Chapter 8
A View of Causation for CSCW: Manipulation and Control in the Material Field of Work

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In this chapter, we attempt to achieve a better understanding of how cooperative work is partly accomplished by virtue of the actors' manipulation and control of causal relationships central to their material field of work. Previous CSCW studies have *not* focused extensively on causation in cooperative work (e.g. see Schmidt and Bannon 2013). Consequently, it is a challenge to find a conception of causation appropriate for the study of cooperative work. This chapter addresses this challenge.

Inspired by manipulability conceptions of causation (e.g. Gasking 1955; Pearl 2009; von Wright 1971; Woodward 2003), we focus on causal relationships in the material field of work that are potentially exploitable for purposes of manipulation and control by the cooperative actors. This is a practical approach to causations with human agency at the centre – often we find that cooperative actors are focused on causation in order to change some feature of their world.

Our empirical data originate from two studies of cooperative work, namely, a study of chemotherapy and a study of the building process. The first study shows that in chemotherapy the actors are manipulating and controlling the causal relationship between drugs and cancer cells. The second study of causation shows that actors in the building process are engaged in understanding and manipulating the causal relationships between the building in the making and the forces of nature. Combined, the two studies point to the centrality of causation in cooperative work. More precisely, the cases show that the cooperative actors are systematically engaged in understanding, manipulating and controlling causal relationships making up their material field of work.

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Broadly speaking, the chapter may be said to address the elusive yet core CSCW problem of characterising the actors' engagement with *materiality* in cooperative work. Analysing how actors manipulate and control causal relationships central to the material field of work is part of this.

We will proceed in the following manner. First, we will discuss causation theory with the purpose of substantiating an approach appropriate for CSCW. Second, we will analyse causation in, respectively, chemotherapy and the building process. Finally, we will discuss our findings and their perspectives for CSCW.

8.1 A View of Causation for CSCW: Manipulation and Control

According to Cartwright (2007), causation is not one monolithic concept, nor is there one single phenomenon – the 'causal relation' – that underpins the correct use of that concept. There are a variety of different kinds of relations pointed to by the abstract term 'causes' and a variety of different – correct – uses of the term for a variety of different purposes. The variety of theories of causation provides one of the major reasons in favour of this plurality view. Each theory or approach seems good for one sort of examples or phenomenon and not others, each theory seems to be good at illustrating the phenomenon selected, but each has counterexamples and problems (Cartwright 2007, p. 44).

Here are some of the key contemporary theories and their major proponents[1] (the list is adapted from Cartwright 2007, p. 43):

1. *Probabilistic theory of causality* designates a group of theories that aim to characterise the relationship between cause and effect using the tools of probability theory. Interpreting causation as a deterministic relation means that if A causes B, then A must always be followed by B. In this sense, war does not cause deaths, nor does smoking cause cancer. As a result, many turn to a notion of probabilistic causation. Informally, A probabilistically causes B if A's occurrence increases the probability of B (e.g. see Spirtes, Glymour and Scheines 1993; Suppes 1970).
2. *Process theories of causation* are based on a distinction between causal processes and noncausal processes. Crudely put, these approaches often distinguish between a process and a pseudo-process. As an example, a ball moving through the air (a process) is contrasted with the motion of a shadow (a pseudo-process). The former is causal in nature, while the latter is not according to this view (e.g. see Dowe 2000; Salmon 1984).
3. *Counterfactual accounts of causation* harbour the basic idea that the meaning of causal claims can be explained in terms of counterfactual conditionals of the form 'if A had not occurred, B would not have occurred' (e.g. see Hendry 2009; Holland and Rubin 1988; Lewis 1973).

[1] It is beyond the scope of this chapter to review these theories in full; please see, for example, Cartwright (2007) for an excellent treatment of the subject.

4. *Manipulability notions of causation* focus on causal relationships that are potentially exploitable for purposes of manipulation and control: roughly, if A is a cause of B, then if I can manipulate A in the right way, this should be a way of manipulating or changing B. This is a practical approach to causations with human agency at the centre, since often we ask causal questions in order to change some feature of our world (e.g. Gasking 1955; Von Wright 1971; Woodward 2003; Pearl 2009).

If we accept Cartwright's (2007) plurality view of causation theories[2], then it becomes pressing to find the theory or view of causation most promising for the enterprise of CSCW, namely, to understand cooperative work in order to be able to better computer support it (Schmidt and Bannon 1992). That is, given the variety of characterisations of the notion of causal explanation, some regimentation of the usage is pertinent in order for our enterprise to move forward. We suggest that for the purposes of CSCW, the distinguishing feature of causal explanation must be that they furnish information that is potentially relevant for manipulation and control (e.g. of entities in the material field of work such as technologies): they tell us that if we change one or more variables, we could change the value of other variables and potentially the outcome of an operation or action. We suggest that causal explanations are informed by our interests as practical agents in changing our world. In particular, we hold that it is useful to think of causal relationships as relationships that are potentially exploitable for manipulation and control. This idea is stressed in manipulability notions of causation such as those developed by Gasking (1955), Von Wright (1971), Woodward (2003) and Pearl (2009).

