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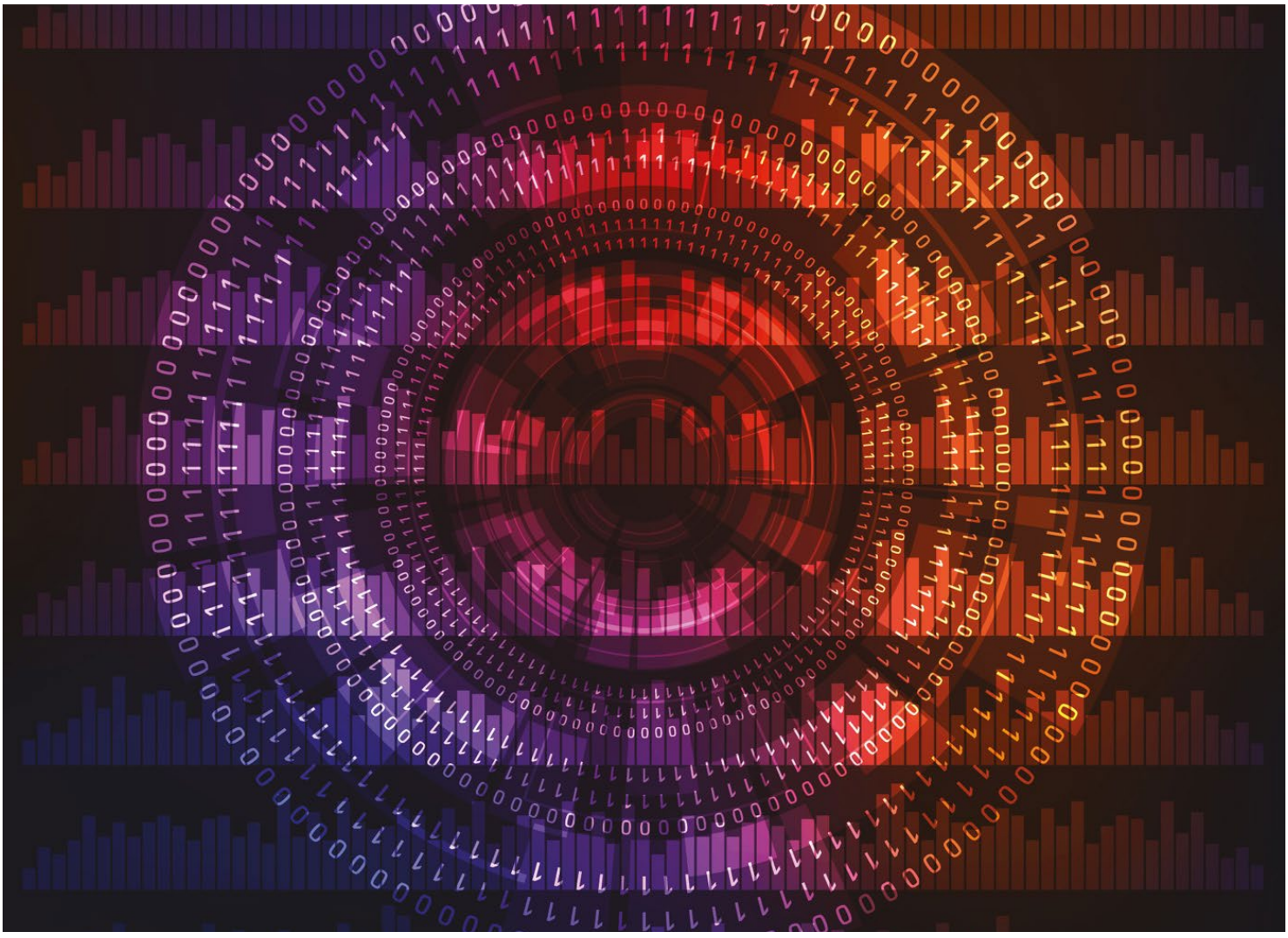
The Digital Turn in the Sciences and Humanities

White Paper



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The Digital Turn in the Sciences and Humanities
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www.dfg.de/en/research_funding/principles_dfg_funding/digital_turn/index.html

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1 Introduction

The ubiquitous and currently dynamic nature of digital technologies makes it necessary for the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) to engage systematically and on a fundamental level with the digital turn in the sciences and humanities. The purpose of this white paper is to present, from the perspective of the scientific community, the key consequences of the digital turn on research and the activity areas that arise for the DFG's funding activities and its advisory function to politics and society. In this paper, the term “digital turn” is used to refer to all relevant changes and effects of an epistemic, ethical, legal, technical, infrastructural, organisational, financial and social nature resulting from the development and use of digital technologies in the sciences and humanities.

