the causal relationships—are not determined in advance, and do not arise until the "intra-action," to stay with BARAD's terminology. The distinctions between cause and effect and between the observed object and the observing subject are only clear after the measurement has been conducted. Methodologically, as FOUCAULT (1980 [1971], p.141) concluded from a similar onto-epistemological standpoint (see also Section 5), this means that it is not necessary to search for the root of the matter. [45]

The second rationale for undertaking a non-classical assessment of quantum theory is rooted in BOHR's (1928) concept of complementarity. In this approach, the concept of incommensurability is accepted on logical grounds—i.e., only one state can be observed after a measurement (e.g., the cat is either dead or alive)—and the superposition of the possible but mutually contradictory states (dead or alive), or phenomena (wave or particle characteristic), and the possible observation positions (measurement of momentum or location) is regarded as equally valid. [46]

However, the non-classical structure of quantum theory does not preclude the possibility that the experimental set-up and the measurements obtained with it may have a classical character. This is notwithstanding VON NEUMANN's (2018 [1932]) assertion that these elements can (and, depending on the question under investigation, must) be described in terms of quantum mechanics, photon sources, mirrors. Measuring instruments, for instance, are manifested as discrete entities. Once the cut between the observer and the observed object is established by the experimental apparatus[9]—for instance, when a detector registers a signal (a "click") and the result is logged—this constitutes a classical relationship. The phenomenon in question is detected, regardless of whether it is a wave or a particle. Quantum states, wave functions and so forth are thus a series of *ex post facto* reconstructions that emerge when the attempt is made to establish a framework for linking configurations of incommensurable experimental set-ups and results (such as those pertaining to waves and particles). [47]

When this non-classical paradigm is applied to research questions in the social sciences it is also necessary to take into account BOHR's principle of complementarity (1928). And the classical concepts would also not by any means lose their validity. It would therefore be erroneous to claim, citing quantum theory,

9 HEISENBERG (1930) referred to this as the "relocatability of the cut between observer and object" (cited in VON WEIZSÄCKER, 1994 [1985], p.520).

that actors and their identities and collectives, and their interactions, do not exist, simply on the grounds that everything is entangled and that a particular cut is only made by an observer's perspective. It would be more fruitful to examine how different methodological approaches and modes of formulating research questions can be used in conjunction, in order to gain deeper insights into the phenomenon under investigation. [48]

Thus, applying BARAD's diffractive method does not mean that the available classical methodological instruments are rejected, as SCHADLER (2019, p. 220) has also emphasized. Similarly, employing analytical research tools does not require researchers to adhere to a representationalist paradigm that assumes the existence of entities, actors, and other identities per se. However, what is needed is a metatheoretical framework that makes it possible to navigate between theoretical domains in a methodologically controlled manner. Only then does it become possible to discern where to expect contingency and where invariance, and which relational structures open up specific possibilities and which constrain them. [49]

3.2 Qualitative methods: Complementary classical approaches to non-classical problems

In order to address this problem systematically, it is helpful to start by taking a look at critiques of social science methods which can, strictly speaking, be considered to be classical in that they focus on only one way in which social reality is manifested (e.g., as actors, interaction, groups, networks, communities, and habitus) and postulate a relatively clear cause-and-effect relationship. [50]

As early as 1969, BÜHL pointed out that while one-dimensional methodological approaches that focus on a causal relationship may be appropriate for certain research questions, they are not suitable for investigating complex psychological and social relationships. Following GÜNTHER (1976), BÜHL (1969) called for a polycontextural perspective that takes into account different perspectives of observation that are incommensurable but mutually dependent. [51]

Furthermore, as NASSEHI and SAAKE (2002) have highlighted in their influential article "Contingency: Methodologically Prevented or Observed? A Contribution to the Methodology of Qualitative Research," it is indisputable that every methodological approach shapes what it is investigating in a specific way, and thus the result is an artifact of the method employed. In their fundamental critique of conventional (qualitative) methods, they argued that qualitative research should focus on contingency (i.e., the fact that a certain configuration or constellation is neither necessary nor impossible) itself, rather than using methods to discover an already presupposed order (p.66). [52]

However, this argument can easily culminate in a (radical) constructivist position that questions the meaningfulness of the methodological approach itself since, if it is not taken into account, only the constructions generated by the method are considered and the overarching mechanisms of social realities are left out of the

picture. Social scientists are faced with a dilemma since they find themselves caught between the Scylla of falling into the trap of rigidly adhering to a methodology that actually produces what it is they claim to be studying, thus following a naïve realism, and the Charybdis of postmodern arbitrariness. On the one hand social and psychological realities are often extremely robust and cannot simply be constructed out of indeterminacies. On the other hand, all specific methodological approaches can be deconstructed and called into question—and shown to be selective and dependent on observation. [53]

Could social scientists not learn from physics how to address this problem? While physics is—rightly—conceived of as a "hard" science, physicists have found productive ways of dealing with their dependence on observation and contradictory modes of description, and the associated plurality of analytical methodological approaches. Could the social sciences not benefit from following a principle of complementarity in regard to both the methodological focus (actor, group, interaction, etc.) and the onto-epistemological stance—one that would allow researchers to follow one perspective without excluding others? [54]

Consider, e.g., a familiar methodological discussion that was conducted within the field of grounded theory methodology (GTM). If we were to apply the idea of the complementarity of methodologies as an approach to qualitative social research, this would mean, for instance, that we would not simply be limited to the approaches of GLASER (2002) who considered his research to be informed by reality alone, or to those of STRAUSS (1987) who saw himself as endorsing symbolic interactionism, or to CHARMAZ (2000), who identified as a social constructivist. Instead, we would be able to adopt both a realist and a relational approach, and also a constructivist one at one and the same time. [55]

In the last 20 years in particular, there have been some moves to develop complementary methodological approaches also in other research traditions. Thinking of BARAD's (2007, pp.235f.) affinity with FOUCAULT (1972 [1969]), we can mention attempts to derive a methodological approach from his social-theoretical and philosophical work. Consider, e.g., his dispositive analysis (DIAZ-BONE, 2006; JÄGER, 2011) with which the intricate interrelationships between language, power and material reality can be elucidated, without simply reducing them to one another, not to forget various different versions of subjectivization analysis (GEIMER & AMLING, 2019) which incorporates socio-phenomenological perspectives into FOUCAULT's governmentality studies. The founders of actor-network theory also felt challenged to develop complementary methodological approaches. LATOUR (2013 [2012]) expanded the theory with the concept of "modes of existence" in such a way that it is not only able to address the infinite ramifications of networks, but also recognizes that clearly defined loci of reflection and observation emerge within social phenomena, each with their own ontology and causal attributions (VOGD, 2015).[10] [56]

10 LATOUR (2013 [2012], p.63) described the "hiatus" between these two complementary levels of description, i.e., the fact that they were logically unbridgeable, laconically as a "problem of 'software compatibility'"

Another approach that deserves mention here is contextural analysis. Drawing on LUHMANN (1995 [1984]), JANSEN and VOGD (2022) argued that references to different systems occur simultaneously and are mutually dependent. Additionally, BOHNSACK (2017) developed the multidimensional typology of the documentary method to reconstruct subjects' specific backgrounds of experience and developmental histories as sociogenetic processes occurring in different places at different times and re-enacted in current local actions. [57]

