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Diagrammatic Representation and Inference

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Preface

The 12th International Conference on the Theory and Application of Diagrams (Diagrams 2021) was hosted virtually during September 2021. For the first time, Diagrams ran as an annual event, representing a departure from its biennial history. The driver for this change was two-fold. Firstly, the COVID-19 pandemic disrupted the delivery of Diagrams 2020 and the Steering Committee felt it important to provide a virtual event that would bring the community together. Secondly, strong submission and attendance numbers in recent years served as motivation for a possible longer term move to an annual event. Diagrams 2021 allowed such a change to be tentatively explored. Diagrams 2021 provided an opportunity for our global community to respond to these challenges and needs in creative and innovative ways as, we believe, is represented in this volume.

Given this historical context, the organizers were keen to enable wide access to the conference from across the globe. As such, registration was free to all delegates, with running costs being absorbed by an underwriting fund. In addition, the virtual nature of the conference was reflected in the program schedule: Diagrams 2021 adopted a novel approach that scheduled talks across the full 24 hour period on each day, enabling fair access to the conference for delegates all over the world.

Submissions to Diagrams 2021 were solicited in the form of Long papers, Short papers, Posters, and non-archival Abstracts. All submissions received three reviews by members of the Program Committee or a nominated sub-reviewer. A rebuttal phase was included to ensure that authors had the opportunity to respond to reviewer concerns. The reviews and rebuttals led to a lively discussion involving the Program Committee and the conference chairs to ensure that only the highest quality submissions were accepted for presentation. The result was a strong technical program covering a broad range of topics, reflecting the multidisciplinary nature of the conference series.

We would like to thank the Program Committee members and the additional reviewers for their considerable contributions. The robust review process, in which they were so engaged, is a crucial part of delivering a major conference. A total of 94 submissions were received across the Main, Philosophy, and Psychology and Education tracks. Of these, 16 were accepted in the Long paper category. A further 25 were accepted as Short papers, 4 as Abstracts, and 22 as Posters, of which 6 are non-archival abstracts. These contributions were complemented by the inclusion of five tutorials, covering a diverse range of topics of interest to Diagrams delegates.

Diagrams 2021 had five outstanding keynote presenters, who delivered a wide variety talks:

– Shaaron Ainsworth, Professor of Learning Sciences at the University of Nottingham: Why and How Should we Draw to Learn.
– Daniel Rosenberg, Professor of History at the University of Oregon: Mapping Time.

– Katharina Scheiter, Head of the Multiple Representations Lab at the Leibniz-Institut für Wissensmedien and Full Professor for Empirical Research on Learning and Instruction at the University of Tübingen: Learning From Visual Displays: Processes and Interventions.
– Atsushi Shimojima, Professor at Doshisha University: A Philosophical View of Fundamental Properties of Diagrams.
– Frederik Stjernfelt, Full Professor of Semiotics, Intellectual History, and Philosophy of Science at Aalborg University: Diagrams and Dicisigns - the Interrelations of Peirce's Doctrines of Propositions and Diagrammatical Reasoning.

These keynotes were complemented by an Inspirational Early Career Researcher Invited Talk. The invitation to deliver this talk was reserved for an active Diagrams researcher, within approximately ten years of their PhD, who has demonstrable potential to be a major leadership force within the community. We were delighted that Francesco Bellucci, Assistant Professor at the University of Bologna, accepted our invitation and delivered a talk on *What is a Logical Diagram?* at the Graduate Symposium.

There are, of course, many people to whom we are indebted for their considerable assistance in making Diagrams 2021 a success. We thank Mohanad Alqadah, Graduate Symposium Chair; Mikkel Willum Johansen, Publicity Chair; Petrucio Viana, Proceedings Chair; Amirouche Moktefi, Finance Chair; and Daniel Raggi, Local Chair. We also thank Richard Burns, for his help producing the Diagrams 2021 website, and Reetu Bhattacharjee for her support with the technical delivery of the conference. Our institutions, Jadavpur University, the University of Cambridge, Lancaster University in Leipzig, Deakin University, and Kyoto University also provided support for our participation, for which we are grateful. Lastly, we thank the Diagrams Steering Committee for their continual support, advice and encouragement.

July 2021

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Abstracts of Keynotes

A Philosophical View of Fundamental Properties of Diagrams

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I will discuss systems of diagrams that may seem ridiculously simple but, in my thought, have some of fundamental properties of more complex graphical systems. The properties in question are closely related to the potentials of free rides, over-specificity, and auto-consistency illustrated and analyzed in [1]. They were characterized roughly in the following way:

Free Ride: Expressing a set of information in diagrams can result in the expression of other, consequential information.
Over-Specificity: Expressing a set of information in diagrams can mandate the selective expression of other, often non-consequential pieces of information.
Auto-Consistency: It is not possible to express a certain range of inconsistent sets of information in diagrams.

In this presentation, I will offer a somewhat more general view of these properties, claiming that they all point to the existence of what may be called "proxy logics" in the diagrammatic systems in question. A proxy logic is a system of constraints that governs the arrangements of symbols and other elements in diagrams, to be distinguished from a "target logic" that governs the things represented by the diagrams. I will show that inference and comprehension that we perform with diagrams heavily depend on the soundness and completeness of the proxy logic relative to a part of the target logic.

This will lead us to the question how a diagrammatic system comes to be equipped with such a proxy logic. I will sketch an answer in the final part of my presentation. According to it, additional meaning relations hold in a diagrammatic system as logical consequence of its basic semantic conventions [1, 2]. Under these additional meaning relations, information is carried by properties of diagrams other than those designated in basic semantic conventions, and different ways in which these additional meaning carriers are related to basic meaning carriers are the basis of the proxy logic in that system and its correspondence with the target logic.

