**Stellingen**

**behorend bij het proefschrift**

**Accidents involving consumer products**

1. De kloof tussen het feitelijk gebruik van consumentenprodukten en het gebruik zoals bedoeld door ontwerpers kan pas uit de wereld worden geholpen als ontwerpers ophouden te denken in termen van abnormaal/verkeerd/oneigenlijk gebruik en misbruik.

2. Een wijd verbreide conclusie uit ongevalsanalyses is dat de gebruiker een verkeerde handeling heeft verricht. Deze conclusie weerspiegelt de neiging om menselijke handelingen als beter beheersbaar en beïnvloedbaar te beschouwen dan produkten en omgevingen.

3. Ter preventie van ongelukken met huis-, tuin- en keukenprodukten is het instrueren van ontwerpers een efficiëntere investering dan het voorlichten van consumenten.

4. Dat een alledaagse redeneerwijze als ‘counterfactual reasoning’ (bijvoorbeeld: als er geen inkt in de drukpers had gezeten, dan was dit vel blanco geweest) tot dusver aan de aandacht van veiligheidskundigen-is ontsnapt, hangt samen met het feit dat niet de vraag naar de oorzaken van ongevallen maar naar de schuldige(n) centraal heeft gestaan.

5. Het Nederlandse verzekeringsstelsel staat een effectieve werking van de wet aangaande de produktaansprakelijkheid als instrument in de preventie van ongelukken met consumenten-produkten in de weg.


7. Vanuit moreel oogpunt is de aarde plat.

**Mieke Weegels**

**Januari 1996**
Accidents involving consumer products
Accidents involving consumer products

Proefschrift

ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft,
op gezag van de Rector Magnificus Prof. ir. K.F. Wakker,
in het openbaar te verdedigen ten overstaan van een commissie,
door het College van Dekanen aangewezen,
op maandag 18 maart 1996 te 13.30 uur
door

Marie Francine WEEGELS

landbouwkundig ingenieur
geboren te Weert.
Dit proefschrift is goedgekeurd door de promotoren:
Prof. ing. A.H. Marinissen
Prof. drs. J. Moraal

Samenstelling van de promotiecommissie:
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Drs. H. Kanis heeft als begeleider in belangrijke mate aan het totstandkomen van het proefschrift bijgedragen.
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1. Introduction

1.1 The problem

In the Netherlands, each year approximately 1.6 million people are medically treated for injuries sustained in accidents in the domestic area (Mulder et al., 1995). Half of these accidents occur in or around the home. In almost two-thirds of the home accidents at least one consumer product - in the broadest sense of the word - is reported to be involved (Mulder et al., 1995).

It need hardly be said that accidents are undesirable for all parties concerned. An accident may severely distress the person(s) involved, physically as well as mentally. Even if minor, physical injury is painful and inconvenient. Accidents may also cost the victim and society considerable amounts of time and money. The interests of manufacturers may be seriously harmed if they become discredited when their products are labeled as not being safe. Consumer products that do not meet safety standards can be excluded from the market. Association of products with lack of safety may provoke negative publicity, for example, when severely criticised in publications of comparative tests by consumer organisations.

Moreover, product liability legislation forces manufacturers and industrial design engineers to face the reasonable use of a product, which according to the Civil Code includes movable objects as well as components incorporated into other movable or non-movable objects (Dutch Civil Code, articles 1407a - 1407j). The financial consequences for a manufacturer may be considerable in the case of an awarded claim (Mauro, 1994).

So far, efforts in the area of consumer product safety have been mainly directed at influencing people's behaviour by means of education, warnings and information. These efforts may be misdirected. As Adler (1995, p. 84) notes, products are easier to re-design than consumers:

After all, patterns of behavior, embedded widely among millions of consumers are extremely difficult and costly to modify.