Related to the above example of GTM, CLARKE (2005) proposed "situational analysis" in which researchers use "situational maps" as a method of accounting for the simultaneous relevance of different 'social worlds' in the social scientific reconstruction of the phenomenon studied. BARAD's agential realism (2007) could open up a metamethodological perspective in which the above-mentioned approaches could be combined in such a way that justice would be done to the complexity not only of the empirical process and the social objects of investigation, but also of that of observing them, and thus also to the apparatus of social science research itself. [58]

4. A First Step Towards Applying the Concept of Agential Realism to Practical Research

Any attempt to use BARAD's theses to enrich social science research and theorizing with quantum theoretical approaches will only be convincing if it is grasped as a theoretical and methodological perspective and not misinterpreted as an explanatory principle from physics. Here are a few general insights to start with:

1. According to the principle of complementarity, which was BARAD's starting point, two different methodological approaches to an event or phenomenon may be mutually exclusive, but simultaneously necessary in order to obtain a comprehensive picture, and so they complement each other. Thus, the focus on the individual *and* the perspective on the collective or society can both be fruitful *at the same time*, even if, at first glance, this could lead to logical aporias (NEHER, 2024, pp.165ff. on the structure of a trans-classical theory dialogue).
2. Drawing attention to dependence on the observer does not necessarily call into question the stability of the objects of investigation, and neither does quantum physics discredit phenomena that can be easily explained by classical physics. [59]

BARAD's approach also allows us to investigate how a combination of determinacy and indeterminacy arises in dependency on a specific apparatus. The methodological approach must therefore be extended by including the following:

1. the order that is dependent on the apparatus, and the indeterminacies, that is, the subjective constructions or the stages of subjectivity, which are generated within it (GÜNTHER, 1978);
2. processes that enable and restrict observation, for example prior measurements, in short, the history; and finally,
3. the superposition of 1. and 2. itself, which is equivalent to adding a further measurement observation. [60]

From a methodological perspective, the recursive hermeneutic circle emerging from the figure of the apparatus must be distributed across different modes of observation and approaches. The apparatus encompasses all processes that make observation possible, including social interactions, psychological processes of the actors involved, written communication, material and legal consequences and approaches to investigating the subject matter scientifically. The apparatus itself is a material, i.e., a hard reality, which is why the term "agential realism" that BARAD (2007, p.132) has chosen as the name of her approach has become established. As mentioned above, this implies a rejection of radical constructivist stances that suggest that in principle, any interpretation or meaning can emerge in an interaction or in subjective experience. In the operator formalism borrowed from quantum theory, according to which observables are no longer seen as being independent of the observation, but as complex functions that have an effect both on themselves and on other functions, subjectivity and interactions are not possible without context but are, in fact, the product of the all-embracing apparatus. And the fact that something can be negotiated in an interaction at all is also only possible because of the multifaceted operations of an apparatus that enables interaction and subjectivity in some places, and not in others. [61]

This cannot be modeled using classical logic or conventional scientific theory (see, e.g., ELLIS, 2001). However, this precise relationship can be described in the terms of the non-classical formalism of quantum theory. When it comes to social science questions, we could also try to reconstruct the probability distributions of what is possible in the present moment as in the SCHRÖDINGER equation. This would allow us to identify a specific group of solutions which could then be conceived of as *eigenfunctions* of the respective social constellations, in analogy to the terminology of quantum mechanics. In social science research, subjects and actors, and also interactions, collective orientations and other social structures could likewise be considered to be *eigenfunctions* or *eigenvalues* of a certain social configuration. [62]

However, if social researchers want to borrow these methodological concepts from quantum theory to reconstruct social processes, they should start by examining whether transferring the theory in this way is suitable for the central

ideas of their project. In what follows we attempt to apply BARAD's diffractive methodology to this end. [63]

4.1 The apparatus, the wave function and superposition: Formulating the questions and envisioning the possible answers

We want to start, following WHEELER's (1990, p.10) comment cited in the introduction above, by focusing on how we formulate our questions and by imagining the possible answers that are possible in this context. In experimental physics, the apparatus can be understood as a specific arrangement of technical elements such as lasers, mirrors, measurement detectors and filters. By contrast, in the social sciences the "apparatus" would have to be understood as a specific constellation of social institutions (such as the economy, the law and organizations), material and technical objects (such as architectures and machines), and people with embodied histories (such as doctors, nurses and care workers). [64]

The quantum mechanical formalism is conceived of holistically and, as VON NEUMANN (2018 [1932]) observed, researchers can place the cut-off point between observation and the observed wherever they wish. Thus, the description of the apparatus could in principle also include other causal relationships, such as geological and astronomical conditions, and also historical and cultural influences. The decision as to what is and what is not to be considered part of the apparatus is always part of the research question. [65]

Researchers interested in the influence of climate change on social conditions in South Sudan will place the cut-off point in a different place from those investigating the decision-making processes of doctors in a contemporary German hospital. The choice of research question thus unavoidably creates an exclusion zone which determines what will ultimately be possible to say about causal relationships, and what not. Every act of measurement alters the wave function, and with it, the range of answers that can be meaningfully articulated. [66]

The wave function of the SCHRÖDINGER equation indicates the probability of something occurring. Superposition means that the probabilities of different catalogues of expectations can be "superimposed" (1935, p.844) productively or destructively. As a result, the wave function of an apparatus is composed of multiple sub-functions.[11] Applied to social phenomena, this would mean that probabilities of certain types of communicative responses can be given for certain constellations of interactions, e.g., the doctor-patient interviews. A specific communicative response selected would then, in fact, be analogous to what appears as a measurement observation in quantum physics. This implies that in

11 The superposition which correctly predicts the empirical observations of quantum physical processes is based on a linear combination of probability amplitudes. It is theoretically possible that when the concept is used to model social processes it will turn out that they cannot always be described by means of linear algebra. This is not relevant to the argument presented here, since it is sufficient to point out that probabilities of communicative response are influenced by many factors, both positively and negatively. However, on closer scrutiny researchers may find that the transfer of theoretical concepts from one discipline to another still requires adjustments.

social aggregates, not only does the researcher measure, but measurements—i.e., communicative responses—are constantly taking place in the social aggregate investigated itself. [67]

It is, however, important to note that the wave function in quantum physics, with which probabilities can be formulated, and the *eigenfunctions* that arise from them have a precise mathematical meaning. In the social sciences it is unlikely that it will be possible to formulate any comparable mathematical structures or operators that would precisely describe the conditions of possibility of certain social realities in the same way. In regards to the probabilities of the occurrence of social phenomena in qualitative research we should therefore speak of plausibility in a less strict sense, e.g., whether in a certain constellation, something seems very probable, less probable but plausible, rather improbable or implausible or virtually impossible.[12] [68]

Regardless of whether it can be formulated with mathematical precision, the theoretical concept of the superposition of different probability functions would, in relation to social realities, reflect the finding of social theory that we live in a "polycontextural" world (LUHMANN, 2012 [1998], pp.75), a "society of present times" (NASSEHI, 2011). According to this theory, there are a large number of systemic contexts that exist simultaneously and social researchers who, e.g., position themselves at a specific location may, but do not necessarily have to, focus on any particular process. In quantum theoretical modeling, this would correspond to BRUKNER's (2017 [2015], 2018) finding that when observers are positioned at different locations in an experimental set-up, under certain conditions they may observe different facts or causal relationships. [69]