In the DFG's view, the digital turn in the sciences and humanities, in spite of its many different effects, does not produce any fundamental change of the requirements of the scientific nature of research. Rather, it primarily comprises the emergence of new, digital research practices which need to be integrated, epistemically and otherwise, in the context of a given discipline.

The digital turn is not a phenomenon restricted to science; digital technologies and processes are relevant to all aspects of society and the economy. The ubiquitous use and development of digital technologies are changing the relationship between publicly funded research and other actors, for example global Internet companies. It is therefore crucial for the scientific community to seize the opportunities offered by the digital turn and actively participate in evaluating and tackling the diverse challenges, thereby following its own principles and interests.

In the future, scientific work in almost all disciplines will be significantly characterised by digital research practices and information infrastructures. The scientific community – researchers, research institutions and organisations, funding organisations and science policymakers – must therefore actively contribute to shaping future research practices and negotiating the basic framework. The changed basic framework transcends national borders, political agendas and previous divides between academic and non-academic research.

This white paper was endorsed by the DFG Senate in July 2020. It results from an intensive engagement on the part of the DFG with the many different effects of the digital turn on the sciences and humanities. It reflects the numerous interdisciplinary exchanges with researchers from all scientific disciplines and a designated expert committee.[1] Section 2 below describes the characteristics of the digital turn in the sciences and humanities, section 3 identifies the consequences on the sciences and humanities and section 4 highlights the activity areas of the DFG with regard to shaping the digital turn.

[1] www.dfg.de/en/research_funding/principles_dfg_funding/digital_turn/index.html.

2 Characteristics

The growing influence of digital technologies on the sciences and humanities can be summed up in two observations affecting all disciplines: firstly, a steady and rapid growth in research data, and secondly – closely linked to the first – a sharp increase in the use of software. In this paper, the term “digital technologies” encompasses not only data and software but also, for example, digitally implemented methods, algorithms, information infrastructures, forms of communication, and access and authentication processes. Digital technologies have critical implications for the preparation and implementation of research projects and the handling of research results.

Depending on the research question and specialist context, a project may involve accessing a large volume of research data – ranging from observation and measurement data from previous research to digitised text and image sources to big data on Internet communication. At the same time, research projects generate and leave behind enormous volumes of data which constitute an important component of the results and should be secured to ensure the traceability of the findings and, in many cases, to allow the data to be reused.

The fundamental importance of software is directly linked to the growing volume of data but also to the essential possibilities offered by the use of algorithms. Only with the aid of software can these enormous quantities of data be adequately exploited, from selection and preparation to analysis and visualisation. In many areas of research, all projects now use software-based methods for at least some work steps. There is also a rise in the number of projects that use simulations and modelling, taking advantage of artificial intelligence methods. In many disciplines, researchers develop relevant software themselves.

The professional use of software and research data depends on algorithmic and numerical thinking but also requires technical, organisational and legal knowledge. Here, this skills set will be referred to as “digital expertise”. Using digital technologies successfully in the various disciplines demands a combination of digital expertise and subject-specific knowledge and skills. Although the value placed on digital expertise may vary considerably in the different subject areas and depending on the research question, as a general principle the growing importance of digital technologies applies to all research areas.

In simplified terms, the effects of the digital turn on the sciences and humanities can be divided into three categories:

- **Transformative change** concerns the transfer of analogue information and practices to a digital form, for example the digitisation of texts, images and objects as well as processes for searching, collection and representation. This transformation is in many ways a necessary condition for the use of other methods.

- **Enabling change** is the use of data-intensive technologies to address research questions that could not be tackled in another form. Prominent examples can be found in omics, modern nuclear and particle physics, and astronomy.
- In **substitutive change**, digital technologies are used to support or even replace conceptual parts of the research process – for instance replacing experiments with modelling and simulation, generating synthetic data or using neural networks instead of prior hypothesis formation. Here, digital technologies result in a complete reorientation of the research approach.

Essentially, all types of change result in modified research practices, but what is actually decisive for the expansion of knowledge-building possibilities are the associated scaling effects (volumes, speed, complexity). In medical research, for example, the enormous increase in digitally recorded patient data, the ongoing development of imaging techniques and the use of self-learning algorithms are opening up brand-new research approaches. In biology, the increasing speed and power of digital analytical processes and the use of extensive datasets are adding spectacular new insights to our understanding of complex life processes.