In addition to consumer education, the technical safety of some products, such as electrical appliances, has already been achieved by various regulations. The product liability legislation emphasises that the safety of products involves more than simply conforming to technical criteria. Generally the occurrence of accidents is equally linked with how and where products are being used (Kanis, 1990). The use of products in practice can deviate greatly from the designers' expectations (Kanis & Wendel, 1990; Öster et al., 1994). The gap between actual use and the
use intended by the designer may have serious consequences, including personal injury. It therefore seems surprising that the involvement of the behaviour and expectations of future users in the design of consumer goods is still in its infancy (Marinissen, 1993; Laughery, 1993; Norman, 1992), while in the human factors literature only global descriptions of the actual use of consumer products are found (Kanis & van Hees, 1995; Kanis & Marinissen, 1991).

Since adequate means to predict how people will use products are not available, an obvious way for manufacturers to secure their interests is to take out product liability insurance. As a consequence, significant increases in liability insurance-premiers are observed (Brack & Gieskes, 1990; Nassif, 1991), and there is no reason to assume that these costs are not passed on to the consumer. This unfortunate situation may be tackled by making available the means to anticipate the future use of products that may result in accidents. The study presented in this thesis is meant as a contribution to the provision of these means.

1.2 Objective of the study

In coping with possible future accidents involving a product being designed, at least two situations may be encountered.

In the first situation, accidents are known to occur with forerunners of the product to be (re)designed. In this case, insights derived from data on accidents with these forerunners may assist industrial design engineers in their efforts to set criteria for a safer product. A prerequisite for this is the availability of methods for the provision of accident data and for the inference of insights from those data.

In the second situation, the product to be designed is suspected of being prone to involvement in accidents, but no empirical evidence is retrievable. Here, general insights into the occurrence of accidents may serve as a basis for the establishment of criteria that should be met by the design. Inevitably, such general insights should be founded upon empirical evidence.

In this thesis, both situations are covered. The aims of the present study are:

- to generate methods for the observation and analysis of accidents;
- to gain general insights into the occurrence of accidents involving consumer products.

The findings obtained should be tuned to application in the design process.

The research discussed in this thesis can be typified as exploratory. The focus is on generating theoretical notions rather than testing hypotheses. Consequently, diversity, for instance in the products involved in accidents, rather than similarity is incorporated in the study.

The study is limited to accidents involving products that are used in or around the home. An accident is defined as the occurrence of immediate personal injury or personal damage during the use of a product (cf. Leplat, 1984; Surry, 1974). The focus is on durable, movable consumer products. Not included are, for example,
food, cosmetics, stimulants, toxins and immovable parts of a house, such as staircases and windows.

1.3 Outline of the thesis

Chapter 2 provides a review of the literature. Given the aims of the present study, the review not only includes existing theoretical notions but also methods of accident research and accident analysis. A distinction is made between perspectives on the emergence of accidents and the causes of accidents. First, the main perspectives, such as systems approach and the epidemiological perspective, are described and evaluated. Then, the (potential) causes of accidents are reviewed. Various types of accident research are discussed. Given the state of the art in the field of consumer product safety, retrospective research into accidents is considered as most appropriate for the objective of this thesis. The validity of retrospective data is always a matter of concern, since memory processes may bias people’s stories. Therefore, the literature on the questioning of eyewitnesses is examined. Several different techniques for the analysis of accidents can be found, such as scenario analysis, deviation analysis and multidisciplinary reviews, which generally involve human judges. Since little appears to be known about the inference of causes by human judges, an additional study into this issue is included in this thesis, see chapter 4.

The observation of accidents is described and evaluated in chapter 3. Existing approaches, which mainly stem from occupational circumstances and traffic, are not an attractive choice as a starting point. Therefore, an approach is introduced which is directed towards the observation of accidents involving consumer products. An accident is seen as a result of the consecutive co-occurrences of the product, use activities and the situation. How, and to some extent also where, products are being used, reflects human interference and thus may be linked with the characteristics of the user. The factors that are suggested in the literature as relevant in the occurrence of accidents are incorporated in the method of data collection. Accidents have been reconstructed in an investigation on-site. Subjects were asked to demonstrate what happened. This was video-recorded and followed by an interview and various measurements. Subjects (n=42) were recruited via various data sources, such as the emergency department of a hospital, general practitioners and public calls. The accident data are explored with respect to indications for lack of validity.
In chapter 4 the additional study into the identification of causes is discussed. Initially, the focus of this study was to explore the inference of causes by human judges. To what extent do judges agree on the causes of an accident? To answer this question twelve judges were confronted with the data of four accidents. Agreement on the causes of the accidents was limited. The question arose as to why various judges indicated different causes. Therefore, the focus shifted towards a means for the identification of contributory factors, by which the inference of causes can be made clear. Judges, however, appeared to use various criteria in deducing causes from accident data. Since similar criteria are found in the fields of social psychology and philosophy, the related literature in these two areas is reviewed. The chapter ends with an appraisal of the criteria used by the judges. The application of these criteria in the analysis of the accidents is elucidated and illustrated.