For us the assumption that in our global society everything can be seen as being related to everything else is central, at least theoretically. However, we mean this not in the sense of causal relationships, but rather of relationships of possibility. On the geographical level a something posted on TikTok by students in Peru could disturb employees at a Berlin institution to such an extent that they make a comment at a team meeting that prompts their boss to make a momentous decision. On the level of time, someone could find a document that was created 50 years ago while they were clearing up his/her storeroom, with the result that its impact would only be felt today. In both the spatial and temporal dimensions many things can be related to many things, but this is so unlikely that it rarely happens. Even if a communicative connection is established, this does not determine *which* connection is chosen. However, this does change the social constellation (i.e., the apparatus) and with it, the set of possible *eigenfunctions*. [70]

We believe that especially the idea of probable improbabilities is also important in the social sciences, as it opens up a methodological approach to the problem of contingency, namely the state of affairs where something is *possible* but *not necessary*. Qualitative researchers, e.g., generally aim to capture subtle

12 However, the possibility cannot in principle be excluded that in certain social constellations quantitative research based on this paradigm could arrive at and formulate more precise probability distributions.

differences and small details, coincidences and empirical peculiarities, in short, uniqueness. However, due to the limitations of their method, they then proceed to classify them as "marginal instances" of sociality and must necessarily submit them to typification and quantification to arrive at a limited number of patterns or grids. Since the objective of research is to avoid arbitrariness, it is necessary to categorize, yet the categorization itself must (methodologically speaking), as an *eigenfunction*, give occasion to discuss scientific theory—e.g., the question as to whether it is to be carried out as an operation in the field under study in a similar way to the research process.[13] [71]

It therefore makes sense to describe modal relationships (something is possible, necessary or impossible) in social science research in the same way as in quantum physics, i.e., as a superposition of probability waves, especially as this offers a methodologically controlled approach to the problem of contingency, as called for by NASSEHI and SAAKE (2002). Qualitative researchers will, however, be less concerned with quantifying the associated probabilities than with qualitative twists and turns, such as tipping points that make a previously probable connection improbable and *vice versa*, and the modalities by which this is conditioned. [72]

Thus, to take the case of a hospital, e.g., various different aspects of the apparatus can be named that can influence a concrete decision-making situation, such as interactions, organization, diagnostic and therapeutic options, existing capacities and technologies, law, love, the economy, science, mass media discourses, the mentalities of the actors involved and many others (for a detailed discussion see VOGD, 2004). Each component of this apparatus would in turn be seen as an operator that influences the probability function and thus also affects what predictions researchers can make about what might be observed in a particular social situation. Influences of the research process itself on the outcome can also be taken into account. Based on the experience of quantum physics, two effects can be distinguished. The first is the selectivity of the research question. The interest in gaining insight and the associated questions determine the focus and the methodology—and thus what can be seen and what remains outside of the field of view (this is unavoidable). Secondly, the apparatus of the configuration to be analyzed may be influenced by the researcher's inquiry in such a way that the probabilities of a certain phenomenon's occurring change substantially. [73]

This would also make it possible to distinguish systematically between different levels of social reality constitution and thus to address the problem that qualitative researchers tend to both under-estimate and over-estimate their own role. On the one hand, it is clear that the role relationship between researcher and research subject, e.g., is only constituted by the research process itself. On the other hand, not every entry of the researcher into the field under research will fundamentally

13 This also provides social scientists with the criterion for deciding whether they want to do reconstructive research (i.e., whether to follow the *eigenfunctions* of the field under study)—or whether to take the view that the production of their results and data will follow a logic of subsumption (i.e., whether it is oriented primarily towards the *eigenfunctions* of the research paradigm imposed from the outside). See Section 4.2 for more on *eigenfunctions*.

change the dominant *eigenfunctions* of the social constellation being studied (i.e., how the social relations "measure" themselves in repeated *intra*-actions). Likewise, and as in ZEILINGER's (2010 [2007], pp.309f.) experiment mentioned above, it can now be assumed that material that was collected for a different purpose may be reactivated *ex post facto* and take on a different meaning, and thus the relationship between researcher and research subjects can be reconfigured at a different point in time. [74]

4.2 *Eigenfunctions* and *eigenvalues*: The (classes of) possible answers to a question

Taking an analogous approach to quantum physics, we can now describe the (social) world as polycontextural, i.e., as a multiplicity of observation positions that mutually engender each other as operators acting on operators, thereby determining the probability of what can be the case at a given position. The observation of what is the case and what can in principle be produced and fixed in the form of data are the *eigenvalues* of this process. Here, the term “data" refers to everything that is collected in the form of texts, images, sound and video recordings, drawings and/or other artifacts in such a way that it leaves a memorable trace. This raises the question as to what could be understood by *eigenfunctions* in a social science context. They could, as in quantum physics, in turn be understood as the solution of a superimposed wave function which indicates the probabilities that something could be the case in a certain apparatus. [75]

An example can be taken from a German hospital which may be viewed as an apparatus. In it, patients are admitted to a surgical ward where a sociological field researcher has just been present. In the next section we will present two concrete examples as a basis for discussing the different ways in which the implications of quantum physics can be applied to hospital ethnography. In the first example, a patient is admitted to the surgical ward, bleeding from the rectum. This patient had already been operated on in the same hospital ten years before and subsequently sued the hospital. In the second example, an elderly man who had already undergone several operations for rectal cancer was refused further treatment because the doctors did not believe that there was any chance of success. We will examine how these patients and their histories were dealt with when they came into contact with doctors, nursing staff and researchers. We will also identify the points at which measurement operations can be empirically reconstructed and how the resulting polycontexturality of the arrangement can be dealt with methodologically. Before doing so, however, we will make some general remarks about working with the diffractive methodology and explain the concept of entanglement, which we have not yet presented in detail. [76]

The data collection conducted in the context of the two case studies and beyond had initially provided a large amount of data on the surgical procedures performed. They included, e.g., the information that the hospital liked carrying out a large number of operations, and also the fact that care was taken to ensure that the cases could be charged at profitable rates. The *eigenfunctions* were

determined by relating the data obtained to the probabilities inherent in the socio-material constellation under analysis in such a way that it was possible to derive a functional relationship from the data obtained (see also LUHMANN, 2005 [1970] on the use of the functional method in the social sciences). [77]

In view of the fact that the apparatus "hospital" implies a certain social embeddedness, the *eigenfunctions* can be seen as related to it. It can be assumed that patients will be examined and treated in hospitals—in line with the official societal function of the hospital institution. It is therefore to be expected that in the surgical unit, patients will undergo surgical examinations or treatment, and that this will involve invasive diagnostics or treatment. This assumption was confirmed by the study. However, it became apparent that not every operation was successful and not every intervention led to a cure or to a diagnosis with a therapeutic option. Yet this did not as a rule compromise the work of the surgeons. It suggests that the core *eigenfunction* of surgery is to operate, not to cure patients. While the operations performed improved the condition of some of the patients, in others they had no effect, and some even died. Other *eigenfunctions* that were derivable from the data were the generation of profit and adherence to legal regulations (VOGD, 2004). Care was taken not to document any actionable errors. Where risks were involved, doctors required their patients to give written consent as evidence of their willingness to accept them. The observation of these activities supports the conclusion that there were also legal *eigenfunctions*. Doctors were also repeatedly reminded by their superiors or the controlling department to code their cases in a certain way and to manage discharges so that the hospital did not end up with a deficit when billing the patients. It can therefore be concluded that economics must also be seen as an *eigenfunction*. [78]

