**When nomenclature matters: Is the “new paradigm” really a new
paradigm for the psychology of reasoning?**

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Abstract

For most its history, the psychology of reasoning was dominated by binary extensional logic. The “new paradigm” instead puts subjective degrees of belief centre stage, often represented as probabilities. The term “new paradigm” refers to Thomas Kuhn’s popular theory of science, which describes scientific progress as discontinuous process of alternating “normal” and “revolutionary” phases. We argue that the “new paradigm” is too vaguely defined and therefore does not allow a clear decision on what falls within its scope and what does not. We also show that before the new developments, the psychology of reasoning was neither in a phase of normal science, nor is the alleged new paradigm as revolutionary as the term suggests. Based on this analysis, we argue that the supposed opposition between a “new” and “old” paradigms hinders progress in the field. A more productive view is that current progress is developing in continuities where rival research programs stimulate each other in a fruitful way. The article closes with some topics where further connections between competing research programs are likely to promote progress in the psychology of reasoning.

Keywords: human reasoning, theory of science, new paradigm, logic, probability theory, mental models

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For most its history, the psychology of reasoning was dominated by classical binary extensional logic. Researchers gave people deductive reasoning problems and measured under which circumstances they conformed or deviated from the norms of propositional or predicate logic. When they conformed to those norms, they were deemed *rational*, otherwise *irrational*. The first such experiments were conducted by Störring (1908) and then by Wilkins (1928) and Woodworth and Sells (1935). The results of these early studies already showed what since then occupied the psychology of reasoning: people make many logical errors, they frequently accept conclusions, which are logically invalid, and they are often biased by factors, which are irrelevant according to the principles of logic (Evans, Newstead, & Byrne, 1993).

Today many researchers declare that deductive logic is not the right standard for human rationality. Hence, the earlier results do not prove people to be irrational, but rather show that the wrong standards are used to define what we should count as rational. This new view has been called the “new paradigm” in the psychology of reasoning (Elqayam, Bonnefon, & Over, 2016; Oaksford & Chater, 2020; Over, 2009; Evans, 2012). It gave the psychology of reasoning new impulses and directed researchers’ attention towards potentially central—but hitherto underrepresented—aspect of human rationality.

The term “new paradigm” refers to the theory of science proposed by Thomas Kuhn in his groundbreaking book “*The Structure of Scientific Revolutions*” (Kuhn, 1962). Broadly speaking, the theory rejects the idea of science as a cumulative record of empirical findings and theoretical generations. In Kuhn's conception, progress in science relies on discontinuities of alternating “normal” and “revolutionary” phases. These revolutionary phases lead to great conceptual breakthroughs and lay the basis for a succeeding phase of “normal science”. A typical example is the shift from Newtonian to Einsteinian mechanics (Kuhn, 1970, p. 102).

The term “new paradigm” refers to a key concept in Kuhn's theory—the “paradigm shift”, which describes the profound, “revolutionary” change in experimental and theoretical practices of a discipline. On the jacket of a recent book Elqayam, Bonnefon, and Over (2016), three main figures in the field, declare:

In recent years the psychology of reasoning has undergone radical change, which can only be seen as a Kuhn-style scientific revolution. This shift has been dubbed “New Paradigm”.

The aim of the present article is to examine to what extent the new paradigm is really a “paradigm shift” in the Kuhnian sense. At first glance, thoughts about nomenclature might seem petty and may hardly make a sufficient theoretical or empirical contribution to the psychology of reasoning. However, nomenclature matters! It sets the tone for how researchers address questions. And we know from research on framing effects that different wordings of a message influence the thoughts and choices of the recipient (Tversky & Kahneman, 1981). The current nomenclature, we

argue, promotes an adversarial approach on the supposed opposition between different empirical and theoretical frameworks, which might detract from achieving progress in the field. In the following, we will, first, examine the claim that the psychology of reasoning was in a phase of normal science before the new paradigm appeared. Second, we will investigate if the current developments indeed can be characterized as a “new paradigm” in the Kuhnian sense. Third, we present some examples where the different coexisting research programs stimulated each other and led to advancement in the field. We conclude that this progress did not rely on revolutions in which one paradigm overturns another, but rather progress evolves in “continuities” within the reasoning community. This view provides a more veridical analysis of current psychology of reasoning. Finally, we present some topics where further connections between different research programs are likely to promote progress in the psychology of reasoning.

Was the psychology of reasoning “normal science”?

In the Kuhnian theory “normal science” is characterized by two aspects: By experimental work that is done within a traditional paradigm and a settled methodological framework. And by slowly cumulating findings in accord with established theory, without questioning the core assumptions of that theory.