On this view, our interest in causal explanation represents a sort of extension of an interest in the manipulation and control of material artefacts, including technologies across various settings and situations. Von Wright (1974, p. 51) argues that the concept of cause presupposes that of (human) action. If man 'stood quite passive' against nature, if he did not possess the notion that *he* or *she* can do things, manipulate materiality, make a difference in the world, then there would be no notion of causality. Dummett (1964) makes a similar argument in saying that if we had been unable to manipulate nature, if we had been, in his example, intelligent trees capable only of passive observation, then it is reasonable to conjecture that we would never have developed the notion of causal explanation and the practices associated with it.

Relatedly, the manipulability conception of causal explanation plays an important role in how scientists think. Weinberg (1985) draws a distinction between descriptive and explanatory science in a paper on recent developments in molecular biology. Weinberg informs us that 'biology has traditionally been a descriptive

[2]In a review of Nancy Cartwright's (2007) book *Hunting Causes and Using Them*, Kevin Hoover (2009) finds that sometimes Cartwright treats the various accounts of causation as if they were so different that it is not clear why they should be the subject of a single book. The critique goes on to say that she fails to explain what they have in common, if, as she apparently believes, they do not have a common essence. In fact Cartwright (2007, p. 44) does state that she finds that the various theories of causation seem to have 'little of substantial content in common'. Do they have a Wittgensteinian family resemblance?

science' that has now moved to provide 'explanations' and identify 'causal mechanisms' primarily due to recent advances in instrumentation and experimental techniques. Note the contrast between description and causal explanation. Weinberg links the ability of molecular biology to provide causal explanations with the practical activity of manipulating and controlling substances – causal explanations inform manipulation and control. In Weinberg's (1985) account, new experimental and instrumental techniques have played a decisive role in developing the field of molecular biology into a science concerned with making causal explanations. New techniques make it possible to manipulate and control biological systems and to observe results in a way that was previously not possible – moving it from description towards intervention, manipulation and control (see also Woodward 2003). According to Weinberg (1985, p. 48), 'the invisible sub-microscopic agents they study can explain, at one essential level, the complexity of life' as manipulating these agents makes it possible now 'to change critical elements in the biological blueprint at will'.[3]

This passage illustrates the underlying idea of the manipulability account of causal explanation: causal explanations (ought to) involve insights that are relevant to manipulating, controlling and changing our world. Take for example computer technology. Computer programs, or subsections hereof, are executed on the computer in an invariant and predictable manner. We are in a position to explain when we have insights that are relevant to manipulating, controlling and changing the computer technology. Or put the other way around, being able to explain the workings of the computer application (to some extend) puts us in a position to potentially manipulate and control the technology. Causal explanations, however partial and incomplete, are part of what makes us able to use (and design) computer applications. It is important to emphasise that when we are talking of causal explanations enabling the manipulation and control of technology, we are aware that these explanations need not be more complete, extensive or consistent than required by the practical demands of the situation. That is, any causal explanation for the purpose of manipulation and control, of, for example, computer technology, is a situational property. This general phenomenon relates to what Schutz (1970) refers to as 'the problem of relevance' and what Bourdieu (1992) has called the 'economy of logic'.

[3]Since we raise the relevance of the manipulability conception of causation for scientific work, it may be appropriate to distinguish our arguments and interests from existing science and technology studies (STS) and sociology of scientific knowledge (SSK) literature. Briefly told, proponents of STS (e.g. Barad, Keller and Tchalakov) and SSK (e.g. Bloor, Collins and Yearly) are primarily interested in how social, political and cultural values influence scientific research and technological innovation and how these, in turn, affect society, politics and culture. In comparison, we are in this chapter, from the starting point of causal plurality, primarily interested in identifying and in turn employing a conception of causation relevant and useful for the enterprise of CSCW. Our evolving argument is that the manipulability conception of causation may be useful for CSCW, and we will as advertised attempt to show that in the following pages of analytical work in relation to two cases of cooperative work. In this manner our interest in this chapter differs somewhat from those of STS and SSK.

Relatedly, there is an important dimension along which causal claims may differ. Consider the following claim: *clicking on the printer icon in my Word application on my computer causes my printer to print out the document in focus*. Assuming that my computer system is functioning normally, the manipulationist view that we are advocating – following in the footsteps of Gasking (1955), Von Wright (1971) and Woodward (2003) – holds that this is a true causal claim and one to which we might appeal to explaining why my computer system has printed out a document on some particular occasion. However, some might say that there is an obvious sense in which it is explanatory 'shallow' compared to the sort of explanation that would account for the internal workings of the computer system that might be provided by a computer scientist or engineer – complete with explanations of Turing machines, Boolean algebra, Shannon's symbolic analysis of switching circuits and more. Some might say that we don't have a very 'deep' understanding of the computer system if we only know that *clicking on the printer icon in my Word application on my computer causes my printer to print out the document in focus.* Some might say that this example illustrates that causal explanations may differ in depth of understanding. But keep in mind that causal explanations are situational properties. It seems that the binary opposition shallow/deep is misleading when talking about causal explanations. Does the computer user need to know more than the claim mentioned above in order to print? Probably not, in most situations that is sufficient causal insight for the situation at hand involving the action of printing a document. So, instead of talking about depth of understanding or the lack of it, we should talk about the usefulness or adequacy of a causal explanation in relation to a particular situation or context.