We might also consider other things that happen in the operating theatre to be *eigenfunctions* of a self-referential relationship. But this would risk ending in arbitrariness and thus ultimately in a tautology in that every datum would at the same time be its own function. This would not be satisfactory from a methodological standpoint. We therefore reject that option and return to quantum theory and the importance of the apparatus. The following must be taken into account:

> "Depending on how the question is posed—i.e. what experimental set-up is chosen—the result is either always the same, or (discrete) random distributions, if the system is not in an eigenstate. Or to quote Heisenberg: 'The results of two experiments can be derived precisely from each other only when the two experiments divide the physical variables in the same manner into "known" and "unknown," i.e., if the tensors in that multidimensional space already used for visualization are viewed from the same direction, in both experiments)' (Heisenberg, 1927, p.183). Thus, if I determine selected properties of quantum objects in a certain way, other properties of these same objects appear indeterminate. For this reason, their properties—what is determined and what is indeterminate—depend on which question I put to the experimental set-up I have designed" (VOGD, 2020, p.47). [79]

HEISENBERG's terminology may at first seem a little confusing. However, once it is recognized that the *eigenfunctions* represent the expected *eigenstates* of a quantum system shaped by an experimental set-up, it becomes clear that the quantum theoretical formalism leads us to expect that there are, on the one hand, certain distinct solutions in an experimental set-up, i.e., the *eigenfunctions* that make it possible to specify a certain class of values. On the other hand, however, other aspects must also remain indeterminate or "unknown," as HEISENBERG (1927) put it. In this case, no clear relationships between values and functions, but rather statistical scattering in different directions, are found. [80]

If we apply this to our example, we can now say that communications and actions revolve around the *eigenfunctions* "operating," "defense against litigations" and "being financially successful." However, the ethnographic data collected also pointed to many other things: Employees could be happy or unhappy, sometimes tired and unfocused, sometimes alert and attentive, complaining about the conditions or satisfied with their position, talking about private matters in their interactions with others, spending more time on some patients, treating others unfeelingly or without empathy, and much more (VOGD, 2004). The same applied to the patients and their families. All of this may have influenced what happened in the hospital in one way or another, and perhaps also the treatment processes (perhaps a doctor was not fully focused during an important conversation because his or her mind was elsewhere). However, it is not possible to relate these effects to the research question systematically in order to identify a clearly identifiable *eigenfunction*, because the characteristics of the data are too "*scattered*" to be seen as a clear solution to the expectations placed on the hospital or, conversely, to be systematically controlled by the design of the apparatus.[14] [81]

With regard to the transfer of quantum theoretical concepts, the question also arises, and in social science and ethnographic contexts in particular, as to the extent to which the apparatus is itself influenced by the research process. Let us recall: The apparatus includes all aspects of a configuration which, or changes in which, influence what is possible in the (observed) *intra*-action.[15] This makes it clear, however, that unlike a physicist, who often spends years devising an experimental set-up with the aid of technicians and precision instruments, field researchers in the social sciences are usually confronted with a set-up that is

14 To put it simply, from the point of view of those in positions of responsibility for institutions and organizations, there is no alternative but to accept such deviations and, e.g., to overlook the fact that their role holders do other things in addition to the formally intended tasks, even if this influences their own functional processes in an uncontrollable way. However, this is exactly what does *not* constitute an *eigenfunction* of the institution, but remains in the area of the indeterminate.

15 As pointed out by VON NEUMANN (2018 [1932]), where the researcher draws the line is arbitrary between aspects that still belong to the apparatus and those that do not, i.e., based solely on the researcher's interest in gaining insight and the selections he or she accordingly makes. When it comes to social science questions, a distinction can be made between reconstructive research and research that is guided by normative self-interest. In the example of the hospital, a social researcher can, e.g., reconstruct in the sense mentioned above what the *eigenfunctions* of a German hospital are, or he/she may investigate, e.g., whether the employees are happy, or whether enough is being done to avoid social inequalities (neither of which are *eigenfunctions* of the hospital).

already elaborated and established. In each of our examples it is a particular society that has created hospitals on the basis of its possibilities. In contrast to the situation with a laboratory experiment, in an established social environment such as a hospital, the researcher usually has little or no influence on the apparatus (action research would be an exception). The fundamental questions regarding the design of (and thus also of the responsibility for) the setting (e.g., hospital funding, social legislation, documentation requirements, medical training, medical technology, the status of the nursing staff, opportunities for contact between doctors and patients) have long since been decided. [82]

4.3 Entanglement: *Cutting* questions and answers *together* and *apart*

At this point, an important theoretical concept that has not yet been considered in detail must be taken into account—namely, entanglement. To put it briefly, applied to this context, entanglement refers to the fact that each new observation or communicative definition creates a constellation in which aspects become indeterminate that were previously defined. The aggregates or subsystems involved are linked to each other in such a way that how they will be defined in the future depends on how they will co-determine each other over time. [83]

In the social sciences, such processes occur, e.g., when a communication conducted from a distance feeds into an interaction between the persons who are present. Suggesting in a memorandum that a patient should preferably not be admitted and treated is very different from looking the patients directly in the eye and empathizing with their reactions to a refusal. In such situations, perspectives can easily become entangled, and while a staff member may have intended to be candid with the patient just a few minutes ago, the intention may weaken in the altered circumstances of the shared space. Because of the entanglement—the loss of previous certainty— it is no longer possible to speak of interaction in the trivial sense. Rather, in the "cutting-together/apart," to use BARAD's (2012, pp.52f.) paradoxical terminology, it is rather that new identities emerge spontaneously from both sides of the *intra*-action, which must now be considered to be related to each other in a complementary fashion. These identities need not be permanent. Rather, the quantum mechanical concept of entanglement implies that existing entanglements can be canceled out or superseded by subsequent definitions in a new *intra*-action, a process which, however, is accompanied by new entanglements. [84]

At this point, one could note critically that in this example certain actors (such as "patients" or "doctors") or objects (e.g., "medical records") are presupposed, although following agential realism, even the ontological status of these parts of the set-up needs to be examined. Ultimately, they too must be understood as arising in *intra*-actions within a specific relational contexture. Our methodological answer to this problem is: Just as physicists have to decide where to make the cut between what is observed and the observing apparatus (which is then treated in the classical way), social researchers also have to decide what is considered classical reality (i.e., what has become established as a stabilized relationship between *eigenvalue* and *eigenfunction*). At the same time, social researchers

must determine at which point methodological space is created in order to examine more closely how certain identities emerge or dissolve in the process of "cutting-together/apart." In other words, in order to be able to investigate the interplay between patients, doctors and medical records and the associated subjunctivization processes, an apparatus that is sufficiently fixed (such as a hospital and people who know under what circumstances they should visit a hospital) is required to ensure the stability of the associated roles.[16] [85]

5. An illustration Using Examples From Hospital Ethnography

We will draw on two examples of hospital ethnography to illustrate the relevance of the methodological concepts we have introduced:[17]

