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GE HEALTHCARE
SPECIAL SUPPLEMENT

Cover Story:

The Future is Digital

The Digitalisation of Healthcare

Summary: Where can digitalisation in healthcare be applied to yield quantum leaps in efficiency, cost-savings, patient safety and care quality?

Almost no other area in healthcare offers so much potential for increasing process efficiency, for improving medical quality as well as patient safety, and finally, for achieving sustainable economic success, as digitalisation.

In particular, applications in the area of quality assurance, knowledge management, Operation Theatre (OR) management, supply-chain management and precision medicine contribute toward process efficiency. Furthermore, digitalisation offers disruptive strategic opportunities in providing medical services globally. Mayo Clinic has announced that it will serve more than 200 million patients annually worldwide in 2020 (Dacy and Olsen 2014) through deployment of smartphone technology, internet communication and telemedicine.

Functional Areas of the "Digital Revolution" in the Healthcare System

Medical services are provided in processes that are subject to the division of labour as well as inter-sector care networks. Digital technologies enable need-oriented solutions and the provision of preventative, clinical and rehabilitative services. In three areas, it becomes evident what impacts forms of treatment, care concepts, the image of the medical profession, and the role of patients: digital health, big data and 3D printing technology. Considered in terms of IT strategy, these areas relate to the opportunities for formulation of hospital processes subject to the concept of "hospital 4.0." New diagnostic and therapeutic approaches are developed with the support of IT management in the context of a "precision medicine" approach.

Digital Health

Digital health refers to the integration of medical knowledge with IT applications or IT technologies, with the aim of improving the medical care and supervision of patients. By doing so, it is possible with a smartphone to determine, round-the-clock, whether a patient has taken prescribed medications, as well as monitor vital data, (pulse, blood pressure, oxygen saturation) and it is also possible to determine through body temperature and movement patterns, whether a patient has fallen down in the home.

Digital health technologies should contribute to the following:

- The elderly being able to remain longer in their familiar social environment, instead of moving to an old age home/care home.
- Enhanced compliance of the therapeutic behaviour of patients.
- Avoidance of unnecessary hospital admissions.
- A prevention-oriented way of life.

In this area, a market worth billions has developed in which players are now investing, who were not previously present in the health area (Apple with its health-monitoring watch and Google with contact lens with glucose monitoring function).

This market for digital health has revolutionised business models in the area of health insurance, as well as those related to organisational forms of medical care, and have also changed the role/relationship between doctor and patient. This is demonstrated by the introduction of an early warning system for heart patients after a pacemaker or defibrillator implant. The CardioMessenger system for a remote domestic monitoring of arrhythmia patients contributes to avoiding unnecessary hospital admissions as well as reducing the treatment cost of patients by approximately 10%.

The savings potential through digital health is estimated at billions - particularly in the area of medication management.

Digital health applications (such as acoustic reminder functions for taking medication at the right time) can contribute to raising therapy reliability as well as enhancing a prevention-oriented lifestyle (eg through glucose monitoring, or movement control).

The digital health card is another example of digital health application.

The savings potential through digital health is estimated at billions - particularly in the area of medication management