Note that although manipulability theories of causation have been criticised on two primary grounds, none of these criticisms are pertinent for our enterprise. Let us elaborate. First, critics complain that these accounts are circular. According to the critics, any plausible version of a manipulability theory must make use of the notion of an intervention and that this must be characterised in causal terms. That is, attempting to link causal claims to manipulation requires that manipulation is more basic than causal interaction. But describing manipulations in noncausal terms has provided a substantial difficulty – causal talk refers to more causal talk – hence the circularity. Attempts to defend manipulability theories from this critique are recent accounts that don't claim to reduce causality to manipulation. These accounts, e.g. Pearl (2009) and Woodward (2003) used in this chapter, use manipulation as a sign or feature in causation without claiming that manipulation is more fundamental than causation and in this manner address the circularity critique.[4]

The second criticism centres on concerns that causal relationships exist in many places where human manipulation and control is not readily possible (an example being the surface of the sun). In this sense, the critics points out, manipulability accounts of causation makes humans (overly) central. In response to this criticism,

[4]For a more in-depth discussion of the 'circularity' issue and its implications, see Woodward (2013).

we may rely on Pearl (2009) to point out that 'cause' does not make sense divorced from manipulability *when the purpose of the analysis is to understand human practice or to furnish information relevant to human practice (the enterprise of this chapter)*. Pearl (2009, p. 407) makes the observation that knowing 'what causes what' makes a big difference in how we act. Let us give you a deceptively simple example. Drawing on Pearl (2009), what if we told you that the rooster's crow makes the sun rise? If that was true the implication would be that waking up the rooster earlier and making him crow would make the night shorter. But this is *not* so, and we act accordingly. Making this type of a distinction is relevant and has implication for how we act. This is true even when we are dealing with relationships that we cannot readily control. For example, we have no practical way of controlling celestial motion (or what goes on at the surface of the sun), and still knowledge of celestial motion is relevant to us. We can, for instance, predict the tide of the seas as a consequence of our understanding of the gravitational pull exerted on the seas by the moon, and just as important this understanding also provides us with assurance that the manipulation of earthly things will *not* control the tide. The point is that not being able to directly manipulate causal relationships does not necessarily mean that knowledge of this relationship is irrelevant to human practice (Pearl 2009).

If we accept the manipulability conception of causality, including the notion of causal explanation as a situational property, then it becomes relevant for us in CSCW to understand causation in various situations, in various work practices. In the following, causation in two cases of cooperative work, namely, chemotherapy and the building process, will be explored and analysed in order to open up the phenomenon for CSCW research.

We shall start by considering causation in chemotherapy and subsequently turn to the building process.

8.2 Causation in Work Practice: Chemotherapy

We shall start by briefly considering the methods and setting of the study before moving on to the analysis of causation in chemotherapy.

8.2.1 Methods and Setting

The study of causation in chemotherapy is based on data generated through 7 weeks of ethnographic fieldwork on oncology departments. The fieldwork included interviews and observations as well as the collection of documents used and produced by the actors.

One of the departments studied consists of an outpatient clinic, a day clinic with room for 12 patients and a ward with 33 beds. In addition, the department has a centre for patient information as well as a centre for cancer research. Approximately

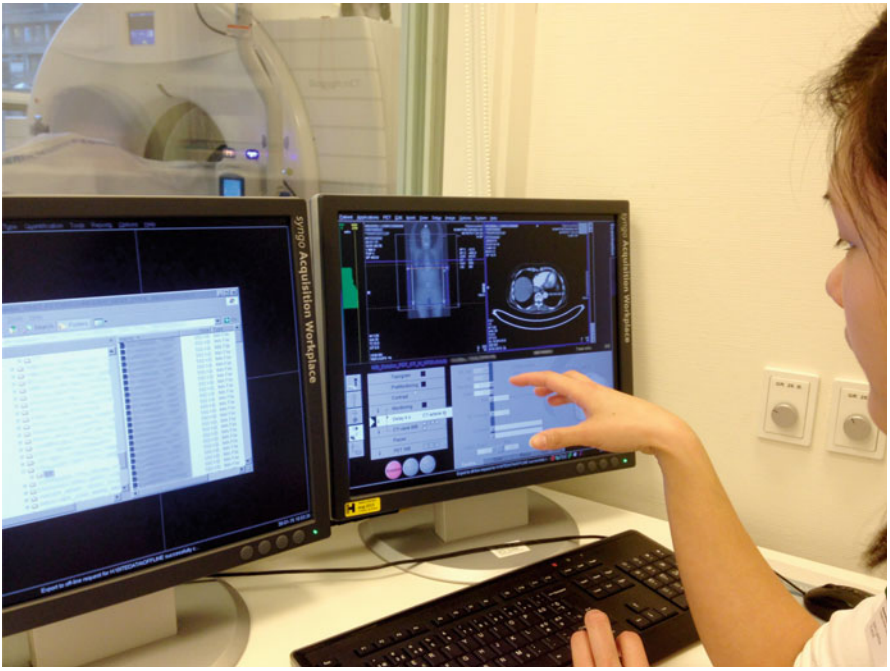

Fig. 8.1 Medical technologist at work scanning the body of a cancer patient

400 healthcare professionals with expertise in cancer treatment, care and research are associated with the department. The department offers radiation therapy as well as chemotherapy. There are approximately 4,400 new referrals to the departments per year and 3,600 admissions. On a yearly basis the department administers 56,000 sessions of radiation therapy as well as 27,000 sessions of chemotherapy. The hospital's surgical department performs tumour surgery in collaboration with the department. Although the department is highly specialised and devoted to chemotherapy and radiation therapy, oncology is highly interdisciplinary. The department needs to cooperate with other clinical specialties, such as the department of surgery, urology and gynaecology, with the laboratory as well as with the pharmacy (Fig. 8.1).