> "Mrs Stark, a 65-year-old patient, is admitted to the surgical ward for rectal bleeding. Ten years ago, the patient was operated on for carcinoma of the bowel in the same hospital. The ward doctor looks at the patient's file and notes that the first thing that catches her eye is that the patient once tried to sue the doctors. She also says that it is of particular note that the patient was referred by two different general practitioners. Some time later, the ward doctor reports the case to the senior physician. Before giving further details of the case, she first reports that on a previous occasion the woman contacted the arbitration board. The senior physician explains that the first diagnostic step is to rule out diverticulitis. The ward doctor adds that the symptoms could also be caused by cirrhosis of the liver. The senior physician replies that the symptoms could be due to any number of things and that it was unkind to send a woman like that to hospital. The ward doctor asks if the patient should have a colonoscopy. Her superior rejects the suggestion, saying that it could be that the woman has metastases, which could be punctured by this procedure and that it would be better to just do an ultrasound examination and then transfer the patient to the medical ward" (VOGD, 2004, p.389). [86]

In this study it was found that in many medical contexts, a kind of early warning system has been established to flag patients who could be likely to sue: An "R," (for *Rechtsanwalt* [lawyer]) was often clearly entered in the file if the person in question was a lawyer. If there were known actions against doctors, this was also clearly noted on the first page of the file. In other cases, it was observed that the

16 In short, looking at it from the point of view of physics, quantum physicists are well aware that electrons, atoms and molecules no longer have classical properties in a vacuum, and that even larger molecules can pass through two slits at the same time if the experiment is set up to allow this (ARNDT et al., 1999). Nonetheless, in their experiments they can rely on the fact that the materials they use—such as experimental tables, mounts, measuring instruments with pointers and recording systems—"behave classically," i.e., that they are sufficiently anchored in their contexts, so that the quantum properties hardly play a role with regard to what they intend to do.

17 The material presented here is taken from a study entitled "Ärztliche Entscheidungsfindung im Spannungsfeld von System- und Zweckrationalität" [Doctors' Decision-Making in the Field of Tension between System and Means-End Rationality] (VOGD, 2004, 2006), which was carried out at the Freie Universität Berlin from January 2000 to June 2006 (the last two years were funded by the German Research Foundation). The study was based on participant observation at four wards of four hospitals. The data were analyzed using the documentary method and, due to the comprehensive scope of the survey, allow a restudy using the diffractive method. The cases presented were selected because they are particularly good examples of how medical identities change their character depending on the context of the observation and interaction.

surgical department did not usually hesitate to carry out invasive diagnostic procedures, even in cancer patients. An ultrasound scan and possibly another non-invasive method might be performed first, but then an operation would be scheduled to investigate the situation in the abdominal cavity. A quick transfer to the medical ward without first clarifying whether the surgical department was still needed seemed atypical, especially as the department could not then bill for the treatment. In short, the brief note about a previous lawsuit called into question the point of carrying out the conventional medical examination and referral processes. Instead, it increased the likelihood of a future potential litigation. Not only did this, together with the observation that the patient had probably sought a second opinion from a second general practitioner, lead to a patient being classified "a problematic and difficult patient," but the classification was taken as fact. [87]

In the discussion with the senior doctor, it was also insinuated that the two GPs had wanted to get rid of the patient without treating her and had "unkindly" sent her to the hospital instead, so that the previous assessment of the patient was further hardened. Remarkably, however, in this case this assessment did not prompt the staff to pay special attention to the patient's needs, but rather to the attempt to get rid of her after the minimum possible diagnostic procedures. [88]

Thus, in the situation described, the doctors *entangled* themselves with the litigation mentality of the system that was invoked by the file. It was of no consequence how long ago it was that this happened (i.e., whether it was ten years after the operation or only one year ago), in what causal, social or spatial context it occurred (in which department and with which doctor and whether it might have been justified by a serious medical error). The complexity of the event was ignored. All that counted was that the patient was defined as a difficult, litigious patient, and it was precisely this that fundamentally changed how the surgical department was organized. The *eigenfunction* "operating" (with the requirement of a reasonably plausible medical indication) receded into the background, while a new *eigenfunction*, which could be labeled "getting rid of the patient quickly," came to the fore. As SCHUBERT (2009) has pointed out, both procedures are among the common *eigenfunctions* of medical institutions. In our example, however, it becomes clear how a single non-medical definition—a small note recorded in the file—had a fundamental influence on the probability of what happened to the patient. Making the medical procedures dependent on legal framing tended to result in safeguarding, so that the likelihood of every possible mishap was clarified in advance or, as a kind of "defensive testing" (DEKAY & ASCH, 1998). Very unlikely consequences were also excluded by extending the diagnostic process *ad infinitum* even if this was liable to be detrimental to the treatment from a medical point of view. It also influenced the ratio of trust to fear in the doctor-patient relationship and thus the way this was experienced subjectively by those involved. [89]

We present the following example, also from the ethnographic study, as a further illustration of the application of the methodological concept of entanglement.

> "An old man who has already undergone surgery for carcinoma of the rectum several times is lying in a room in a surgical ward with a large malignant mass in his abdomen. The man wants to undergo treatment urgently. The observer asks the ward doctor, who is a specialist herself, what will happen next and whether the patient will have a feeding tube inserted, as he has requested. The doctor replies, "No, there's no point in doing that, he will only live a few more days. And anyway, it's the doctors who decide what happens, not the patient." Half an hour later, the observer accompanies the doctor on the senior physician's ward round. Outside the patient's room, the ward physician and the senior physician have a brief discussion and come to the conclusion that the feeding tube no longer makes sense, from a medical or treatment point of view. In the patient's room, the senior physician asks: You actually wanted to be tube-fed, didn't you? The patient looks the surgeon straight in the eye and says: 'Please, please, help me.' Two hours later, the patient is wheeled into the operating theater and the tube is inserted" (VOGD, 2009, p.97). [90]

From the moment he arrived it was inevitable that an entanglement between the patient and the surgical unit would occur. Initially, the roles of patient and expert were clearly defined, as were the diagnostic and mandate and the treatment mandate, if required. What remained undefined, however, was what exactly was to be done, e.g., whether surgical procedures were to be performed, and if so which, and who the surgeons in charge would be. As time went on, further specifications were made, e.g., the ward physician who was to assume responsibility for the patient's care was identified, and it was decided what additional diagnostic measures were necessary. This eventually led to the diagnosis of an inoperable tumor and the decision not to insert a feeding tube. When the researcher learned of this, he asked the treating physician what would happen to the patient who still wanted to have surgery. This question suddenly defined the doctor, who had presumably been thinking about other things, as the doctor responsible—and she confirmed by her answer that she was the one who would make the decision based on her expertise. One could also say that as a result of the question, the doctor became the subject who would make the decision. Positions and *eigenvalues* arose spontaneously in the intra-action of the cutting together/apart—here "I as decision-maker," there "the objectively classified problem," on the one hand the "answerer," and on the other the "questioner" (the researcher). [91]

Interestingly, however, a chain of *intra*-actions unfolded during the ward round that called into question the doctor's previously articulated position. First, the specialist ward doctor and the senior physician discussed the case outside the patient's room and, in a professional exchange, concluded that it was pointless to insert a feeding tube. To express it in terms of the quantum mechanical formalism, this could be seen as a repeated measurement that did not change the *eigenfunctions* (the doctors decide what the case is) and the expected *eigenvalue* (do not operate). [92]