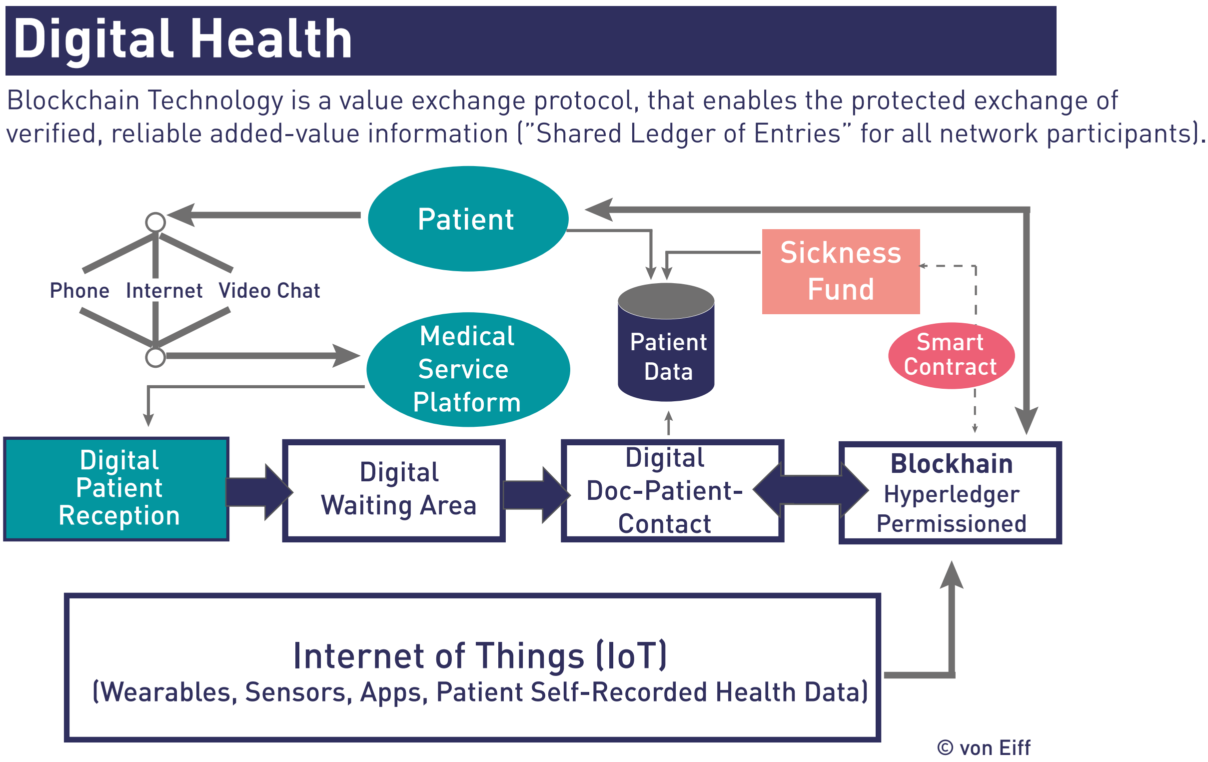

Figure 1: Digital visits and the associated data streams

The advantages of electronic health cards can be summed up as follows:

- Increased patient safety through (automatic) reaction control (interactions) with newly prescribed medications (integration of regulatory software).
- Reduction of treatment costs of patients (avoiding duplicate examinations).
- Goal-oriented, medically appropriate treatment through the availability of laboratory findings, knowledge of previous illnesses, visual data from MRT, CT, US, OCT, etc and process controls of important parameters (HbA1c-values, left-ventricle function, blood pressure).
- Rapid availability of second opinions from specialised medical centres.
- Declining costs through a direct accounting system between doctors, pharmacies and hospitals (estimation: approximately €200mln per year) (Müller 2017), through avoiding insurance fraud (picture of insured on the card; estimation: €1bln a year) (Statista 2018). In total, experts assume that savings through electronic health cards (EHC) in the health system are achievable, which could lead to a reduction in member contributions to a level of 3.7 percentage points (Arthur De Little 2013).
- The costs of the EHC-introduction are estimated at €1.5 bn Euros (Krüger-Brand 2006).

In a digitalised "Continuum of Care," medicine comes to the patient, which is enabled by smartphone technology in combination with the telemedical infrastructure and leads to a change in the doctor-patient relationship. The Medgate approach is a good example (see Figure 1), which, via the Internet, provides the patient with the option to come into contact with an appropriate doctor for his or her particular complaint and to make an appointment directly, as well as to receive medical treatment through a teleconsultation. During this teleconsultation, health data, including that provided by the patient (eg through Apple Watch) as well as data from the Internet of Things (Home Care Monitoring), is integrated. All data is saved securely by means of Blockchain technology. Through a "Smart Contract" function, the hospitals receive the accounting data derived from the treatment data.

Big Data

Big data, ie dealing in a structured manner with large quantities of data, makes it possible to derive information that is relevant for decision-making purposes. This can then generate goal-oriented knowledge in the shortest possible time for use in a problem-oriented and problem-solving manner.

Because of its use so far for military, secret-service or economically-oriented applications, the concept of big data tends to have a negative connotation. In the same manner, big data technology enables the development of patterns of buying behaviour of shoppers in supermarkets or book purchases from Amazon, for example.

3D - Printing-Technology

3D-Printing-Technology makes it possible to build up three-dimensional work pieces made of fluid and/or solid material.