The staff at the department is organised in teams with each team focusing on a particular kind of cancer such as lung cancer, breast cancer, prostate cancer or colon cancer (our focus).

8.2.2 Causation in Chemotherapy

In chemotherapy, understanding and manipulating the causal relationship between cytotoxic drugs and cancer cells (as well as the wider human body) is central to the work practice.

In short, chemotherapy is the treatment of cancer with one or more drugs (chemotherapeutic agents), often used in conjunction with other cancer treatments such as radiation therapy or surgery. As mentioned above, whether or not chemotherapy is given with a curative intent or with the aim to prolong life or to palliate symptoms, it has the purpose of destroying cancer cells. That is, the drugs *cause* the cancer cells to wither away and die. This is the central rationale of this clinical practice. It is done with this aim in mind.

At the department, patients with a particular kind of metastasised colon cancer are offered a tested and tried protocol of carefully regimented chemotherapy with biweekly infusions of cytotoxic drugs that affect rapidly dividing cells. Chemotherapy can be said to roughly consist in the administering of drugs, in multiple cycles, and the monitoring the state of the patient. Chemotherapies are based on hundreds of clinical protocols, with specifications of combinations of drugs and cycles.

Following the manipulability conception of causation, we may say that understanding and manipulating the causal relationship between cytotoxic drugs and cancer cells is (very) central to the practice. As we shall see, taking blood samples, analysing blood samples, administering drugs, regulating doses, observing patients, performing PET/CT scans and doing the documentation are (partly) about understanding and manipulating the causal relationship between drugs and tumour in order to destroy the cancer cells. Of course there are other concerns or aims as well intertwined in chemotherapy such as minimising side effects, optimising the welfare of the patient, not getting sued for malpractice, making a cost-efficient effort and so on. However, it remains accurate to say that one relationship very central to this *clinical* practice is understanding and manipulating the causal relationship between drugs and tumour. Without this causal relationship chemotherapy would not be chemotherapy.

We are *not* trying to reduce the varied and complex practice of chemotherapy to a matter of controlling and manipulating one causal relationship – there are many such relationships in chemotherapy not to mention oncology as a whole – but we are pointing out that the causal relationship between drugs and tumour is central to chemotherapy.

It is worthwhile to consider how causal relationships in chemotherapy intersect in practice and must be balanced by the actors. The premise of this balancing act is that in chemotherapy it is relatively easy to kill all cancer cells with highly toxic drugs, but relatively hard to do so without also killing the patient. This is the reason for the monitoring of not only the causal relationship between the drugs and the tumour but also the relationship between the therapy and the patient's body as a whole. That is, we may say that there is a myopic view or interest in the causal relationship between drugs and cancer cells. For example, are the drugs destroying the cancer cell? Can we see the tumour shrinking when we are comparing PET/CT scans of the tumour over time? In addition, there is the interest in the causal relationship between the chemotherapy (as a whole) and the patient's body (as a whole). For example, what are the side effects of the treatment? How is the patient's performance status effected by the treatment? Can the patient's body tolerate the doses?

The organising principle for chemotherapy in relation to, for example, colon cancer is as indicated the concept of 'series'. Each cycle or series involves the infusion of drugs at the 14th day of each series,[5] as well as control in terms of the establishment of performance status, blood values, side effects and tumour size at the 7th day of any given series.[6] In this manner each series of treatment and examination amounts to the manipulation and control of the causal relationships mentioned above between (1) drugs and cancer cells and (2) the chemotherapy (as a whole) and the patient's body (as a whole).

In practice, these two causal relationships are as indicated represented and monitored in different ways. While the causal relationship between drugs and tumour is monitored primarily via PET/CT scans, the causal relationship between therapy and the patient's body (as a whole) is recorded as side effects on a form according to a grading system (from 0 to 4 where 4 is most severe). Let us elaborate.

PET/CT scans are the primary means of evaluating the causal relationship between drugs and tumour. PET/CT imaging combines nuclear medicine techniques with special x-ray equipment to produce multiple images of the inside of the body that many be compared over time. These cross-sectional images of the area being studied can then be examined on a computer monitor or printed. PET/CT scans of tumours reveal more details than regular x-ray exams. The objective is to identify when tumours in cancer patients improve ('respond'), stay the same ('stabilise') or worsen ('progress') during chemotherapy. These criteria are specifically *not* meant to determine whether patients have improved or not *per se*, as these are tumour-centric, not patient-centric, criteria.