One key characteristic of the digital turn is the simultaneous and in many ways apparently comparable use of digital methods (such as machine learning) across disciplinary boundaries and the enormous scale of this use in the sciences and humanities.

3 Consequences

3.1 Epistemic and ethical challenges

Digital technologies are not only a means to conduct research, but also a subject of research in various fields in which method research occupies an important place. These research approaches play a special role with respect to the digital turn in the sciences and humanities, creating an essential impetus for the use of digital technologies in other subject areas. Because of this significant value to other subject areas, method-oriented areas of research on digital technologies are referred to in simplified terms as “digital enablers”. The subject areas in which this kind of research often takes place include computer science and areas of mathematics, especially mathematical statistics and scientific computing. Other subject areas also make important contributions to digital method development, for example bioinformatics, computer linguistics and applied statistics.

In nearly all disciplines, the application of digital technologies requires digital expertise for quality assurance and the contextualisation of research results. If this expertise is lacking in a research project, there is a risk that important theoretical requirements will not be taken into account in the use of algorithms, making it difficult to anticipate errors and systematically question the robustness of one's own results.

This fundamental epistemic challenge is of particular importance to science given the simultaneity and scaling effects of the digital turn. In research practice, this challenge is magnified by the fact that digital methods are available in readily accessible and user-friendly forms through software implementations.

Self-learning algorithms represent a special case because in the data-driven research process new epistemic questions arise naturally with respect to the explainability of scientific findings. It was traditionally held that findings should, as far as possible, be understandable, traceable or verifiable by humans. The use of digital technologies, and particularly the scaling effects, are challenging this principle.

In spite of this, the scientific requirement for the traceability and reproducibility of results has not changed. It is not only the mere repeatability which is crucial, but even more so, the robustness of the applied methods, the quality of the underlying data and the documented configuration of the software used. This once again stresses the tantamount importance of both subject-specific knowledge and skills and digital expertise.

The requirements of scientific ethics are not essentially altered by the digital turn. However, in many disciplines the widespread availability and extensive use of research data make the need for solutions to protect privacy all the more urgent. Due to the volume and combination of data, it is becoming increasingly time-consuming and difficult to adequately verify the provenance of the data and their collection methods. The fact that digital technologies tremendously facilitate the

(further) processing of large volumes of data presents an additional challenge, as the workload involved in a critical assessment may be underestimated. However, a thorough review of the data basis including its often complicated processing history is essential in order to prevent adverse and undetected effects (up to and including discrimination against groups of persons) when new digital methods, such as self-learning algorithms, are used. In addition, in many cases the assessment of ethical aspects relating to the use of software to analyse large datasets has not become an established part of the research process in all disciplines yet. This includes, for example, risk assessment for automation and issues relating to assignment of responsibility (for instance in the case of machine decision-making).

3.2 Subject areas and their relationships

For science, cooperation between digital enablers and the disciplines in which digital technologies are applied (application fields) is the key success principle of the digital turn. This cooperation has led to enormous advances in knowledge and at the same time allowed new (method-driven) fields of research to arise and new cooperation structures to emerge. In spite of this, frequently conflicts of interest arise in joint projects, which often result from the different status of methods research for the cooperation partners.

In simple terms, digital enablers are often interested in methods research – developing or improving algorithms, for example – and less so in the application and adaptation of methods to address research questions in other disciplines. Conversely, in application fields there is a pragmatic attitude to the use of digital technologies and their adaptation. In all application fields there is a growing demand for digital expertise. This need is met in various ways: by awarding service contracts, by means of temporary collaborations with digital enablers or by developing the relevant skills autonomously. This development can fundamentally transform the repertoire of methods and potentially also the way in which a particular subject area views itself.

In this way, the simultaneity and scale of the use of digital technologies have a systemic effect on the relationships between subject areas, with the result that the digital turn operates as a new and additional factor on the internal differentiation within the sciences and humanities. Over and above individual research projects, this has implications for organisational and institutional structures as well as for the funding and financing of research.

3.3 Effects on employment and social dimensions

The digital turn increases the need for specialist knowledge in the development and application of digital technologies. Complex projects can only be carried out through divided responsibilities and collaboration between individuals with different areas of expertise and complementary skills. This applies generally to every joint research project but it is amplified by the digital turn in the specific sense that cross-disciplinary digital expertise is required.