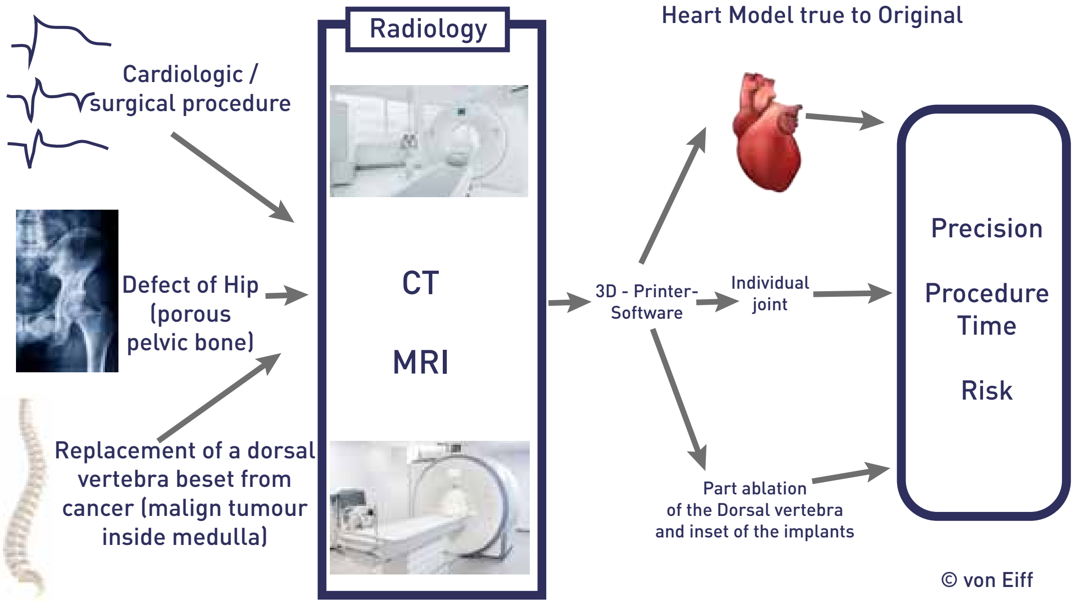

Figure 2: 3D-printing technology supports individual therapy approaches

Hospital IT Management

The Hospital Information System plays a pivotal role to ensure an Integrated IT Infrastructure