The causal relationship between the therapy as a whole and the patient body (as a whole) are considered in terms of side effects. That is, a nurse interviewing and observing the patient makes use of a side-effect form in order to quantify, in accord with WHO standards, the performance status as well as fatigue level and level of pain experienced by the patient after each chemotherapy session. This is done according to a grading system (from 0 to 4 where 4 is most severe). This is a process that relies on the expressions and observations of feelings of pain and discomfort as relayed by the patient to the nurse.

When the two causal relationships, between drugs and tumour on the one hand and on the other hand between therapy and the patient's body (as a whole), intersect in practice, a causal nexus emerges that must be handled by the physician. For example, in a situation where the patient is suffering third-degree side effects such as severe diarrhoea, the treatment of the patient is postponed by the physician until the side effect has been reduced to at least grade 1 and thereafter only continued with 75 % of the original drug dose. This is done routinely according to the protocol described in a dose-modification guideline set up to handle this balancing act. In this manner two causal relationships very central to chemotherapy may be represented, intersected and balanced by the actors.

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[5]This is from series 3 and onwards once the preliminaries such as establishing a baseline have been completed.

[6]There are 53 series of examination and treatment in total in this protocol of chemotherapy.

Again, we are *not* trying to reduce the varied and complex practice of chemotherapy to a matter of merely controlling and manipulating one set of causal relationships – there are obviously much more to oncology as a whole – but we are pointing out that there are causal relationships central to chemotherapy.

Generally speaking, in work practice actors are often manipulating a set of fundamental causal relationships. We have considered chemotherapy and the relationship between drugs and the patient's body – let us now turn to consider a different practice, i.e. the construction of a building.

8.3 Causation in Work Practice: The Building Process

Before moving on to an analysis of causation in the building process, we shall first consider the methods and setting of the study.

8.3.1 Methods and Setting

The study of causation in the building process is based on data generated through ethnographic fieldwork carried out in the course of fourteen months in architectural offices and on building sites (see also Christensen 2013). One of the building projects studied was the development of the new domicile for a publishing house, a multistorey building in glass, steel and concrete constructed at the city of Copenhagen's waterfront.

It is a relatively large building of 18,000 m^2 distributed across eight floors (see Fig. 8.2). A combination of observation and interviews was used. The fieldwork also included collecting (scanning, taking screenshots or photographs of) artefacts used and produced by the actors engaged in the building projects.

8.3.2 Causation in the Building Process

One fundamental causal relationship in a construction project is between the building in the making and the forces of nature including gravity. There will be no building if we cannot adequately manipulate and control the materiality of the building in the making in order to secure its stability (see also Christensen 2013). Arguably, for example, aesthetics and financial concerns are subservient to the matter of harnessing the causal relationship between building in the making and the forces of nature. We could, for example, have a beautiful design or a very low-cost building project, but if the finished building cannot stand, it is in the context of the building industry considered a failure.

Fig. 8.2 One of the building projects studied, a domicile for a publishing house

The actor's ability to adequately understand, control and manipulate causal relationships is fundamental to the building process and evident (1) in the design of the building by way of static calculation and design, (2) in the choice of building materials and (3) in the sequential order of construction work. We shall start with statics engineering, move on to consider causation related to the choice of building materials and finally consider how causal relationships influence the order of construction work on the building site.

8.3.2.1 Causation: Statics Calculation and Design

In a building project, it is very rare for the architects to vouch for the stability of the building themselves. Although the architects may select and design the general appearance of the load bearing elements, it is the engineers that craft a set of static plans for the building project, placing particular emphasis on statically relevant elements (Fig. 8.3). Statics describe the distributed forces in a system such as a building at rest. Buildings and parts of building are usually motionless (if we disregard wind-induced movement), and all the effective forces are calculated to balance each other out for the benefit of the stability of the building. Static calculations may include determining the assumed loads involved, calculating the forces that affect a particular structural element and the forces that it transmits to others, calculating the forces within structural elements themselves, determining the stability of the planned construction, etc.