The findings concerning the patterning of accidents are reported in chapter 5. To what extent characteristics of the product, the use activities and the situation can be identified as contributory is examined first. To find out whether regularities in the occurrences that precede accidents can be detected, the sequences and combinations of contributory factors are explored. Subsequently, the characteristics of the user, that may be related to how and where products are used, are discussed. The extent to which subjects differ from other people with respect to their physical characteristics and their involvement in accidents is addressed. Finally, the question to what degree deviations can be related to the emergence of accidents is answered.

Chapter 6 gives a general discussion of the findings in this thesis. Limitations of the study, implications of the findings and possible directions for further study are considered.
2. Review of the literature

The main perspectives on the emergence of accidents are discussed (§ 2.2). In § 2.3 the factors considered in the literature as contributory to accidents are reviewed. Prevalent methods used for obtaining insight into accidents are evaluated in § 2.4. Also, literature on validity in retrospective research is considered. Current techniques for the analysis of accidents are discussed in § 2.5. The chapter concludes with implications for the present study (§ 2.6).

2.1 Introduction

Given the objectives in this thesis, the review of the literature includes the following subjects: a) theoretical insights into accidents, b) methods of accident research, and c) techniques of accident analysis. Since every method for the collection and analysis of accident data entails suppositions on how accidents occur, the chapter starts with a review of existing theoretical notions. A distinction is made between perspectives on the emergence of accidents and literature on the (potential) causes of accidents, or - in other words - the factors that may contribute to the occurrence of accidents.

Within the context of this thesis, the vast amount of literature in the area of safety can only be presented in a rudimentary form. The references given should primarily be seen as illustrations of the various viewpoints and methods rather than as being comprehensive.

2.2 Perspectives on accident emergence

The perspectives on the emergence of accidents are ordered according to the view of how accidents occur, e.g. accidents as a result of deviations, and according to the area that is described, e.g. behavioural or technical aspects (see § 2.2.1). Of course there is overlap: the various perspectives are not mutually exclusive. For example, a human information processing model inherently comprises a chain of multiple events. The ordering of the perspectives corresponds more or less to groupings provided by, e.g. Benner (1985), Hale & Glendon (1987), Hale & Hale (1972), Hoyos & Zimolong (1988), Kjellén (1984), Kjellén & Larsson (1981), McKenna (1982), Smillie & Ayoub (1976), Surry (1974) and Thygerson (1986). The applicability of the perspectives as a starting point for the observation of accidents involving consumer products is assessed in § 2.2.2.
Theories from areas such as psychology (e.g. learning theory, perception theory and personality theory, see Huguenin, 1988) that are not attuned to accidents or safety are left out of consideration.

2.2.1 Review of perspectives

Monocausal view
In this view, accidents have only one cause. An example is accident proneness, which is regarded as the single cause of accidents. A monocausal view is also represented in risk homeostasis theory (Wilde, 1982, 1986, 1989). In this theory the number of accidents in society is supposed to operate as the single factor in controlling people's risk behaviour. Accident proneness and risk homeostasis are further discussed in § 2.3.4.

Chain of multiple events
As soon as recognition grew that accidents have multiple causes, the idea arose that accidents are preceded by a chain of events. The well-known domino theory of Heinrich (1959) depicts such a chain of multiple factors, of which injury is the final result, see figure 2.1. The factors are depicted as dominoes. When one domino falls, the subsequent dominoes also fall. Accidents can be prevented by removing one of the dominoes. According to Heinrich, the unsafe acts and mechanical/physical hazards are easiest to remove, as these are identifiable in observations, surveys and inspections before they have resulted in accidents (Heinrich, 1959).