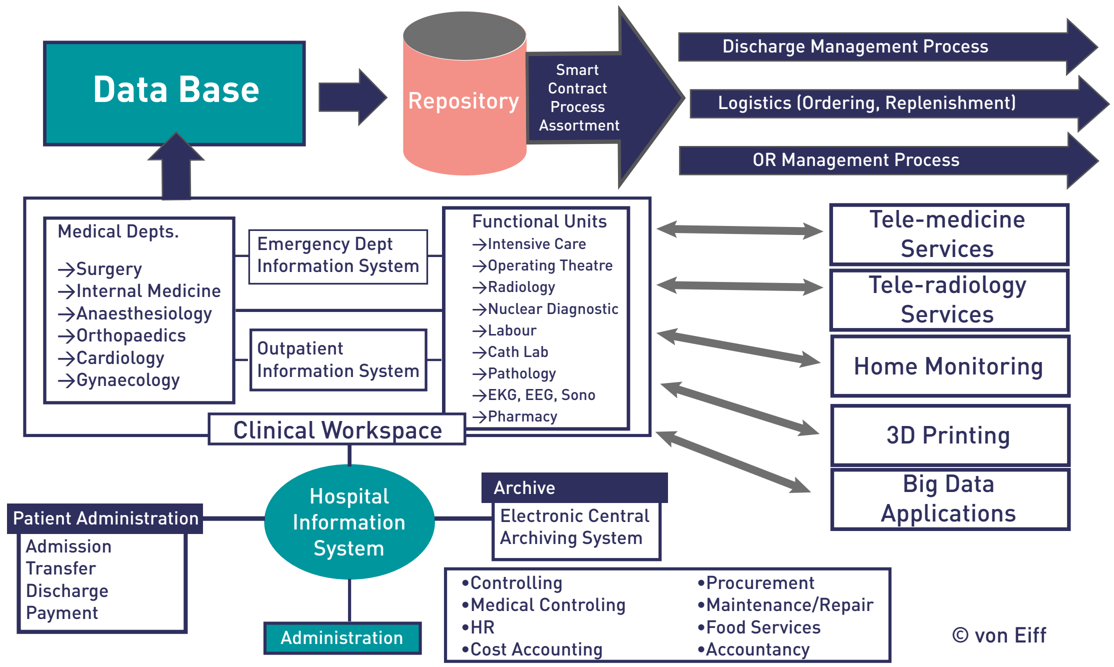

Figure 3: The clinical workplace and the central data base have a capstone function in the digitalised hospital 4.0.

In the field of medicine, big data applications aim at:

- Raising the precision of diagnostic practice.
- Shortening the period between primary diagnosis and therapy.
- Raising therapeutic precision.

Particularly in the area of tumour diagnosis and tumour therapy, the advantages of big data become evident. For example, in order to provide a genetic sequence for the purpose of analysing the genetic material of tumours within 24 hours, as well as comparing tissue samples within a maximum of two days, it is necessary to use superfast computers. These, by means of an effective method of data compression, generate a variety of molecular biological information for generating goal-oriented knowledge.

The potential for personalised medicine (precision medicine) can only be exploited partially without the use of big data technologies.

3D Printing Technology

A 3D printer is a device for creating three-dimensional works (models, bodies, organs), which are computer controlled and made out of liquid or solid materials (synthetic materials, synthetic resins, ceramics, metals). 3D technology enables the development of complex forms, although for their manufacture, no forms are necessary and the manufacturing process proceeds without material loss, because no materials are wasted in the process (screwing, drilling, milling or cutting).

3D models are useful in medicine in order to obtain a precise understanding of the anatomical particularities of an individual patient with the aim of preparing for complex operations. The production of a model (eg heart, hip, arteries), proceeds on the basis of MRT and CT data, which by means of special software is converted into a 3D model and produced by means of a 3D printer. In this manner, tailor-made, individualised heart valves, jaws, hip implants, etc can be manufactured (see Figure 2). Examples of applications are already very convincing:

- Accordingly, there is a report of the splinting of a tracheobronchomalacia of a 20-month-old baby (University of Michigan) with the aid of a bioreabsorbing splint.
- As well as the production of individual prostheses sockets in the context of leg amputations in Uganda.

The application of 3D printing technologies (see Figure 2) offers in the field of medicine a series of qualitative and economic advantages.

In the orthopaedic area, the technology enables individual implants from 3D printers with the following effects:

- Shortening of operation time.
- Reduction in after-care and convalescence time.
- More effective functioning of implants.
- Dispensing with adhesive material (cement, screws, external fixators) in the replacement of cancerous vertebrae.

Also, for heart, vascular and neurosurgery, 3D printer models enable a precise preparation for complicated operations. Roughly 1.5-5% of the population develop an aneurism over the course of their life, in the form of a ventricle aneurism (heart wall aneurism), in other words a bulge in the heart wall as a result of the thinning of the wall tissue. Through the sack or spindle formed extension of the heart wall, the danger arises that these sack-like bulges can burst, which, for example, in the case of an aneurism in the head, can lead to death. Accordingly, an intervention is necessary. The size and location of the aneurism determine choice of therapy. Such interventions are, however, far from standard operations because each aneurism has a different structure. A working group from Hamburg presented at the annual meeting of the German Society for Neural Cardiology a method of creating original and accurate models of individual aneurisms on a 3D printer. On this basis, it is possible to test in advance which therapy is the most promising. Complicated operations can then also be tested on this model. At the Research Centre for Medical Technology in Hamburg, as well as in the Clinic and Polyclinic for Neuroradiological Diagnostics and Intervention at the UKE Hamburg, researchers have developed a method for creating and manufacturing models of aneurisms through the 3D printer. Accordingly, the method can enable cost-effective, accurate and realistic replications of individual brain aneurisms of a specific patient, which can contribute substantially to therapy planning. The models can be used in order to determine which interventions should be used, because they can also simulate the passage through the aneurism. In addition, the exact placing for example of a platinum spiral (coil) can be simulated, and thus optimised, and finally, the operation can be rehearsed in advance.