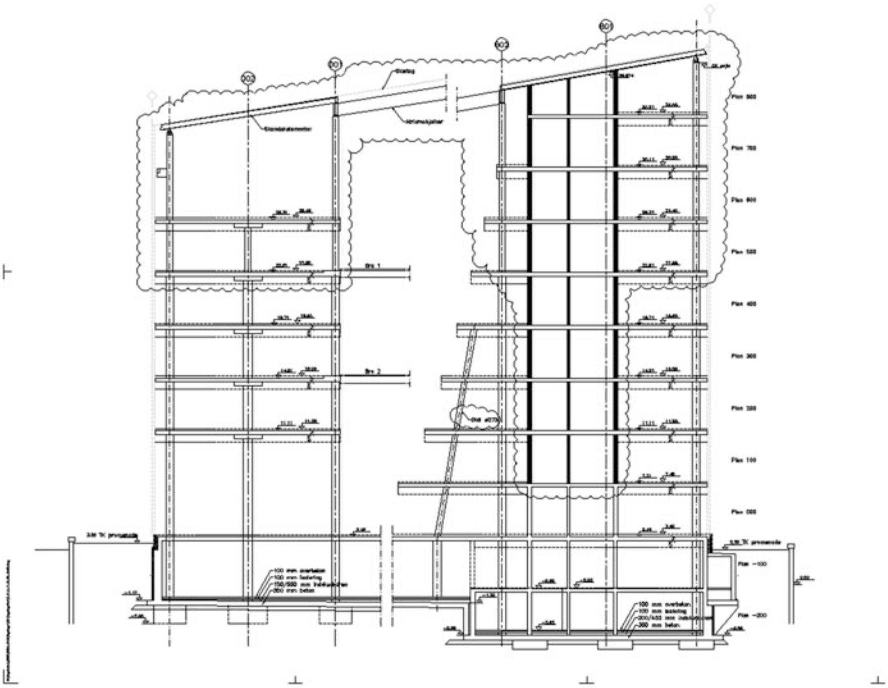

Fig. 8.3 Plan pertaining to the load bearing 'skeleton' of the domicile

The load bearing structure of the, for example, the domicile building (our building project in focus), is a so-called skeleton construction made up of bar-shaped elements forming a structure like scaffolding. Exterior façade panels and interior walls are then added to this structure. The load bearing structure and the elements that create the interior spaces are, in effect, two separate systems.

Fundamentally, the skeleton structure of the domicile is made up of three kinds of structural elements: the columns and the decks that absorb vertical loads and the walls in the kernels that absorb horizontal forces. All the vertical forces from the floor slabs (decks) are transferred into the columns, and this means that the point of transition from columns to floor is very heavily loaded. There is a risk of the column punching through the floor. To avoid this, the columns must be evenly spread and appropriately dimensioned. The structural engineer distributes these structural elements appropriately as he or she designs the load bearing structure.

Of course, there are various approaches and options available in a building project when considering and planning for the structural integrity of the building. However, the reality that structural integrity is called for is probably not debatable considering the ubiquitous presence of the forces of nature, including not least gravity. We could suggest that some form of load bearing structure is a necessity in a large and complex building project.

Structural engineers craft a set of static plans for the building project, placing particular emphasis on statically relevant elements (Fig. 8.3). Here, it is also important to establish which structural elements load with others. For example, the roofing is not just supported by the roof structure but also affects the beams, decks and columns, right down to the foundations. It must be established which structural elements absorb the loads of the upper storeys.

In addition, there are numerous other cases that we could mention in passing where causal phenomena are evident and may be anticipated in design. For example, the anticipation of temperature fluctuations may be related to the design of heating and cooling systems, the anticipation of the build-up of air contamination may be related to the design of the ventilation system, the anticipation of wet weather conditions may be related to the design of the exterior of the building (i.e. roof, façade, windows and so on), etc.

Perhaps it is evident by now that designing a building such as the domicile for the publishing house – a large and complex eight-storey building – involves understanding, manipulation and planning for the casual relationship between the building in the making and the forces of nature (i.e. gravity, weather, temperature, etc.). Perhaps we could assert that such design practice is conditioned by 'natural necessity'. In order to give ourselves the opportunity to properly asses this assertion, perhaps we ought to take a closer look at one of the central concepts used, namely, that of 'natural necessity'.

Harré and Madden (1975) coined the expression 'natural necessity' in their seminal work on causal powers. The notion captures the host of complex connections, actions and reactions that stem from the causal relationships inherent to not least to our natural world (Harré and Madden's 1975). In the context of describing the building process, using the notion of natural necessity may make us receptive to the assertion that in the building process, there is no known option but to act in accord with nature by anticipating the forces of nature – hence the expression natural necessity.

8.3.2.2 Causation: Choosing Building Materials

Furthermore, the notion of natural necessity may also be relevant in regard to the discussion of other types of design choices not least the choice of building materials. That is, perhaps the choice of some building materials is conditioned by natural necessity. Let us take a closer look.

According to Harré and Madden (1975, p. 11), the notions 'natural necessity' and 'power' are intimately interwoven. Moreover, Harré and Madden (1975, p. 85) report that under the influence of Ryle (1949) and others, a particular way of handling the ascription of power to material entities has become widespread. Ryle and others recommend that we treat power ascriptions not as the assertions of the presence of qualities but analyse them as hypothetical or conditional statements. For example, the meaning of 'It is brittle' is supposed to mean 'If maltreated, it will break'. In a similar spirit, 'It is poisonous' is held to be identical with 'If taken, it will kill or make ill', and 'It can crush a car' is taken to mean 'If it presses a car, the car will be reduced to the size of a suitcase'. Following this approach, 'It is strong' may mean 'If placed under great pressure, it will hold'.

However, according to Harré and Madden (1975, p. 86), the problem of what the ascription of a property or power to a thing means when it is not exercised is not really solved in this approach. To hold, for example, that to assert that a particular slab of concrete is strong is to make a prediction about how it would behave, if certain conditions of pressure were fulfilled is only part of it. That is, conditional statements are not enough when ascribing powers to things or materials. Things and materials have powers even when they are not exercising them, and this is a current fact about them manifest in our language about them, a way in which they are currently differentiated from other things or materials that lack these powers. Indeed, the reason why we believe that a certain disposition can be asserted of a thing or material is that we think or indeed know that it currently has such and such powers.