Especially the first criterion seems to adequately describe the traditional research in the psychology of reasoning. A view in the literature shows that more than 90% of the reported experiments were concerned with deductive reasoning problems in which participant were asked what necessary (logically) follows from the premises

and their responses were compared to the normative standards of propositional and predicate calculus from classical logic. The experimental paradigms were highly homogeneous: participants were confronted with a set of premises, told to assume the premises as true, and could generate or evaluate conclusions by mouse or button clicks. Slight variations of this paradigm existed—the number of premises varied, whether they are presented one by one, on the same screen, self-paced, or with a time limit, etc. However, the authority of the established deductive paradigm is obvious, and this indeed looks like “normal science”. In their influential book *Deduction* Johnson-Laird and Byrne (1991) wrote:

Why deduction? One reason is because of its intrinsic importance: it plays a crucial role in many tasks. You need to make deductions in order to formulate plans and to evaluate actions; to determine the consequences of assumptions and hypotheses; to interpret and to formulate instructions, rules, and general principles; to pursue arguments and negotiations; to weight evidence and to assess data; to decide between competing theories; enter solve problems. A world without deduction would be a world without science, technology, law, social conventions, and culture (p.3).

The quote illustrates the focus on deduction that the psychology of reasoning followed and is criticized by the new paradigm. However, it is wrong to believe that classical logic was used in an unquestioned way – as required by the second criterion of the Kuhnian theory. In fact, the field always comprised a plethora of rival theories

and theoretical frameworks that used classical logic in many different ways as *normative* or *descriptive* framework for human rationality. Broadly speaking, normative theories are taken as standards for how rational reasoning *ought* to be, whereas descriptive theories seek to describe how humans *actually* reason (Elqayam & Evans, 2011; Knauff & Spohn, in press). Normative theories provide an idealized view on rational reasoning. Descriptive theories rely on empirical findings and are open to falsification. Today both views are influential in the psychology of reasoning.

Table 1 show which role different reasoning theories assigned to classical logic. The *mental proof theory* and the *natural logic theory* both used binary extensional logic as the normative and as descriptive theory of human reasoning. But they varied in their assumption regarding the correspondence between formal and mental logical rules. The theory of *pragmatic schemata* and the *classical version of the mental model theory* used binary extensional logic as a normative, but not as descriptive theory of human reasoning. In fact, already the classical model theory emphatically argued against the claim that human reasoning relies on logical rules. Reasoning in this theory relies on peoples' ability to construct and inspect (iconic) mental representations that capture what the premises mean. Today, the revised model theory is even more far away from logic, as we will show later (Johnson-Laird & Byrne, 2002; Johnson-Laird, Khemlani, & Goodwin, 2015). For a long time, different versions of *dual process theory* assumed that system 1 uses non-logical heuristics, and system 2 relies on logical reasoning. Today the theory uses probability theory and is part of the "new paradigm" psychology. The *evolutionary theory* explains reasoning as a process of adaption to the environment, and the argumentative theory as a means to convince

others. Finally, there are many *micro theories*, such as atmosphere hypothesis and matching theory, which use binary logic as normative theory for good reasoning, but explain errors by non-logical factors that bias people towards certain conclusions.

This brief summary shows two things: On the one hand, the limitation to deductive reasoning indeed had characteristics that conformed with Kuhn's concept of normal science. Until 1970 logic was generally accepted as the norm for human reasoning (Inhelder & Piaget, 1958; Woodworth & Sells, 1935). On the other hand, however, from then on there was never a unitary descriptive or normative theoretical framework with one major theory at a time. At any one time there has been a large number of different theories, each of which had different communities and leading advocates. Because of this persistent disagreement between competing schools of thought, and even though there was not much research that went beyond the deductive reasoning, there never has been enough agreement to justify the term "normal science" to describe the psychology reasoning before it became interested in uncertainly, probabilities, beliefs of degrees, and so forth.

Tab 1. The diversity of logical approaches in the psychology of reasoning

Theory	representative reference	normative	descriptive	main assumptions
Mental proofs	Inhelder & Piaget (1958) Rips (1994)	yes	Yes	mental logical reasoning proceeds analogous to formal logic
Natural logic	Braine & O'Brien (1998)	yes	Yes	meaning of logical terms in natural language can differ from formal logic
Pragmatic Schemata	Cheng & Holyoak (1985)	yes	No	people use their knowledge about what is permitted and forbidden to reason

Mental model theory	Johnson-Laird (1983) Byrne & Johnson-Laird (1991)	yes	No	people reason by simulating possible interpretations of the premises
Dual process theory	Evans (2009) Stanovich (2011)	yes/ no	yes/ no	System 1 is fast and based on heuristics, system 2 is slow and based on logic; today the approach is part of the “new paradigm” and uses probabilities instead of logic
Argumentative theory	Mercier & Sperber (2017)	yes	Yes	people have learned to reason to convince others
Evolutionary adaptation	Cosmides (1989)	yes/no	No	reasoning for identifying cheaters and violations of social rules
Atmosphere, matching bias, etc.	Woodworth & Sells (1935) Evans (1972)	yes	No	surface features of the problem bias reasoners towards certain conclusions

* Only some representative publications are listed. The table just gives a rough depiction of the theory, although they are more complex. The "normative theory" (column 3) defines the standards for rational reasoning, while the "descriptive theory" (column 4) describes how actual reasoning proceeds and why deviations from normative theory occur.