The models may also be suitable for testing new medical products. Already, in Hamburg, the 3D models are being used for therapy planning in the context of complicated aneurisms. In a few years' time, in the view of the Hamburg researchers, all patients with complex aneurisms should benefit from this innovation.

The future vision is the production of body tissue and organs. On this basis, 3D technology will raise a series of ethical, medical, as well as economic and legal questions.

POCT Technology

The critical elements of point-of-care testing (POCT) are rapid turn-around and communication of results to guide clinical decisions and completion of testing and follow-up action in the same clinical encounter. On the one hand, POCT is represented by laboratory tests directly determined at the bedside, in the emergency department, in the OR, and in the intensive care unit conducted by non-specialised hospital staff by using user-friendly technologies eg transportable handheld instruments and small bench analysers. These tests refer to rapid cardiac markers (troponin) inside the ED, infectious disease testing

(MRSA, Chlamydia, Clostridium difficile), blood glucose monitoring (bedside or at home) and faecal occult biood analysis among others. On the other hand, the concept of POCT has gone beyond its use in laboratory services to also encounter technologies like ECG pulse oximeter, ultrasound and echocardiography based on smartphone devices (Lumify), and patient data management systems (PDMS) as well as physician order entry systems whereby diagnostic results were presented electronically to the physician at the point of care. POCT devices contribute to enhanced clinical quality, higher patient outcome, more efficient use of resources and reduced costs.

Artificial Intelligence (AI)

AI (including the subclassifications machine learning and deep learning) in healthcare is the use of complex algorithms and software to emulate human cognition in the analysis of complicated medical data or of complex medical interactions in the human body. AI technology is able to gain decision-relevant information out of complex systems and recognise patterns in behaviour by using machine learning algorithms.

One aim of health-related AI applications is to analyse relationships between prevention, diagnostic or treatment techniques and patient outcomes. Furthermore, AI programmes are used to improve diagnostic procedures, to develop treatment protocols (eg in cancer therapy), and to personalise medical regimes. Also in medication management, AI applications contribute to enhanced patient safety, higher effectivity of therapy and cost containment when using algorithms to identify drug-drug interactions.

Using AI software in the medical area of imaging a lot of different applications will be common in near future. These include:

- The X-ray of a hand can be combined with an automatic calculation of the bone age.
- Skin cancer could be detected from images more accurately (detection rate 95%) by an AI software than by a dermatologist (detection rate 86%) (Esteva et al. 2017).
- AI-based thermography to detect breast cancer operates as follows:
  - works without any exposure to radiation,
  - happens without any body contact and therefore is a non-invasive and painfree procedure,
  - is a low-cost application,
  - is highly sensitive in detecting cancer in a very early stage of illness, also in women under forty years old and
  - detects the tumour before a lump is palpable.

Hospital 4.0

The digitalised Hospital 4.0 is characterised by four main elements:

- Realtime communication about clinical and administrative data between clinical workplaces, medical controlling, purchasing and logistics, as well as the finance and personnel departments. This communication takes place without media disruptions, is error-free and does not require any additional organisational or improvised coordination aspect.
- Intelligent process-organisation according to the principle "End-to-End," that is, without trigger-actions from people in order to set the process in motion or to complete the process.
- Digital networking through the Internet of Things, Internet of Services, expert knowledge and the use of the "Wisdom of Crowds.
- Orientation around the management philosophy of a "value orientation and patient-centredness in the provision of health services."

Hospital Management 4.0 is achieved when the four "4.0 elements" in all care processes that are necessary and relevant for patient care have been established comprehensively. Hospital Management 4.0 contains "procurement management 4.0," "personnel management 4.0," "OT management 4.0," "imaging management 4.0," etc, and connects all of these subdivisions so that they are oriented towards the processes. Accordingly, each process is characterised by action, implementation, information and decision-making components and these elements are networked according to the processes in question.

Results and Insights

Digitalisation through its main emphases on big data, digital health and Hospital 4.0, opens up new potential for the organisation of medical care processes, but there are limits to their application:

- Economic success and medical quality arise through optimal process organisation, which in turn, requires effective IT management.
- Personalised medicine is only achievable to a limited extent with effective big data management.
- Change Management emerges as a success factor.
- Insights from the area of Behavioural Medicine must certainly be taken into account in formulating concepts for the organisation of health services.