One of our reasons as actors, and sometimes our only reason, for believing that if certain conditions are met, then a material or individual thing will behave in a certain way, is that the thing or material now has the power to behave in that way should the conditions obtain. The difference between something that has the power to behave in a certain way and something that does not have that power is a difference in what they themselves are now as material entities, rather than solely a difference between what they will do under certain conditions, since it is contingently or circumstantially the case that their powers are, in fact, ever manifested. It is a difference that may be ascribed to intrinsic nature, rather than only to extrinsic circumstances (Harré and Madden 1975). In this manner Harré and Madden refuse to base their characterisation of the powers of material entities solely on conditional circumstances, and in addition to these relational parameters, they retain the notion of powers as internal or intrinsic to the particular thing or (composite) material such as the reinforced concrete used for the domicile.

Harré and Madden's position can be understood in the context of a particular tradition of language philosophy concerned with the everyday or common use of language (e.g. Wittgenstein, Austin, Searle and Ryle). Arguably, it is in this tradition that Harré and Madden are asserting that when we talk about the powers of things and materials, we routinely ascribe intrinsic powers to them as well as extrinsic conditions. 'In a sense the ascription of power is a schema for an explanation of the manifestation of the power' (Harré and Madden 1975, p. 87). That is, in explaining the powers of material entities, both extrinsic conditions and intrinsic qualities may be invoked or referenced. This view may be corroborated if we consider, for example, how Hegger et al. (2007) describes the (compound) material concrete with reference to both intrinsic qualities and extrinsic conditions:

> The mixture of cement, aggregates and water determines the properties of concrete. The cement acts as the binder, the water is present so that it can set, and the aggregates cut down the amount of cement needed and determine density, strength, thermal conductivity and heat storage capacity. Typical concrete has a high gross density, great surface hardness and great strength. The usual aggregate is gravel. The structure of large and small granules

> is calculated to create as few cavities as possible. The gravel will be completely enveloped by the cement and bound to it non-positively. The smaller granule sizes help the concrete to flow more easily. The properties of the concrete are determined by the aggregates. Normal concrete has high thermal conductivity and heat storage capacities. Thermal conductivity can be significantly reduced by changing the aggregates, for example by using expanded clay, particularly porous clay balls or wood chips. Thermal conductivity can be reduced further by introducing air pores as an insulation device. This is done by means of blowing agents, which make the concrete rise like a cake. The result is called aerated concrete. Chemical substances can also be added to make the fresh concrete easier to work; or colour pigments to dye the concrete. (Hegger et al. 2007, p. 42).

In this paragraph Hegger and associates seem mostly to describe concrete with reference to what Harré and Madden (1975) call the intrinsic qualities of the material (e.g. '[. . .] concrete has a high gross density, great surface hardness and great strength'). However, they also refer to extrinsic conditions:

> As a simple mixture, concrete has little tensile strength, so if it is used structurally it will always be reinforced concrete. Reinforcing steel is introduced into the concrete at the points where loads have to be absorbed. (Hegger et al. 2007, p. 43).

In this paragraph Hegger and associates (2007) seem in part to refer to what Harré and Madden (1975) describe as extrinsic conditions (e.g. '[. . .] if it is used structurally').

It is not uncommon, then, to explain the choice of building materials such as (reinforced) concrete with reference to the intrinsic nature of the compound, i.e. 'concrete has great strength', as well as by conditional statements such as 'if used structurally steel reinforced concrete will hold'. In a similar spirit, we could suggest that 'glass is transparent and wind breaking' and this makes it suitable, 'if used in windows or even sections of a roof'. Note how this allows for making a distinction between changes in the material itself and changes in extrinsic circumstances. We could argue that if a strict relational or conditional view were maintained as argued for by Ryle and others, changes in the material itself would be hard to express or speak of.

While on the subject of materials, we could briefly return to the load bearing structure of the domicile. In principle, any material that has the properties of being both compression and tension resistant can be used for the load bearing skeleton structures, for example, timber, steel or concrete. Each of these has its own construction methods with a particular set of problems arising from the material and the methods used for joining it (we won't go into the details of this). The material chosen mainly for the domicile's skeleton structure is concrete or, more precisely, the compound steel reinforced concrete. We may note, then, that a strong rather than a brittle material is chosen for the load bearing structure of the domicile, a compound material that if placed under great pressure will hold rather than crumble. In this manner the designers anticipate the forces of nature in their choices of building materials. That is, choices are made partly out of natural necessity (and partly out of concerns for cost, aesthetics, etc.).

8.3.2.3 Causation: The Order of Construction Work

As mentioned above, the ability to understand, control and manipulate the causal relationship between the building in the making and forces of nature also influences the order of construction work. The construction of the building follows what is known as 'the load bearing path'.[7] This means that the building elements that are capable of bearing the load of other elements are built before the latter are. One obvious example is that the foundation is built before the walls and the walls are built before the roof. This is the general order of construction work. An example at another level of granularity is that the concrete decks must be cast before the ventilation ducts or electrical cables are fitted or hung underneath them. This may be described as a matter of natural necessity considering that forces of gravity have a large part to play.