In the patient's room, however, an *intra*-action occurred that changed the *eigenfunction* of the configuration. Following LÉVINAS (1986 [1983]), who developed a phenomenology according to which the subject only comes into

being when it is rendered responsible by an ontologically unreachable other,[18] one could say that a new entanglement began when the patient directed his *pleading gaze* at the two doctors. The previous definition (the intent not to operate) dissolved. The treatment prospects thus appeared indeterminate again. This process can also be described as *cutting together/apart* as defined by BARAD et al. (2012, pp.19f.). The patient's question led to a new cut which was accompanied by an entanglement—something previously determined was now undetermined again (the issue of the surgical insertion of a gastric tube was now present again). This opened up the possibility of a new definition (insertion of a tube after all), initiated by the senior physician's question: "You actually wanted to be tube-fed, didn't you?" Although the "actually" indicated that there was another perspective—i.e., the medical perspective, according to which the procedure would be pointless, and the two doctors had already objectively decided on that option—this was associated with a high probability that the patient would be activated as a subject and would no longer appear simply as a body to be diagnosed. [93]

The plea "Please help me" reversed the subject-object relationship. Every communication can be seen as an *intra*-action in which the distribution of roles and the understanding of information and communication emerge for the first time. In this case, the patient appeared as the subject who demanded and thus determined what was to be done ("Help me"), while the doctors present were pushed into the complementary role of complying with his plea. They now appeared to be wholly defined by their role as helpers and to have missed the opportunity to oppose this development as subjects, although a few minutes earlier, they had still been able independently to articulate a different position. [94]

Developments such as these are not at all improbable, as DÖRNER (2001) has pointed out from the perspective of medical phenomenology. He identified three *eigenfunctions* of the modern doctor-patient relationship: The first is to make the doctor the subject who objectifies and manipulates the patient as a body. The second *eigenfunction* is the doctor allowing the patient to submit to her/him as helper, so that the doctor's actions are guided by their suffering. The third *eigenfunction* consists of a special form of dialogue, which is shaped by the legal requirement of shared decision-making (CHARLES, GAFNI & WHELAN, 1997, pp.691ff.) and leads to a mutual exchange of arguments and needs in order to conclude a treatment contract. In the doctor-patient relationship, all three variants can in principle be activated and they often oscillate back and forth. In the conversation documented here, however, there was no exchange of arguments, nor did the doctors counter the patient's wishes with their own position. How can this be analyzed using the diffractive methodology? [95]

18 LÉVINAS was therefore central for BARAD when it came to developing an ethical stance from agential realism: "For Emmanuel Levinas, responsibility is not a relation between two subjects; rather the otherness of the Other is given in responsibility. [...] Ethics grounds human experience (not the other way around). Levinas rejects the metaphysics of the self that serves as the basis for conventional approaches to ethics. Subjectivity is not a matter of individuality, but a relation of responsibility to the other" (BARAD, 2007, p.391).

To put it in terms of the formalism of quantum theory: There is an apparatus (a constellation) with a modified wave function that makes certain communicative responses probable and others less probable or even impossible. In the example given, the apparatus of a surgical department exhibited certain *eigenfunctions* associated with specific *eigenvalues*. "Operating" was almost always an option, even if the outcome promised little or no benefit to the patient. On the other hand, conducting a detailed discussion with patients and relatives about what it means to be close to death and how to deal with it is not an *eigenfunction* of conventional surgical departments, but it is one of, e.g., palliative care wards. It is also not common on surgical wards to conduct long negotiations with patients about their treatment. Patients are given an information sheet, their questions are answered, and they are requested to sign. [96]

This does not, however, rule out the possibility that some of the doctors may have a different attitude to pre-operative informative talks from the one laid down in the standard operating procedures and may then—as in a palliative care unit, for example—be able to raise issues such as fear of death or the danger of pointless medical interventions, and be ready to have a longer conversation about them. However, even if individual doctors had been personally willing to do this, it is unlikely that they would have been able to do so, because their own personal *eigenfunctions* would also have had to fit in with the *eigenfunctions* of the organization as a whole. Since the major part of the work was done in the operating theater and in post-operative care, the *eigenfunction* required that patient consultations and ward rounds be kept short. [97]

In quantum theory the link between *eigenfunctions* and *eigenvalues* is established by applying operators to wave functions. When this procedure is applied to the social science problem at hand, it becomes evident that the operator "conversation, dialogue, talking a lot" would have altered the wave function of the surgical department in such a way that the surgical staff's ability to work would have been put at risk. Accordingly, in view of the probability that there would have been longer conversations between doctors and patients, *destructive interference* was to be expected in relation to the operator that defined the *eigenfunction* of surgery ("operating," "economy," "protection against legal liability").[19] As regards the catalogs of expectations regarding *intra*-action in the patient's room, it can therefore be assumed that only the intrinsic functions of "operating" and "helping the patient" remain. [98]

This would—if analyzed as in the quantum eraser experiment (see Section 2.3)—also lead to the erasure or exclusion of identities that had previously been defined. In the "cutting together/apart" process in previous *intra*-actions, the surgeons may have self-confidently identified themselves as subjects who alone decided what seemed medically indicated. In the patient's room, however, the position they had assumed disappeared and was no longer articulable as a voice.

19 Personal idiosyncrasies of the surgeons, which would then also shape their actions or decisions, were still in principle possible. However, the associated deviations could be expected to be part of further *intra*-actions, which would have reduced the variances again over time. By way of illustration, more experienced colleagues were observed advising junior doctors not to talk to patients for too long during ward rounds (see also VOGD, 2004, p.212).

A certain subjective position and the decision-making power associated with it can therefore no longer be seen as intrinsic characteristics of people (e.g., of highly qualified doctors). Rather, a concrete subject-object relationship emerges situationally from the *intra*-action, according to which something concrete is the case—and in each case this is the observed datum as the *eigenvalue* of the specific relations. [99]

However, the facticity of the measurement (which can also consist in the subjective sense of having a specific identity) conceals the fact that the space of possibilities of what can be the case is opened up by the *eigenfunctions* of the entire constellation (the apparatus). According to the methodology inspired by the formalism of quantum theory, this space can be described as a superposition of enabling or limiting probability distributions (expected values). The latter determine what can be the case, i.e., what is possible in the position of subject (as observing and deciding entity) and object (observed or manipulable entity). [100]

This approach leads to a description that neither negates the relevance of subjective positions nor reifies it as if there were subjects or observers who could stand outside the material constellations that produce them. It becomes possible to reconstruct how subjective positions and the actions and decisions associated with them emerge—and disappear again—out of a psycho-physio-social fabric in conditioned co-production at different points. And it becomes visible how the conditions of each possibility influence each of the others. [101]

6. Conclusion

It thus seems possible, at least in the abstract, to transfer the theoretical concepts of quantum theory—expectation catalogues, *eigenvalues* and *eigenfunctions*—to social science questions. As soon as something happens, i.e., as an *intra*-action occurs—and something is thus defined—the apparatus changes, and as a result what is now excluded or remains indeterminate, i.e., what may possibly be an *eigenfunction* in the event of a further *intra*-action, changes. The pattern of the entanglement's changes. [102]

What happens in the process follows a "grammar," which describes an arrangement or configuration that provides for positions in which it is not pre-determined what can happen in an *intra*-action and what can be found to be the *eigenvalue* of the arrangement at this point. However, what is defined at other points determines what is possible now, which is entirely consistent with the quantum-theoretical notion of "cutting together/apart" (BARAD et al., 2012, p.19). [103]