Is the new psychology of reasoning a “scientific revolution”?

For Kuhn, a scientific revolution is a sudden eruption ushering in radical change in theories and beliefs of the entire scientific community. This leads to a new way of thinking in the discipline that the members of the community from then on accept. Applied to the psychology of reasoning, Elqayam and Over (2013) describe the main idea of the “new paradigm” as follows:

The old paradigm focused on binary truth and truth preservation from assumptions, whereas the new paradigm puts subjective degrees of belief centre stage, represented as probabilities. Subjective psychological value, or utility, and social pragmatics also play a central role (p.249).

The quote shows that the main intention of the new approach is to replace binary logic by subjective probabilities. But is this a scientific revolution, a radical paradigm shift in the Kuhnian sense? We believe not. One reason is that already in the classical model theory probabilities were discussed, even though they were rejected at that time. In his famous book, Johnson-Laid (1983) writes:

At the point at which most inferences are made they can seldom be securely established: they are plausible conjectures rather than valid deductions. Many psychologists are accordingly inclined to suppose that they must depend on the computation of probabilities. However, there is no need to suppose that individuals compute probabilities [...]. The mechanism is more likely to consist of a device that constructs a single mental model on the basis of the discourse, its context, and background knowledge (Johnson-Laid, 1983, p.128).

The quote demonstrates that even in the early phases of the psychology of reasoning probabilities and uncertainty have been considered. Later, however, these topics were largely forgotten again and most researchers adhered to the deductive paradigm.

A second argument against a scientific revolution, which is even more important, is that the so-called new paradigm is still too vaguely defined to be called a “new paradigm”. Proponents of the new paradigm state that it delimits itself from the “old” tradition of studying deduction. But, it is not clear which position they take towards logic in general. Initially, before the term “new paradigm” was introduced, Oaksford and Chater formulated in their pioneering book “Bayesian rationality”

(2007) a more general critic on all kinds of logic, not only binary deductive logic. They criticize that throughout the entire history, rationality has been explained by comparison to systems of logic, which are truth-preserving and just distinguish valid from invalid arguments. Their main claim is that the classical conception of the mind as a logical system is flawed at the very outset (see also Oaksford & Chater, 1991).

Such vague descriptions of what the authors consider the “old” approach were later corrected by Over (2009), who clarified that the criticism was only meant against binary logic (see also Evans, 2012). Nevertheless, there exist many different types of logics besides classical logic (see Antoniou, 1997; Ragni, Eichhorn, Bock, Kern-Isberner, & Tse, 2017). And it is important to know which role these other logics play in the new paradigm. Are non-monotonic logics and logical systems with more than two truth values considered part of the new paradigm? If the answer is no, then we cannot talk about a scientific revolution in the Kuhnian sense, because there are still other paradigms based on logic that coexist and survived from previous times (e.g., Da Silva Neves, Bonnefon, & Raufaste, 2002; Stenning & Lambalgen, 2005; 2008). A paradigm that ignores such co-existing approaches cannot claim for itself to embody a radical change in the theories and beliefs of the entire scientific community. However, if the answer is yes, then the new paradigm would encounter another difficulty: it would be defined solely by its non-deductiveness and would need to specify the relative importance of probabilities in their framework. This leads us to another problem related to the vague definition of the “new paradigm”: Is it defined by the Bayesian or other calculi from probability theory?

Most advocates of the “new paradigm” largely agree on Bayesian probabilities as an appropriate framework for dealing with subjective degrees of belief. Oaksford and Chater are completely wedded to Bayesianism and one might gain the impression that Bayesian updating is an essential defining characteristic of the new paradigm. However, the literature is equivocal in this respect. Different theories from the new paradigm vary significantly in adopting Bayesian principles as descriptive or normative theories of human reasoning. And there are even proponents of the new paradigm that do not use probabilities at all (e.g., Bonnefon, 2009). Table 2 shows the role that different probability-based theories assign to Bayesian principles. The theories of *Bayesian rationality* and *computational rationality* postulate that Bayesian principles are a suitable framework for cognitive reasoning with subjective beliefs. The basic assumption is a strong coherence between the normative and descriptive levels of analysis. In contrast to these purely Bayesian approaches, *supposition theory* and *probability logic* do not use Bayesian updating, but other foundational work on subjective probability theory. Finally, *ranking theory*, which became popular in the last years, does not use the Bayesian framework, neither as normative standard nor as a descriptive theory of human reasoning. Even supporters of the “new paradigm” realized the heterogeneity in the present approaches, and try to deal with it by talking of “strict” and “soft” Bayesianism (Elqayam, & Evans, 2013). Yet, this cannot hide that fact that there is still no theoretical framework which is commonly accepted by all the members of the new “probabilistic” community.