What this implies, then, is that natural necessity in part necessitates certain sequences of work, a certain ordering of the construction tasks. In combination with the specialised division of labour found among the network of actors, natural necessity influences the ordering of the construction tasks. For example, the concrete crew necessarily must perform the work of constructing the foundation and load-bearing superstructure of the building before the carpenters can do their part on the interior of the building. This implies that the carpenters (as well as electricians, plumbers and painters) must rely on the concrete crew and associated actors to literally lay the foundation for their subsequent work. Note that there is nothing arbitrary about this specific ordering of the cooperative work tasks in this case. For example, the work on the foundation must according to natural necessity be completed before any subsequent task literally resting on this can be performed.

This discussion implies that when designing or constructing a building, the cooperative work ensemble must out of natural necessity manipulate and control the causal relationship between the building in the making and the forces of nature, and this is manifested in static calculation and design, in the choice of building materials and in the order of construction work. All this may be verging on the trivial; however, one point is perhaps worth making: if they ignore or fail to do so at a critical juncture, the building simply will not rise let alone stand. This may be a trivial observation; however, it does underpin the building process. Let us now turn to discuss our findings.

8.4 Discussion

Does it make analytical sense to talk of *central causal relationships* when trying to understand cooperative work practices such as chemotherapy or the building process? Let us discuss.

[7]This is a member's concept, i.e. an expression used by the actors on the building site.

In chemotherapy, for example, we found the manipulation of the casual relationship between drugs and cancer cells to be very fundamental to the practice. Could it be *the central causal relationship* of the practice? Chemotherapy would not be chemotherapy, as we know it, without the control and manipulation of this causal relationship. In a similar manner, in the building process, we also found a significant causal relationship. That is, we found the manipulation and control of the relationship between the forces of nature and the building in the making to be literally very fundamental to the practice. Paraphrasing our conclusion on chemotherapy, the building process would not be the building process without the actor's manipulation and control of this causal relationship.

We are probably able to identify a *central causal relationship* (or set of relationships) in many other practices too.

Having a research interest in causal relationships in work practice may help us understand something very fundamental, namely, what are the actors doing? What are the basic causal relationships co-constitutive of a given practice? Arguably, this goes beyond the explanatory power of common sense ideas like 'skilful tool use' as it has the potential to analyse the constitutive elements of complex work practices. Focusing on causal phenomenon may help us as we have seen in relation to understanding both chemotherapy and the building process. However, can we always expect to be able to identify *central* causal relationships in any given cooperative work practice?

It is probably possible to identify causal relationships in most work practices both in technical domains and on other occasions. But the question of whether or not these relationships are to be deemed *central* to the practice is an empirical question entirely. Above we have seen how manipulating and controlling causal relationships are *central* to both chemotherapy and the building process. We have argued that it is a defining feature of these practices. However, we cannot take it for granted that the manipulation and control of causal relationships in the material field of work is *central* to *all* work practices. It is an empirical question.

Relatedly, if we turn to the use of computers in general, then at first hand the picture becomes perhaps a bit murkier as it can be hard to identify any one causal relationship to be 'very' fundamental or central, and all talk of a 'causal base' may evaporate. Computers are hardware machines (CPU, motherboard, ram and much more) running software machines (OS, applications, Internet services and much more) with multiple countless interconnected causal relationships crisscrossing. If we wish to say something about computer technology and causation, then we have to be very specific about the use of the technology. Again, it is an empirical question. The point being that computers are used in many practices, and as such central causal relationships, to the extent than they can be identified, will vary. Perhaps we may even say that what may differentiate one practice from another practice is precisely differences in regard to what can be considered to be 'central causal relationships' – to the extent that they can be identified and identified as central. That may serve as a way to differentiate between practices in a relatively consistent way, and that may be helpful when we are asking questions such as 'what are the actors doing' or 'what fundamental causal relationship (or set of relationships) is the cooperative actors involved in manipulating and controlling, and how do we computer support this practice?'

8.5 Conclusion and Perspectives

In this chapter the manipulative account of causation has been brought forward as a conceptual framework for the understanding and analysis of causal relationships central to cooperative work practice. Causal relationships central to, respectively, chemotherapy and the building process have been described and analysed.

In chemotherapy, we found that it is a central part of work practice to understand, manipulate and control the causal relationships between drugs and cancer cells in an effort to destroy the latter. Furthermore, it is also part of chemotherapy to monitor and manipulate the causal relationship between the therapy (as a whole) and the patient's body (as a whole) in order to safeguard the wellbeing of the patient. In practice these two relationships form a causal nexus intertwined in an intractable manner yet handled routinely by the actors in the clinic.

The study of causation in the building process showed that the cooperative actors are engaged in manipulating and controlling the causal relationship between the building in the making and the forces of nature. This is evident in the design of the building by way of static calculation and design, in the choice of building materials and in the sequential order of construction work.

In terms of perspectives for CSCW, we may say that studying causation may also address the elusive question of how to deal with the actor's engagement with materiality in the study of cooperative work. That is, in this chapter the analysis of materiality in cooperative work has been cast as the study of the actor's manipulation and control of key causal processes in the material field of work. This is a path that could be explored further in future studies of cooperative work that has an emphasis on the materiality of the work setting.

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