Linked to this are social aspects of an individual's role and status, particularly reputation, recognition and authorship. Such social differentiation can already be observed within the research system (including new professional roles such as research software engineer, data scientist and data librarian). In addition, some shifts between academic and non-academic research have taken place, which can be seen in the competition for professionals with digital expertise on the labour market. In many cases, the enormous demand for professionals currently leads people to move to the private sector. In some cases this happens even before people finish their PhDs, as academic training loses attractiveness compared to well-paid employment in industrial research.

Therefore a key challenge is to train research staff and create more favourable conditions to encourage them to remain in academia. This includes establishing adequate processes and structures for performance recognition and reputation for professionals with digital expertise that make a decisive contribution to the success of research projects.

3.4 Effects on research practice

Given the key role of data and software in research practice, it is vital that researchers themselves develop and establish science-driven quality criteria and quality assurance mechanisms.

The scientific value of data, like the appraisal of its quality, depends on the disciplinary context and the research question. Since digitally stored data can in principle be used multiple times and in different contexts without loss and may originate from very different sources – including non-scientific sources – a scientific evaluation is always necessary. A consideration of quality criteria and the establishment of standards to describe research data (metadata) must therefore form an integral part of research practice.

The same applies to the use of software in research projects: particularly the combination of data and software must be taken into account in scientific quality assurance. For the development of research software, scientifically suitable quality criteria and methods must be formulated and applied, ensuring sustainability after projects and PhDs have been completed.

Researchers can only make optimal use of the opportunities offered by the digital turn when data and software can be used in a cohesive, effective and organisationally and financially sound work environment. Such a digital work environment comes with extensive requirements, ranging from the local workstation to the university computing centre and the global repository.

Essentially, the current challenges associated with the digital turn in terms of enabling excellent research practice are:

- Given that **access to data and software** are of central importance to science, comparable to publications, data arising from research should be made accessible in line with the FAIR principles, unless there are ethical or legal reasons not to do so. It is equally relevant that, wherever possible, software too is findable, freely usable and documented for researchers

on an open source basis. In many cases the prerequisites for this are not in place, as the challenge lies in the subject- and context-specific regulation and implementation of access (e.g. multilevel access rights, embargo periods).

- The **digital infrastructures** essential to research must be built for long-term service while allowing rapid adaptation to technical changes without losing reliability, security or stability. This will require new organisational and responsibility structures (e.g. in computing centres, data centres and libraries), including the sustainable use of energy resources (green IT). It is characteristic of the digital turn that the conventional division between providers and users, or between service functions and research, no longer fully applies. In many cases, close cooperation between information providers and applied and knowledge-oriented research is vital in order to develop new digital technologies and build the infrastructural foundation required to ensure accessibility and usability.
- The digital turn in the sciences and humanities is associated with enormous **financial challenges** which far exceed the time-limited possibilities of third-party funding. These range from the longer-term and joint funding of national and international digital infrastructures to the funding of staff with digital expertise in research and infrastructure projects. Digital services from commercial providers also come with a significant cost element (e.g. the acquisition of data and software). The financial exigencies and dependencies that this produces have already been evident for some time in the publishing sector (the licensing model for published products). Similar effects can also be seen, however, in services which, although only indirectly linked to research projects, have an important practical everyday function and therefore have systemic effects – for example research information systems and academic social networks.
- The use of digital technologies in research always requires the **clarification of legal questions**. Some legal issues, especially those touching on the use of (personal) data and software, have already been clarified in principle, but the needs of science are not always addressed with such precision or sufficient concreteness as to allow legal requirements to be implemented easily and unambiguously in research practice. The use of digital technologies also gives rise to new legal questions, resulting not least in a considerable need for research and structuring in legal scholarship. With the rapid progress of technical developments and their relevance across the full range of disciplines, there is a growing need for action. Within the existing legal framework, it must be ensured that legal aspects at the level of individual research projects are better understood, respected and regulated. In this respect, social practices are as relevant as the legal requirements.

4 Activity areas of the DFG

The DFG's most important aims are to support knowledge-driven research, the best minds, and cooperation within the sciences and humanities. As the central self-governing organisation and largest funding institution for the sciences and humanities and research in Germany, it is able to support and help shape the digital turn in manifold ways. The DFG has already been using this opportunity for some time, partly in cooperation with its partner organisations in the Alliance of Science Organisations in Germany.[2]

In recent years, the DFG has promoted dialogue on the digital turn in the sciences and humanities and created additional, specific funding options (including topic-specific calls on Next Generation Sequencing, Research Software Sustainability and Artificial Intelligence) in a science-driven discussion process. The recently adopted new version of the *Guidelines for Safeguarding Good Research Practice* (2019)[3] also incorporates specific aspects of the digital turn.