Figure 2.1
*The domino theory of Heinrich (1959, p. 14). The first domino comprises the influence of the social environment, which constitutes undesired personal traits that are inherited or developed during education. These personal traits cause faults in people, such as nervousness and recklessness, the second domino. Faults explain why people do not act safely and why mechanical and physical hazards exist. Unsafe acts and mechanical/physical hazards - together the third domino in the row - result in accidents (the fourth domino) and consequently in injury, the fifth and last domino.
Other examples of accidents depicted as resulting from a chain of multiple events can be found in Kjellén (1984), Kjellén & Larsson (1981), Wagenaar & Reason (1990) and Williamson & Feyer (1990).

**Epidemiological perspective**
In the epidemiological perspective, which originated from the study of disease epidemics, an accident is seen as a result of the interaction of three factors: the inflicting agent (which can be physical, chemical or biological), the recipient subject or object (also called the host) and the environment in which the agent and the subject meet (see Gordon, 1964; Himmelfarb, 1985; McFarland, 1964). If there is an equilibrium between host and environment no accidents occur. Only in the case of a disturbance in this equilibrium, generally caused by a particular combination of agent, host and environment, an accident may occur (cf. Gordon, 1964, p. 20).

**Energy exchange model**
According to Haddon et al. (1964), a typical feature of accidents is that abnormal energy exchange takes place. The energy exchange model is based on the principle that injury is caused by the collision of a human and an uncontrolled flow of energy (see, e.g. Gibson, 1964; Haddon et al., 1964; Harms-Ringdahl, 1987; Page, 1995; Shannon & Manning, 1980; Skiba, 1973). Most authors make a distinction between thermal energy, radiation energy, chemical energy, electrical energy and mechanical energy.

**Systems approach**
Many perspectives in the field of safety are interspersed with the concepts of systems approach (see, for instance, Hale & Glendon, 1987; Kjellén, 1984; Leplat, 1984; Stoop, 1990; Surry, 1974). As in the epidemiological perspective, systems approach emphasises the interaction between man and machine in their environment.
A system comprises an organisation of elements - the system variables - which interact with each other. System variables may be both human and technical (Hale & Glendon, 1987; Leplat, 1984). The system is separated from the environment by the system boundary. Where the system boundary is drawn depends on the objectives of the researcher. Systems exchange matter, energy and information, via the system boundary, with the environment. The stream of matter, energy and information from the environment (in) to the system is called input, the stream from the system (in) to the environment is called output. Systems are assumed to be directed towards some kind of goal. The output is compared to the goals of the system, such as the expected output. Via a feedback mechanism the input can be adjusted. Figure 2.2 is a common representation of a system with a feedback mechanism.
In terms of systems approach accidents are often seen as output as a result of undesired deviations from the intended functioning of the system (Kjellén, 1984; Leplat, 1984). This interpretation refers to the concept of deviations.

![Diagram of a system with feedback mechanism](image)

**Figure 2.2**  
*Representation of a system with a feedback mechanism (cf. Hale & Glendon, 1987, p. 4).*

**Concept of deviations**  
A corollary of systems approach is that accidents are seen as arising from a change, deviation or disturbance in the prescribed/normal task, procedure or functioning of the system (see e.g. Andersson et al., 1978; Kjellén, 1984, 1987; Leplat, 1978, 1982, 1984; Moyen et al., 1980; Winsemius, 1965, 1969a).

Kjellén (1984, 1987) elaborates on the concept of deviations, contending that the principle of variation, change and deviation is reflected in various accident theories and models. The deviation concept is based on the assumption that accidents are preceded by deviations from normal and planned functions in a system. Any system variable deviates when its value falls outside a norm (Kjellén, 1984, 1987). Thus, it is assumed that it is possible to dichotomise the values of system variables into two classes: normal and deviant. As Kjellén states, this is an oversimplification.