The definition of the “new paradigm” gets even more vague when Elqayam and Over (2013) state that the new paradigm also seeks to integrate knowledge, belief, pragmatics, and values into the psychology of reasoning (see also Evans, 2012). Certainly, this is important, but is not exclusive to the new paradigm. Hundreds of experiments of the last decades have already shown that human reasoning is affected by many factors that are not relevant according to the principles of classical logic, e.g., that people reason better when the conclusion agrees with their prior belief and less well when the conclusion disagrees with prior beliefs (Evans, 1993; Klauer, Musch, & Naumer, 2000). Similarly, numerous studies have shown that the linguistic form and social pragmatics play an important role in reasoning (Evans, Legrenzi, & Girotto, 1999; Gigerenzer, & Hug, 1992). Of course, the difference between this research and to the so-called “new paradigm” is that previous experiments draw a clear distinction between reasoning and knowledge, whereas now knowledge and other factors are integrated into the reasoning process. Certainly, this is an important extension of previous research, but we can hardly call that a revolution or paradigm shift in the Kuhnian sense.

Tab 2. The diversity of probabilistic approaches in the psychology of reasoning

Theory	representative reference	normative	descriptive	main assumptions
Bayesian rationality	Oaksford & Chater (2007) Hahn (2014)	yes	Yes	dual process theory provides the algorithmic-level underpinning to the computational-level functions
Supposition theory	Evans & Over (2004) Edgington (1995)	yes	no	uses “Ramsey test “to simulate the antecedent and evaluate the consequent of a conditional

Probability logic	Pfeifer & Kleiter (2009) Pfeifer (2013)	yes/no	No	uses Adams' (1998) concept of p-validity; an argument is p-valid, if the uncertainty of the conclusion cannot exceed the sum of the uncertainties of the premises
Computational rationality	Tenenbaum, Griffiths, & Kemp (2006) Gershman, Horvitz, Tenenbaum (2015)	yes	yes	Bayesian updating procedures are used to compute and revise probability distributions; most?? spelled out theory on the algorithmic level
Ranking Theory	Spohn (2012) Skovgaard-Olsen (2016).	no	no	ranking functions are used for deductive and non-deductive reasoning; represents belief in a proposition (= taking it to be true), or in degrees of belief (= beliefs as more or less firm), accounts for the dynamics of beliefs

* The "normative theory" (column 3) defines the standards for rational reasoning, while the "descriptive theory" (column 4) describes how actual reasoning proceeds and why deviations from normative theory occur.

Current research programs are not incommensurable: two examples

So far, we were concerned with the relations between deductive reasoning, binary extensional logic, uncertain reasoning, probabilities, Bayes theorem, etc. The central question now is to what extent these approaches are incommensurable with each other. We do not want to dive here into the many discussions on what Kuhn conception of "incommensurability" exactly means (Hoyningen-Huene, 1990). For us, it just means that there is a change in scientific problems and theoretical concepts to solve these problems. In reasoning research, maybe the most obvious observation is that the deductive paradigm is incommensurable with the problems and concepts for uncertain reasoning and subjective degrees of beliefs.

So, if the new paradigm is solely defined by its non-deductiveness, then the trend towards uncertain reasoning, defeasibility, and graded beliefs, is a new and an important advancement of the field. But is that enough for talking of a new paradigm? Probably not. More than a radical shift of paradigms, the investigation of beliefs and uncertainties during reasoning was a continuous development that slowly emerged from findings that were unexplainable within the deduction paradigm. Deductive theories motivated the investigation of probabilities and also probabilistic theories have motivated deductive theories to adapt and account for uncertainties. In the following, we present two examples in which—in contrast to the alleged incommensurability—reasoning research benefited from the interaction of the two theoretical frameworks.

One example in which both approaches benefited from each other is the ongoing dispute about how people deal with conditional statements, if p then q . Today, the main rivals to explain conditional reasoning are the mental models theory and the theory of Bayesian rationality as the most important theory in the probabilistic new paradigm. Take, for instance, the following inference (see Gazzo Castañeda and Knauff, 2020; De Neys et al., 2002):

If a person does sports (p), then then person loses weight (q).

A person does sports (p).

Therefore, the person loses weight (q).