In the future, the following six core concepts are central to the DFG's approach to the co-design of the digital turn in the four key activity areas described below. The DFG will

(1) work to ensure that scientific principles continue to prevail within the framework of the digital turn;
(2) reinforce the importance of knowledge-driven research to society to advance digital technologies as well as to critically reflect on and evaluate its impacts on society;
(3) intensify its efforts to communicate the science-specific opportunities and challenges of the digital turn;
(4) examine opportunities to participate in the longer-term funding of system-relevant digital tools and infrastructures;
(5) promote research-oriented training and professional development to strengthen digital expertise in the sciences and humanities;
(6) promote greater cooperation and permeability in relation to industrial research to make knowledge-driven research more attractive to professionals with digital expertise.

4.1 Activity area I: Subject-specific and interdisciplinary discourse

The consequences of the digital turn for research practices and scientific cooperation outlined above require a continuing, intensive subject-specific and interdisciplinary discourse. This science-driven dialogue is crucial to the evaluation of developments, the exploitation of opportunities and the overcoming of challenges. The DFG will use existing formats (roundtable discussions,

[2] E.g. through the Digital Information Initiative: www.allianzinitiative.de/?lang=en.

[3] www.dfg.de/en/research_funding/principles_dfg_funding/good_scientific_practice/index.html.

symposia, networks and initiatives) to effectively support this discourse. The topic areas below are of particular urgency:

- Development and quality assurance of digital methods;
- reflection on digital research practices, including new ways of working and publishing;
- subject-specific perspective on digital aspects of good scientific practice;
- fundamental reflection on ethical questions in relation to digital technology;
- clarification of requirements for the legal framework in the digital turn;
- enhancement of digital expertise in the sciences and humanities;
- strategic discussions on the relationship between knowledge-driven research and industrial research with a special focus on the development of digital technologies.

4.2 Activity area II: Statutory bodies and expertise at the DFG

To clearly establish the relationships between the effects of the digital turn and the basic frameworks of research, the DFG's bodies must be able to give advice on essential aspects of the digital turn on a regular basis and with due regard to current requirements. This will also assist with preparation for political advisory processes, enabling the DFG to better represent the interests of the scientific community and be more effective in its advisory role to politicians. The DFG therefore intends

- to establish a long-term discourse on the digital turn with the review boards;
- to strengthen professional expertise in digital technologies on its advisory and decision-making bodies;
- to set up appropriate processes for DFG bodies to engage with the relevant topics and to further develop funding offers.

4.3 Activity area III: Funding requirements and conditions

The growing importance of digital technologies is creating new needs for cooperation in research projects, changed performance expectations and roles, but also potential conflicts of interest between digital enablers and application fields. The DFG will therefore examine the possibility of adapting its funding programmes in order to better satisfy the needs of the sciences and humanities in the context of the digital turn. This specifically applies to the following aspects:

- Definition of requirements relating to the handling of research data and research software in funding;
- further development of criteria and processes for the review and evaluation of research projects and research achievements in order to take better account of digital expertise,

digital method development, novel project configurations, publication forms and forms of research practice;
- improving opportunities for cooperation between academic and industrial research in the development of digital technologies.

4.4 Activity area IV: Funding offers

In addition to previously launched funding initiatives, the DFG will push forward the flexibilisation and expansion of existing funding opportunities to better satisfy the needs of the sciences and humanities within the framework of the digital turn. Incentives in particular areas of research can be developed through the use of specific calls for proposals and ongoing opportunities in the funding portfolio. These incentives will further strengthen the development of digital methods and foster open access to the products of scientific research (publications, data, software). This includes the following:

- Impetus through calls relating for example to the quality-assured development of digital methods, to research software and to digital infrastructures;
- expansion and flexibilisation of existing programmes for the promotion of research software sustainability and for the curation of research data;
- examination of longer-term funding opportunities for system-relevant digital tools and infrastructures;
- expansion of funding opportunities to develop digital expertise;
- introduction of measures to increase the attractiveness of a scientific career for staff with digital expertise;
- upscaling of advisory activities and monitoring for digital research projects.

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