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Why and How Should We Draw to Learn

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In recent years, there has been increasing interest in asking learners to draw diagrams for themselves. When learners pick up a pencil and paper or move a stylus on a screen to create a visual representation (i.e. one that uses position and space meaningfully), they can enhance this understanding. This is true whether they are learning chemistry, fashion design or medicine and at all stages of education. However, to date, most (but not all) studies have focussed on a narrow range of pedagogical practices based upon a predominantly cognitive approach. In this talk, I want to join with others to argue that to move the practice of drawing to learn forward, we must develop a synthetic theoretical framework that understands learning at multiple timescales (from the millisecond to millennium) and levels (from the neuron to the society).

Taking this approach leads us to recognise that drawing diagrams is not an optional "nice-to-have" but is fundamental to the way people learn. New knowledge emerges when we engage in representational practices such as drawing, as expressing what we currently know in external forms recruits cultural, cognitive, and sensory-motor resources that develop our own and others' understanding.

This also invites us to notice that drawing can serve many purposes: for example, we draw to prepare, to observe, to remember, to understand and to communicate. We can draw many sorts of things - varying from a quick back of the envelope sketch to a particular diagram whose form we may have struggled to learn. We can draw at different points of the learning process, and sometimes we draw for ourselves, our colleagues or our instructors.

In this talk, I illustrate these purposes of educational drawing using lots of examples from diverse domains, address what successful drawing looks like in each case and what support learners might need. I will also consider several open questions, such as whether everyone can draw to learn and if there are certain situations where we should avoid drawing diagrams.

You are warmly invited to draw your response to this talk.

Learning from Visual Displays: Processes and Interventions

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In education, visual displays are ubiquitously used to teach students. Visual displays typically consist of multiple representations such as combinations of written explanations and illustrations (e.g., diagrams, pictures, animations, or simulations). I will refer to three potentials of visual displays for education, which are particularly relevant in many STEM domains: representing visuo-spatial information (visualization), enabling interaction with real-world phenomena (exploration), and augmenting phenomena beyond the observable (abstraction). To help students learn from visual displays, it is necessary to understand the learning processes that are linked to student achievement. In my talk, I will present studies that investigated said learning processes using eye tracking, log file analyses, and verbal protocols for different types of visual displays. A main finding of these studies is that learners often fail to apply effective learning processes spontaneously. Understanding these learning processes builds the basis for developing at least two types of support aimed at fostering their use: First, the design of the visual display can be optimized so that it will nudge students in applying helpful processes during learning. Second, trainings or processing prompts can be used to convey knowledge on learning processes and promote their application during learning from visual displays. In my talk, I will provide examples for both intervention approaches as regards their development and application in education.

Diagrams and Dicisigns: The Interrelations of Peirce's Doctrines of Propositions and Diagrammatical Reasoning

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Keywords: Diagrams · Propositions · Peirce

Famously, Peirce ascribed to diagrams a very central role in his philosophy and semiotics. Mathematics is possible only by the manipulation of diagrams and simultaneously, all deductive reasoning is taking place by means of diagrams. These ideas have a number of important implications:

1) Every investigation process involves a diagrammatic phase. In Peircean terminology, an abductive guess leads to an ideal hypothesis, more or less explicitly expressed in a diagram. [1] This diagram is subjected to manipulation, leading to a number of deductive implications of the hypothesis – theory development, if you so wish. Finally, these hypotheses are verified/falsified by the inductive sampling of evidence pertaining to them. Obviously, this general epistemology considerably generalizes the everyday notion of "diagram" [2].
2) This furthermore indicates that wherever, in the special sciences, in applied sciences or in everyday reasoning where deduction takes place, mathematical diagrams, simple or complex, are at work, more or less explicitly.
3) Some of such diagrams may remain implicit, in language, images, gesture, action, etc.

Reasoning, however, deductive or not, has to do with the truth-preserving derivation of *propositions*. How does that square with the claimed center role of diagrams? This paper makes the claim that diagrams form stylized iconic predicates of propositions. This is based on Peirce's less widespread theory of propositions – or "Dicisigns" – which is, importantly, multimodal. [3]) Much discussion of propositions in the analytic tradition is based on a tacit presumption that propositions are invariably linguistic, expressed in ordinary or formal languages. Peirce's doctrine of propositions differs here: it is purely functional, requiring of a proposition sign only that it fulfills the two functions of *denoting* some object and *describing* that same object. These functions may be satisfied by non-linguistic or partially linguistic expressions. Thus, when giving a basic example of a proposition, Peirce often picks "a painting with a label"; the painting serving the descriptive or predicative function and the label serving the denoting or referring function of the proposition.

In the light of this multimodal theory of propositions, diagrams in use are typically involved in propositions in the descriptive function. Stating some purported truth about some state-of-affairs, the denoting or referring function is indicated by the addition of subject indices to the naked diagram structure. In this analysis, diagrams are predicates, describing the detailed character of some structural property of the states-of-affairs under study. Doing so, diagrams may vastly transgress the linguistic limit of 3–4 subjects per sentence, and they add an indefinite increase in precision over merely linguistic predicates. [4] Simultaneously, they form the core of Peirce's version of what was later called "truth-maker" realism: real is that whose existence is presupposed by a true proposition. [5] Reality, then, is involved in three ways in true diagram propositions: 1) the diagram predicate describing some real structure; 2) the diagram subject indices pointing to the phenomenon possessing that structure; and 3) the diagram proposition as a whole depicting the real state-of-affairs described by the diagram and indicated by its indices.

This complex of ideas I shall present and discuss in the paper with a number of examples.

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