In the future, digital health networks and telemedical forms of care will determine both medical quality as well as the economic viability of a health system.

The "clinical workplace" (see Figure 3) constitutes the core of a hospital IT-system. This is a component of clinical information systems, which contain clinical patient data, which is interrelated in terms of content and function and ensure the link to specific externally oriented services (eg second-opinion procedures via teleradiology, the monitoring of arrhythmia (irregular heartbeat) patients via home monitoring, big data analysis through a timely reading of genetic sequences). The integration to patient administration, archives and business-related as well as logistical data rounds off a comprehensive

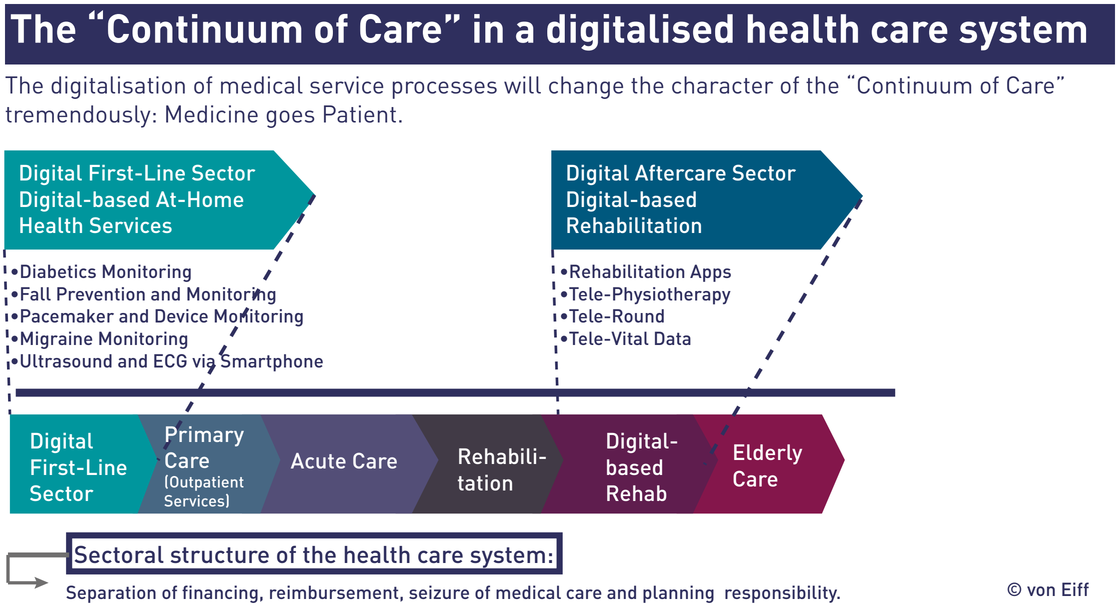

Figure 4: Digitalisation results in a new virtual sector in the health system.

hospital information system.

The "digitalisation of healthcare" will contribute to relieving medical service provision from routine tasks (Smart Contract Function) and improving the precision of diagnosis and therapy (precision medicine, theragnostic, big data). Additionally, it will support promotion of the application of Point-of-Care Testing Technologies (POCT) in all areas of the health system (primary care, emergency care, acute treatment, rehabilitation).

A new healthcare sector will be developed: The First-line Digital Sector (see Figure 4).

This is characterised by teleconsultation, telemonitoring and an intensive use of POCT, applied particularly to patients at home.

Accordingly, patients will be able, within the privacy of their own homes, to be monitored and cared for medically, without having to leave their familiar social environment. In this manner, not only will unnecessary hospital admissions be avoided, but also the sector will be relieved of completely hospital-based stationary care. This greater patient autonomy is, however, based on increased patient compliance in order to ensure appropriate and optimal medical results.

Bottom-line: there is a new basic principle in providing health services: virtual services first, GP/outpatient services second, acute care services and third, the smartphone will become the stethoscope of the 21st century.

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Key Points

- Digitalisation will leave no healthcare area untouched.
- Effective deployment of technology will lead to a sustainable system through improvements in efficiency, care quality and cost savings.
- Big data, POCT technology and 3D printing are contributing toward better healthcare.
- Eldercare will benefit from integration of technology through remote home monitoring.

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