In propositional logic this inference relies on the material conditional which has the extensional form:

$$(p \& q) \text{ or } (\neg p \& q) \text{ or } (\neg p \& \neg q), \text{ where } \neg = \text{not.}$$

In most publications, mental model theory has used this interpretation of the conditional as a normative standard for human reasoning. Following this interpretation, model theory assumed that the conditional is represented by the following three mental models:

sports	loses weight	$(p \& q)$
$\neg$ sports	loses weight	$(\neg p \& q)$
$\neg$ sports	$\neg$ loses weight	$(\neg p \& \neg q)$

From these models the conclusion “The person loses weight” (q) follows because $p \& q$ is the only model in which p is true, and q is also true. If reasoners gave other answers, they were deemed irrational. However, in daily life people often do not accept this inference because they can retrieve prior knowledge about disabling conditions from long-term memory (Cummins, Lubart, Alksnis, & Rist, 1991; Gazzo Castañeda & Knauff, 2016, 2018, 2019, 2020). Disablers are conditions that prevent q from happening although p is true. For example, a sportive active person may not lose weight due to bad nutrition or wrong exercises. In other words, disabling conditions lower the perceived sufficiency of p for q and thus lead to a lower acceptance of the conclu-

sion (Thompson, 1994, 1995). From a classical logical point of view, this is a violation of the fundamental law of monotonicity, which states that a logically valid conclusion can never be retracted, not even in the light of new information.

One of the main criticisms of the model theory is that by using classical logic as norm, it accepted the long-known paradoxes of material implication, which show that the conditional is not interpreted according to the norms of propositional logic (Lewis, 1912). Proponents of the new paradigm argued that this demonstrates the inadequacy of classical propositional logic as a normative theory for human reasoning. It cannot explain that conditional reasoning depends not on pure principles of propositional logic, but on a combination of background knowledge and conversational principles (Oaksford & Chater, 2020). It is a most notable fact, however, that even in its early times the model theory argued that researchers can either “*abandon the truth-table analysis of conditionals (even if it is supplemented by inferences based on general knowledge) or to accept the validity of this apparently paradoxical deductions and to explain why they seem improper* (Johnson-Laird & Byrne, 1991, p. 74).

Nevertheless, model theory has changed dramatically in recent years, maybe also in response to the criticism of proponents of the new paradigm. While the classical theory postulated that reasoners represent compound assertions by constructing models of the disjunctive alternatives, the revised mental model theory postulates instead that compounds refer to conjunctions of possibilities, which hold in default of knowledge to the contrary. Consequently, the paradoxes of the material conditional are no longer valid for the natural language conditional (Johnson-Laird et al., 2015),

and indeed “if p then q ” has fully explicit models that each represent a default possibility (Khemlani, Byrne, & Johnson-Laird, 2018):

possible ($p \ \& \ q$)

possible ($\neg p \ \& \ q$)

possible ($\neg p \ \& \ \neg q$)

It is obvious that this is a substantial theoretical modification that makes the revised model theory more suitable for dealing with the defeasibility and nonmonotonicity of daily life reasoning. It also means a substantial change on the normative side. The revised model theory is no longer wedded to classical logic as a normative framework, but uses possibilities that represent the meaning of natural expressions as a norm for reasoning. The new paradigm advocates’ criticism of the mental models theory as a “logical theory” is thus not justified anymore. One may even say that these modifications bring the revised model theory closer to the central assumptions of the new paradigm—showing that both frameworks can indeed be commensurable.

This also becomes obvious in our second example, which is concerned with the disjunction, p or q . Consider the following problem from Hinterecker, Knauff, and Johnson-Laird (2016):

There’s an ace (p) or there’s a king (q) in the hand, or both ($p \ \& \ q$).

Therefore, it is possible that there’s both an ace and a king in the hand (possibly ($p \ \& \ q$)).

The inference is a typical example of modal reasoning about what is possible or necessary. In Hinterecker, Knauff, and Johnson-Laird (2016) we reported three experiments in which participants accepted such inferences as valid, though they are invalid in probability calculus. Yet, they are valid in revised model theory. In contrast, inferences of the sort

p or q, but not both.

Therefore, probably p or q or both.

are valid in probability calculus, but not in revised model theory. Participants rejected these inferences. We concluded that participants did not respond based on probabilistic validity, but that they did rate acceptable conclusions as more probable than unacceptable conclusions. We also showed that our results disagree with any known modal logic, which again shows the differences between revised model theory and (all sort of) logic. In a comment, Oaksford, Over, and Cruz (2019) criticized that we have misrepresented Bayesian rationality theory and this sort of inferences are anyway peripheral to the theory. In Hinterecker, Knauff, and Johnson-Laird (2019) we replied to Oaksford et al. (2019), but it is not necessary here to get down to fundamental level of this debate. The main point is that there is a productive debate between advocates of the different approaches and that it is possible to perform critical experiments and that the competing theories can thrive or fail in the face of their outcome. The ability to conduct such crucial experiments is a key feature of continuous scientific progress, not a sign that one paradigm replaces another (Lakatos, 1970).