According to Kjellén (1987), several different types of norms, on the basis of which deviations are established, can be identified in the safety literature. These norms for the ‘ideal’ value of system variables may consist of standards, rules or regulations. In addition, judgements of what is (a) adequate or acceptable, (b) normal or usual, (c) planned or intended, may serve as norms.

By examining whether the actual output of a system deviates from a norm, the system can be moved in the direction of the norm. Thus, a basic premise is that the probability of an accident can be reduced if deviations can be eliminated or controlled (cf. Harms-Ringdahl, 1987).
Technical approaches
Some authors study accidents exclusively from a technical viewpoint (for instance, Ferry, 1988; Hammer, 1980; Himmelfarb, 1985; Lement & Harwood, 1992; Thygerson, 1986). These technically oriented approaches generally comprise a systems perspective. Ferry (1988), for example, discusses possible technical failures within various types of systems, such as hydraulic, electrical and robotic systems.

Behavioural approaches
Behavioural approaches entail models of information processing, decision-making and the cognitive control of behaviour.
Many accident theories emphasise the relevance of the information processing and decision-making processes of the individual (see e.g. Andersson et al., 1978; Chang & Jovanis, 1990; Feggetter, 1982; Hale & Glendon, 1987; Ramsey, 1985; Rasmussen, 1986; Robinson, 1981; Surry, 1974). Information processing - which is generally involved with decision-making - is seen as taking place in several subsequent phases: perception, recognition, evaluation, decision and performance. The human is seen as an information processing channel with a limited capacity. A deficiency in one of the phases eventually leads to a badly adjusted response. As a consequence, the probability of an accident increases (see e.g. Ramsey, 1985; Surry, 1974). As an example Ramsey’s model of accidents involving consumer products is given, which is based on Surry’s model (1974). The model is a mixture of information processing and decision-making, see figure 2.3.

A model of the cognitive control of human behaviour is the Rasmussen model (Rasmussen, 1983, 1986, 1987, 1990a), in which a skill-based, a rule-based and a knowledge-based level are distinguished. Skill-based behaviour ‘represents sensori-motor performance during acts of activities that, after a statement of an intention, take place without conscious control as smooth, automated, and highly integrated patterns of behaviour’ (Rasmussen, 1990a, p. 47). At the rule-based level ‘the composition of a sequence of subroutines in a familiar work situation is typically consciously controlled by a stored rule or procedure that may have been derived empirically during previous occasions’ (p. 49). At the knowledge-based level, the control of performance moves to a higher level: ‘the goal is explicitly formulated, based on an analysis of the environment and the overall aims of the person. Then a useful plan is developed - by selection. Different plans are considered and their effect tested against the goal, physically by trial and error, or conceptually by means of 'thought experiments'’ (p. 49). These three levels are not mutually exclusive. A task can be controlled simultaneously at different levels.
The Rasmussen model has been used as a framework for classifying human errors (see Reason, 1990). A frequently made distinction is the one between slips and mistakes. Slips, i.e. actions other than intended, occur on the skill-based level, and
mistakes, i.e. intentions that are not appropriate for the purpose, can be found on
the rule- and knowledge based level (Rasmussen, 1990a; Reason, 1990).

![Figure 2.3](image)

The accident sequence model of Ramsey (1985, p. 116). The model depicts various levels of human interaction with a hazardous product. The hazard must be perceived (via one of the senses) to be recognised as a hazard, which requires information processing. When the user recognises the hazard, he/she has to make a decision whether to avoid the hazard. If the user decides to avoid the hazard, he/she has to be able to do so, an ability that is limited by the user's anthropometry, motor skills and biomechanics. With each unsuccessful phase, the probability of an accident increases.

Human errors are assumed to provide insight into accidents, since they are presumed to have similar precursors (Reason & Mycielska, 1982; Reason, 1990). Hale & Glendon (1987, p. 8) note that this assumption has remained largely untested. As with the concept of deviations, the assignment of error assumes a criterion for what is correct (cf. Kjellén, 1984; Lewis, 1981).
Combinations of approaches
In fact, many combinations of the various perspectives can be found. As previously mentioned, they are not mutually exclusive (cf. Andersson et al., 1978). For example, Shannon & Manning (1980) combine the chain of multiple events with energy exchange. Tuominen & Saari (1982) unite the chain of events, systems approach and the energy exchange model. Corlett & Gilbank (1978) use a combination of systems approach, the human information processing model and the epidemiologic perspective. Kjellén & Larsson (1981) use the deviation concept with the chain of events. The Rasmussen framework, systems approach and information processing are linked up by Hale & Glendon (1987).