At first glance, it looks as if social researchers can only observe how probabilities play out. In our example it seems to be a question of "yes" or "no," treatment or no treatment. A medicine that knows only health—the absence of suffering, death and pain—cannot grasp the full spectrum of the human condition. In our example, focusing on the goal of *being healthy* and the associated negation of the variability of life meant that other possibilities were not recognized, even when they were explicitly on the table. Not until the researcher intervened did a new

space of probability seem to open up. This in a sense prompted the doctor to some extent to recognize and answer her own question—"Can I still cure him?"—in the negative—and also to recognize how both the question and her answer were defined; she said, "No, then there's no point in inserting a tube any more"—and went back again. The patient's cry for help prevented her from keeping to her stance. Such cross-cutting and the introduction of new, different points of view that have the potential to make everything appear in a completely new light, are precisely what BARAD's diffractive methodology is designed to analyze. While it draws on the foundations of quantum physics, it can also be used to identify completely new perspectives for the logics of social science methods. [104]

For us, the concept of *intra*-action is crucial here—because it means that individual semantics such as life and death, health and illness, higher goals and immediate responsibilities, morality and many other things can no longer be seen as absolutes, but must now also be seen as fundamentally relational. This inevitably opens up an (implicit) ethical perspective, because those involved have to assume responsibility for what arises in an *intra*-action, whether they like it or not. Whether one enters into contact or asks a question, or avoids contact and does not ask a question, makes a difference. [105]

7. Discussion: Taking Responsibility for the Entanglements in Which One Becomes Involved

We believe that the above examples show convincingly that it can be profitable to apply the theory of quantum physics to problems in social science research. It makes it possible, when analyzing qualitative data, to systematically address the issue of contingency—i.e., the recognition that the data and results that researchers obtain may possibly reflect the true state of affairs, but not necessarily so, and that while the range of what can be the case is diverse, it is not arbitrary. [106]

As NASSEHI (2016, p.15) has pointed out, "it could be possible to get to the heart of the problem of the difference in perspectives in a systematic way" in a radically empirical sense, because "a toolset [is now] available that actually focuses on the empirical connectivity between perspectives that cannot be mapped on to or harmonized with one another" (ibid.). [107]

In order to use BARAD's diffractive method in the reconstructive qualitative research we have described in this article, social researchers would have to:

1. reconstruct how the plausibility's and probabilities of communicative responses change (are refracted) when changes occur in the configuration (apparatus) they are analyzing;
2. ascertain how the *eigenfunctions* and associated *eigenvalues* change;
3. see what entanglements arise and what configurations of definitions and indeterminacy are generated, i.e., what is excluded or becomes indeterminate

> or simply improbable when the *eigenfunctions* of the apparatus employed make certain *eigenvalues* possible (or impossible). [108]

Used in this way, the diffractive methodology can be understood as a kind of hermeneutics, with which the underlying "diffractive patterns of constructive and deconstructive interference" (BARAD et al., 2012, p.13) can be reconstructed by "the work of tracing the entanglements" (p.21). The data that are produced in observational research are not, in and of themselves, results that can be used to form typologies (as in a content analysis that is conducted in a positivist mode, for example). Rather, they are the starting point for a search for regularities, which are constantly regenerated in a chain of observations (*intra*-actions) that has no beginning or end, and through which the condition of the possibility for their further development is co-created. [109]

Like all hermeneutics, it is based on methods of comparative analysis. Hypotheses regarding *eigenfunctions* and probabilities of communicative responses are used as minimum and maximum contrasts to altered arrangements or configurations, with the objective of attaining a progressively more nuanced understanding of how a configuration that gives rise to a specific form of data arises. The diffractive methodology does not therefore differ in its approach from sophisticated reconstructive methods (see, e.g., BOHNSACK, 2014). What does distinguish it is its interest in what is excluded, what is concealed and remains undetermined by the operation of defining and observing, in other words its degree of sensitivity to the problem of contingency. [110]

This also explains the affinities between BARAD's theory and the rhizomatic thinking of Deleuze and Guattari (2005 [1980]), e.g., with the central figure of connections in their conception of knowledge systems,[20] and particularly with FOUCAULT's (1972 [1969]) genealogy and archaeological method, which can also be used to reconstruct the constitution and breakdown of ontological and epistemological orders (i.e., an observational situation) without, however, oneself ontologizing without justification. However, FOUCAULT's approach is far from trivial. It is based on synthesizing large amounts of archived data in novel and creative ways in order to elucidate epistemic ruptures and continuities. In some instances, there is also a general refusal to keep to a particular methodology (NEHER, 2024). [111]

Because the quantum theoretical formalism provides precise definitions of its guiding theoretical concepts, BARAD's diffractive methodology appears to be more rigorous, which facilitates methodological reflection. It should, however, be noted that in order to make use of the diffractive methodology, researchers need

20 DELEUZE and GUATTARI (2005 [1980], p.362) also criticized a form of science that always seeks a complete unity of knowledge. They refer to the desire to occupy research spaces in all aspects as royal science that attempts to transform research fields into countable, vectorial or topological spaces through extensive movements. In contrast, they conceptualized a science that is “nomad” (ibid.) in the sense that the researcher moves in the research space, inhabiting it and moving around in its manifoldness, but without affecting it at all points (ibid.). Here, the universality of the singular, the becoming, transformation and heterogeneity are central. BARAD would not go so far, but would rather avoid ontological commitments within these concepts.

to have an extensive body of data collected from a wide range of perspectives and ideally also employ a variety of methodological approaches. The diffractive methodology is therefore particularly suitable for re-reading comprehensive studies that are themselves based on multi-perspective, thick description and extensive comparative analysis. This is because such studies already employ the broad spectrum of methods required for comparison in diffractive hermeneutics. It makes it possible to draw conclusions about the diffractions produced by the apparatus in the various constellations observed. [112]

The main advantage of BARAD's approach is therefore above all that it opens up a metamethodological perspective. The diffractive methodology does not replace the existing methodological approaches, but rather makes it possible to relate them to each other in a productive way in accordance with Bohr's principle of complementarity, in order to facilitate a more dynamic understanding of the object of investigation and the observational states of affairs inherent in it. It makes it possible to avoid approaching the data with fixed ontological presuppositions, such as causal assumptions, from the start, without having to do without a systematic methodology. It sheds new light on post-structuralist and systems-theoretical approaches, which, on the one hand, posit that objects are not independent of the observer, but whose protagonists are, on the other hand, moving away from the ideas of the philosophy of the subject, for compelling reasons. The diffractive method offers an approach to the object that can and must account for both hardened structures and the emergence of subjective perspectives, without having to reify them ontologically. Distinguishing methodologically between *eigenvalues* and *eigenfunctions* provides us with a contextualized understanding of the subject matter of discourses, identities and the associated subjectivity. This understanding is achieved by considering the specific constellation in question, without it being necessary to deny the existence of subjective positions and the associated identities. [113]

Last, but not least, with diffractive methodology, introducing new research questions becomes possible. Due to the sensitivity of the approach to what is excluded by the apparatus employed, not only what appears as a datum in a given constellation comes into view, but also what can*not* appear. Examples are the development of a novel methodological approach to topics such as the (cultural) anthropological subjects of "taboos" (BATESON & BATESON, 2004 [1987], pp.65ff.) and collective remembering and forgetting. In some social constellations, there are things that cannot be said, and often cannot even be thought or experienced, whereas this may easily happen in other constellations. In light of the examples from hospital ethnography presented in the preceding sections, such questions can now be addressed in a systematic manner by investigating, as in the quantum eraser experiment, how a certain modification of the apparatus permits or prevents the emergence and dissolution of particular forms of subjectivity and identity. [114]