Popper called this the “game of science” in which we accept some scientific propositions and reject others (Popper, 1934).

Continuity rather than revolution

It is, of course, not easy to say how dramatic a change in theory and experimentation needs to be to constitute a genuine paradigm shift. Perhaps the concerns raised about the current nomenclature are therefore somewhat exaggerated. However, this argument underestimates the importance of wording and the connotations that different terms have. One may think that “new paradigm” means “better” and “old paradigm” means “outdated“, but this wording does not reflect the state of art in the psychology of reasoning and can hinder the collaboration between different approaches and (therefore) progress in the field.

It is, overall, questionable, whether the Kuhn-style terminology can be applied to any era and field of psychology. Many authors have argued that it cannot and that even the “cognitive turn”, one of the most central turning points in the history of psychology, was not a paradigm shift in the Kuhnian sense (O’Donohue, Ferguson, & Naugle, 2003; Sturm & Gundlach, 2013). Moreover, Masterman (1970) points out that Kuhn uses the term “paradigm” in 21 distinct ways in *The Structure of Scientific Revolutions*. Later, Kuhn himself argued that there are reasons why some fields within the social sciences could not sustain extended periods of normal science (Kuhn, 1991). The best-known alternative to Kuhn theory is the theory of Lakatos (1970), in which scientific progress evolves in “continuities”, rather than in revolutions, in which one paradigm downturns another. It is certainly true that in the history

of a scientific discipline, different theories compete with each other. However, according to Lakatos, different research programs do not rule out that critical experiments are performed, that is, the programs are not incommensurable.

Indeed, there are many elements in the psychology of reasoning that look like continuities rather than a revolution: First, probabilistic theories coexist about a decade with model-based and logic-based approaches, each showing different advantages and disadvantages in explaining experimental result (Ball, & Thompson, 2017). Second, probabilistic and non-probabilistic programs, such as the model theory, are commensurable—as we have shown—and the different research programs contributed mutually to the further development of each. In fact, mental models theory and probabilistic theories both agree that “*logic is neither a theory of what conclusions individuals tend to draw nor a theory of how they draw them*” (Johnson-Laird, 2010, p. 218). This is an important point of agreement that is often overseen. The disagreement lies on the normative side. However, even here we can see an important point of agreement, which brings us to the third, and probably most important argument against a paradigm shift: both programs consider normative theories essential for understanding human reasoning. This is in sharp contrast to pure “descriptivism” that argues against the comparison of human reasoning with any normative standards of rationality (Elqayam & Evans, 2011). Indeed, classical model theory and the probabilistic program both compare answers of people to their respective normative theory, classical logic or Bayesian probability theory. In revised model theory, it is argued that in logic, conditionals and other connectives have a constant meaning, whereas in daily

life their meanings vary from one assertion to another (Quelhas, Rasga, & Johnson-Laird (2018, p. 2209). Hence, modulation is a crucial process and inferences in daily life have to be evaluated on their own merits (Khemlani, Byrne, & Johnson-Laird, 2018). Although this makes the norms for valid inferences fuzzier, the crucial point is that there is a “right” or “wrong” answer in both model theory and probabilistic theory. This is a central consensus of both programs in which both continue the tradition that is present throughout the entire history of the psychology of reasoning.

Future Directions and Challenges

In the last section, we have highlighted the continuities in the different research programs. Of course, there are still significant differences, which we do not want to hide. One of them is that a complete explanation of a cognitive function should cover different levels of description (Marr, 1982). Yet, probability theory currently has no “algorithmic level” explanation for how the mind computes probabilities. Advocates of the approach say that they are just interested in explanations on the “computational level”, whereas other programs see that as a grave shortcoming of the “new paradigm” and provide detailed cognitive modellings that reconstruct the mental representations and processes that underly many forms of human reasoning (Bara, Bucciarelli, & Lombardo, 2001; Khemlani, Byrne, & Johnson-Laird, 2018; Ragni & Knauff, 2013; Rips, 1994). Although this is a crucial difference, we think that it is nonetheless worthwhile to address some further issues where the establishment of further connections between different the programs are likely to promote progress in the field.

One topic where more cooperation is desirable is the connection between reasoning in domains about which people have substantial prior knowledge and domains where they do not possess such knowledge. We can hardly deny that one of the main achievements of the probabilistic research program was to direct researchers' attention more towards prior knowledge and subjective beliefs. This certainly helped to better understand how people reason in their daily life. Yet, a comprehensive theory of human reasoning should also account for abstract reasoning with unfamiliar materials. For instance, you can tell people "If there is a red ball in the box, then it is open. There is a red ball in the box" and people will be able to reason with this information, although they do not have prior knowledge related to these statements (see Gazzo Castañeda & Knauff, 2020).

Currently, the probabilistic approach is far from accounting for such forms of conditional reasoning, although it is at the heart of human intelligence to be able to reason from new information on which we don't have any prior knowledge. Deductive theories are much better in explaining these forms of reasoning that rely on our capacity to reason from mere hypotheses on highly abstract material for which no prior information can be retrieved from long term memory. So, how can the two programs be combined to explain reasoning with both familiar and unfamiliar content? Gazzo Castañeda and Knauff (2020) have suggested an approach in which reasoning with familiar conditionals can be predicted by conditional probabilities, whereas reasoning with unfamiliar conditionals is explained by the consideration of counterexamples, which lies in the core of model theory. In a similar vein, Verschueren,

Schaecken, and d'Ydewalle (2005) and Markovits, Brunet, Thompson and Brisson (2013) proposed to combine models and probabilities. Singmann, Klauer, and Beller (2016) explain probabilistic conditional reasoning by the consideration of both, prior knowledge and the logical form of an argument. Handley and Evans (2010) use supposition theory to explain human deductive reasoning. And Wolf, Rieger and Knauff (2008) found evidence for both the probabilistic approach and model theory when people revise existing beliefs in a conversational context in the light of new information. Such hybrid approaches are not in agreement with the alleged incommensurability of the different research programs, but rather demonstrate where both ways of thinking could be more fruitfully combined with each other.

Another issue for more collaboration is related to task instructions, experimental setups, and response format. Typically, probability theorists ask participants for the degree to which they believe in a conclusion and present them with a scale at which they can give graded responses. They usually also instruct participants “to reason as a daily life” and use problems for which participants have prior knowledge. In contrast, deductive theories often provide participants just two response options and ask them to ignore their prior knowledge and decide whether a conclusion is true or false. It is obvious that these different procedures can trigger very different reasoning strategies, and may bias people to react in exactly the way the researchers want to support their respective theories (cf. Markovits, Lortie Forgues, & Brunet, 2000).

To avoid such biases, our group has developed a novel response format in which participants can freely choose between a graded and a dichotomous response

format to evaluate conclusions (Gazzo Castaneda, Sklarek, Dal Mas, & Knauff, submitted). Do people really always prefer graded responses as suggested by probabilistic theories on reasoning? Our results show that the participants' choice was largely depended from the way they were instructed: under deductive instructions, almost all participants preferred dichotomous responses, whereas under probabilistic instructions most participants decided for the graded response format, although there was a considerable number of participants that even under this condition preferred the dichotomous response format. Apparently, such design decisions have a great influence on current discussions as they support one research program or another. More cooperation between the different research programs could free our research area from such counterproductive factors.

Another challenge for future research is to account more for the social character of reasoning. Currently, most of the research focuses on the study of individuals. However, in our daily life, we rarely reason alone. In our society, many essential decisions are made by groups of people who deal with collective problems of, and with, the group as a whole. Hitherto none of the existing reasoning theories have systematically studied the cognitive foundations of reasoning in interacting groups of people. We agree with Oaksford and Chater (2020), who emphasize the importance of research on argumentation, which has a genuine social character. For the model theory, people are victims of cognitive illusions when they find invalid arguments persuasive (Khemlani & Johnson-Laird, 2017). In contrast, the probabilistic program argues that

people appropriately change their degree of belief in a conclusion given the new arguments.

The direct connections of reasoning to argumentative fallacies is indeed one of the important achievements of the probabilistic program that other programs should also consider. However, even when studying argumentation, the probabilistic program still sticks to experiments with individuals and thus leave many important questions of social reasoning unaddressed. Some questions for future research are: How does the reasoning of groups differs from those of isolated individuals? How does the reasoning group put together the group members' individual conclusions to reach a joint conclusion? Can joint reasoning debias individual reasoning? Is group reasoning prone to other cognitive biases than individual reasoning? What kind of social conditions are conducive of rational group reasoning? Currently, there are some studies that included social aspects in their experiments, for example, by embedding premises in conversations (e.g., Demeure, Bonnefon, & Raufaste, 2009; Stevenson & Over, 2001; Wolf, Rieger, & Knauff, 2012). But there are only a few studies that measured reasoning in groups. One exception is from our group, where we investigated collaborative spatial reasoning (Reis & Knauff, in prep.). Other exceptions are the classical experiments by Laughlin and collaborators, who also studied logical reasoning in a cooperating group (Laughlin & Adamopoulos, 1980; Laughlin & Ellis, 1986), and Moshman and Geil (1998), who reported that that groups perform better than individuals in the Wason selection task. However, these experiments still leave most questions unanswered. What contribution can probabilistic approaches make

here? And which research programs can better explain the cognitive processes involved?