There are methodological links not only to FOUCAULT's (1978 [1976]) work on the material conditions of subjectivization processes, but also to the systems-theoretical method of contextural analysis (JANSEN, FEISST & VOGD, 2020;

VOGD & HARTH, 2021). Using his theory of polycontexturality, GÜNTHER (1979) developed the concept of a *Leerstellengrammatik* [grammar of empty places] (VOGD & FEISST, 2022) as an arrangement that provides for places where it is not (necessarily) fixed what will appear as a specific subject-object relationship in each place. At the same time, what is predetermined or predefined elsewhere also determines what is possible at another place. Like BARADs quantum-theoretical concept of "cutting together/apart" (2012, p.52), empty place grammar allows us to describe "a structural layer" in which "the difference between subjectivity and objectivity must first become established and therefore cannot yet be presumed to exist there" (GÜNTHER, 1976, p.216). Taking a closer look at BARAD's theoretical concepts would seem worthwhile, if only simply to further sharpen methodological reflection on these processes of defining the empty places. [115]

Finally, an examination of the research ethics perspective opened up by BARAD (2007, pp.353ff.) is warranted. This perspective is predicated on the assumption that researchers bear responsibility for the consequences of their research questions and the methodologies they employ. The question thus arises as to what forms of subjectivity and materiality of the object(s) of their investigation are made possible by these choices. However, this responsibility is not based on an ability to develop criteria for what is "right" and "good" from a normative standpoint. Rather, it lies precisely in the fact of being situated within the situation, as LÉVINAS (1986 [1983], p.345) has suggested, and thus becoming a subject in the ethical sense.[21] This results in a radical position that encompasses ethical, epistemological, and ontological aspects.

> "The separation of epistemology from ontology is a reverberation of metaphysics that assumes an inherent difference between human and non-human, subject and object, mind and body, matter and discourse. *Onto-epistem-ology*—the study of practices of knowing in being—is probably a better way to think about the kind of understanding that we need to come to terms with how specific intra-actions matter. Or, for that matter, what we need is something like *ethico-onto-epistem-ology*—an appreciation of the intertwining of ethics, knowing and being—since each intra-action matters, since the possibilities for what the world may become call out in the pause that precedes each breath before a moment comes into being and the world is remade again, because the becoming of the world is a deeply ethical matter" (BARAD, 2007, p.185). [116]

One might argue, as do HOPPE and LEMKE (2015, p.263), that the "concept of responsibility" has become so "far-reaching" that the associated "ethicization of the political" is difficult to distinguish from the "de-politicization of the ethical." However, this criticism is diminished when one ceases to perceive one's mode of relating to the world and the assumption of responsibility that goes along with it as an abstract process, but rather as a concrete configuration, i.e., the network of

21 In his "Glass Bead Game," HESSE (2000 [1943]) used the story of the inner transformation of the protagonist Josef Knecht to express the different epistemological and ethical attitudes. At some point, Knecht has to abandon his detached attitude towards the world in order to plunge into life, but with the consequence that the ethical responsibility that he now assumes in practice proves to threaten his own life.

relationships in which one finds oneself directly involved as a researcher. And it does in fact make a difference ethically which ontology and epistemology one adheres to. [117]

For example, when nuclear physicists like HEISENBERG (2010 [1969]) considered whether they could better serve the discipline of physics if they continued to work under the Nazis or if they emigrated, then according to BARAD (2015 [2005], p.107) their responsibility lay less in the decision as to whether to leave or to stay than in their lack of awareness of their own question and the standpoint from which they were making the decision. HEISENBERG elected to remain in Germany. From his autobiographical works (2010 [1969]), it is evident that he was a connoisseur and admirer of PLATO and thus an idealist who was interested in physics as such, regardless of its practical applications, and thus could not perhaps have decided any differently, given this ontological background. In 1941, Carl Friedrich VON WEIZSÄCKER applied for a patent for an atomic bomb in Berlin for reasons of peace policy (as he later justified, see SCHULZ, 2010). In turn, BOHR, unsettled by some sketches HEISENBERG had shown him,[22] felt compelled, despite his ethical ambivalence, to urge British and American politicians to build a nuclear weapon (BERNSTEIN, 1995). It is inevitable that the production of scientific insights will have consequences. With regard to the question of responsibility, however, different ethical, epistemological and ontological attitudes can be adopted, as the example of the three physicists demonstrates. [118]

The relational structures in which qualitative social researchers are involved may appear less dramatic than those of physicists who discovered the potential of nuclear fission, at least at first glance.[23] If they are serious about their work, they initially only place themselves in a situation that challenges their existing ethical convictions. Insofar as they adopt an open stance in regard to their subject matter, they are not yet in a position to establish in advance what is the case or what is good. Instead, they allow themselves to be influenced by the subject matter in a process of *intra*-active investigation. This can result in their being challenged to act as ethical subjects, as LÉVINAS (1986 [1983], p.356) demanded. As JANSEN and VOGD (2022, pp.193f.) wrote,

> "this is precisely where the deeper, hitherto barely recognized interpretation of the term 'value-freedom' lies. It is not a freedom *from* values, but a freedom *for* values. The freedom associated with one's own research activity makes it possible to decide in favor of a particular course of action, i.e. to utilize one's own involvement to shape relationships in a manner that is consistent with one's own existential position as a researcher." [119]

22 This is how his son, Aage Niels BOHR (1967 [1964], p.191) remembered it, and in reference to PAIS' (1991) reflections on BOHR's biography.

23 At second glance, the responsibility of a social scientist does not seem any less when we consider, as does PIRKTINA (2019, p.472), the apparent ease with which they sometimes tend to "assert an ontic [...] situation," which "means creating a powerful and dangerous ontology. Philosophically, to make such an assertion is to relapse into metaphysics, but in general it means constructing an ideology."

This means both being part of a relationship and generating descriptions that suggest that one could "step out of the world," as if they were functioning ontologies, and have sufficiently understood the situation analyzed in terms of the essential causal relationships and associated ethical consequences.[24] The two mutually exclusive poles of allowing oneself to become entangled and distancing oneself to create a (supposedly) knowledgeable overview must thus also be seen as complementary, as defined by BOHR (1928). Both options—committing to a position and assuming responsibility for it, while still remaining open and vulnerable, would be a crucial element of any professional scientific ethics, even if this may be challenging and does not guarantee the moral certainty that one secretly desires.[25] [120]

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24 This is precisely the point made by TAGUCHI (2013), who demonstrated in her study that the subjectivity of the researcher and the ontological determinations associated with it persist even when participants engage in a diffractive dialogue. The enactment of the role of researcher in a given *intra*-action inevitably entails the adoption of specific functioning ontologies, regardless of the researcher's intentions.

25 To paraphrase BARAD: "And likewise, yes, scandalous as it may be to some, agential realism could ultimately prove to be wrong, or at least not sufficiently responsive to various 'human' and 'nonhuman' *intra*-active engagements that matter. That vulnerability to my mind, is a real strength of any theory ('scientific' or otherwise), not a failing" (2011, p.446).

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