A further topic for future collaboration is relational and visual reasoning. Currently, most debates revolve around natural language conditionals and conditional reasoning. This narrowing of the research field on a very specific kind of inferences might have to do with the fact that here the competing research programs can best be compared. In relational reasoning, however, there is not such a disagreement on the underlying cognitive processes. Even proponents of the probabilistic approach have admitted that relational reasoning might be best explained by mental models (Oaksford, 2015). One of the most important findings in this area is that when there are a large number of logically equivalent mental models, the human reasoner often prefers one of the models and ignores others (Knauff, Rauh, & Schlieder, 1995; Knauff, 1999; 2013;; Rauh, et al. 2005). Within the mental models program, we have explained such preferred models with an approach that is similar to default logic, in which a conclusion is taken to be true as long as there is no contradicting evidence. However, it might also not be too difficult to develop a probabilistic account for such empirical preferences, in which one model is considered to be more likely than another based on background knowledge and prior beliefs. Such an account would certainly create further connections between model theory and the probabilistic research programs. In this context, it would be also interesting to see how the probabilistic program can account for the many experimental findings on the role of visualizability on reasoning. Some studies have shown that people make less reasoning errors if the

content of the problem is easy to visualize, whereas others have shown that visual mental imagery can impede reasoning (Knauff, 2013; Knauff & Johnson-Laird, 2002; Knauff & May, 2006). How the probabilistic program can explain such findings?

A final topic for future collaboration can be the neural correlates of the different programs. There are many findings on the neural correlates of deductive reasoning (e.g., Goel & Dolan, 2003; Noveck, Goel, & Smith, 2004; Knauff, Mulack, Kassubek, Salih, & Greenlee, 2002; Knauff, Fangmeier, Ruff, & Johnson-Laird, 2003). However, probability theorists have criticized the fact that the background knowledge and prior beliefs of participants have not been sufficiently considered in these experiments. Moreover, they argued that although these experiments instructed participants to reason deductively, they probably considered their prior knowledge anyway and engaged in defeasible reasoning (Oaksford, 2015). However, this camp of researchers has not yet carried out own brain imaging experiments to support these arguments. To take up their criticism, Gazzo Castañeda, Sklarek, Dal Mas, and Knauff (submitted) conducted an fMRI experiment in which conditionals with high and low conditional probabilities and abstract conditionals were used and participants either had to evaluate the probability of the conclusion or received deductive instructions. During brain scanning, participants who received deductive instructions showed elevated cortical activity in regions that can be associated with the inhibition of prior knowledge, while participants with probabilistic instructions showed activity in areas correlated with the retrieval of prior knowledge. Our interpretation is that people's consideration of prior knowledge and their preference for graded responses is not omnipresent. In fact,

people can flexibly activate or suppress background knowledge when they reason probabilistically or deductively. Again, this calls into question how meaningful and empirically justified the conflicts between the different camps in the psychology of epistemic rationality are.

Conclusions

Bernhard I. Cohen, one of the founders of the modern study of the history of science, defined several historical criteria for the attribution of a scientific revolution to a discipline (Cohen, 1985). First, the scientists involved in the development must perceive themselves as revolutionaries. Second, later historians must agree with this attribution. Third, later scientists working in that field or its successors must count it as a “revolution”. It is obvious that the “new paradigm” does not meet all of these criteria. This leads us to adopt the following statement from Nickles (2017):

With this view, Cohen excludes people who claim in their days to be revolutionaries, but do not know how sufficient their impact on the field is to sustain the judgment of history (Nickles, 2017).

Maybe Cohen’s criteria for a Kuhn-like scientific revolution set the bar too high. And we already have seen that the Kuhnian conception of progress in science might not be applicable to the psychology of reasoning. The main goal of this article was thus to provide a more pluralistic and conciliatory view on the current developments in the psychology of reasoning. Just as in many other areas of the cognitive and behavioral sciences, the great progress in the last decade of reasoning research has only been

possible based on the joint endeavor of different schools, research focuses, community, and so forth (Colombo & Knauff, 2020). It is certainly true that currently different theories compete with each other, and this is, in fact, inspiring for the field. However, we have shown that we still miss a clear definition of what the “new paradigm” is. As long as we do not have such a definition it is impossible to decide what falls inside and what falls outside this new research paradigm, and if it overall deserves this term. If it is just the departure from deduction, then almost all current research, including that from model theory, belong to the new paradigm. If it is Bayesianism, which would be the other extreme, then the definition is too narrow and thus not enough accepted in the community. It would be thus better to talk instead about coexisting, albeit competing research programs. Such a view has clear advantages. It makes the difference between the theoretical and empirical frameworks more explicit than the current nomenclature, which is more confusing than helpful. This, in turn, we hope, may also change the tone for how researchers address questions. And, most importantly, it points to the fact that the rival research programs have a common basis and are linked by a common “hard core” of shared commitments.

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