2.2.2 Discussion

In most approaches - implicitly or explicitly - traffic and occupational conditions are emphasised rather than the use of consumer goods. Usually, aspects which typify the use of consumer products, such as the considerable diversity in user populations and the great amount of freedom as to how, where and when to use a product, are not taken into account. Rather, job selection, training, specified tasks and environments are considered (cf. Cushman & Rosenberg, 1991, p. 1-3). In several approaches, such as systems approach, the deviation concept and human error models, the notion of a norm does not match with the aforementioned characteristics, like the relative freedom of how and where to use a consumer product. Nor is this freedom reflected in frequently heard terms such as ‘abuse’, ‘misuse’ and ‘improper use’ (see e.g. Kreifeldt & Alpert, 1985), which point to the assumption that some kind of normal or correct way of how to use a product exists. Such an assumption betrays an observer’s perspective, which may be completely at odds with the user’s perspective of what is normal or reasonable to do with a product (cf. Hale et al., 1990, p. 1379).

The widespread systems approach is criticised by some authors, e.g. by Singleton (1984, p. 3). He argues that theories of the systems type ‘can explain anything but predict nothing’. According to Huguenin (1988), system-analytical models neither explain nor comment on patterns of behaviour. These criticisms, however, seem to account for all perspectives dealt with in this paragraph. They appear to be conceptual frameworks rather than theories.

The behavioural and technical approaches can be characterised as one-sided. In the technical approaches, the human elements remain out of the picture. In the behavioural approaches, the product is allotted only a marginal position. See, for example, Ramsey’s model (figure 2.3), in which the interaction with the product is limited to a block attached to the top of the figure.
Chapter 2

Rasmussen (1986) emphasises that human error should merely be seen as a result of human variability, which is an essential element in human learning and adaptation. However, the concept of human error as a deviation from some kind of norm seems incompatible with the inherent variability in human performance. What should then be taken as a norm?

Several other difficulties have been observed with the notorious concept of error (see Ridley, 1991). Apart from the confusion surrounding the definition of ‘error’, the term ‘error’ has a moral overtone implying blame (Brown, 1990; Hale & Glendon, 1987; Ridley, 1991). Sellen & Norman (1989) conclude that the available theories of human error do not yet help in the prediction of accidents, since a coherent perspective on errors is lacking, and since the predictive power of existing theories is limited (see also Ridley, 1991).

The monocausal view of accidents is obviously too narrow a perspective on accidents with their multifarious characters (cf. Hale & Hale, 1970). The energy exchange model does not exclude anything, since all physical events involve energy exchange (Surry, 1974). The chain of multiple events and the epidemiological approach both miss what the other has. A chain of events does not explicitly reflect the interaction between man and machine, while in the epidemiological approach the perspective of accidents as a result of a sequence of events seems to be ignored.

The shortcomings indicated above make a single approach to the observation of accidents involving consumer products an unattractive choice. Therefore, an approach is introduced that is attuned to accidents with consumer products, see chapter 3.

2.3 Contributory factors

This paragraph provides a review of the factors that have been put forward as (possibly) relevant for the occurrence of accidents. The factors are ordered in terms of actions by the user (§ 2.3.1), the product (§ 2.3.2), the environment (§ 2.3.3) and the user (§ 2.3.4). These are common elements found in the literature, see Lehto & Salvendy (1991).

Some statements on the relevance of the contributory factors mentioned hereafter are no more than suggestions. Other statements are based upon empirical evidence. Note that in most cases this evidence was obtained by means of the various research methods that are discussed in the next paragraph.

Some authors emphasise the importance of the task people are carrying out (for instance, Drury & Brill, 1983; Winsemius, 1969a). Authors’ opinions on what constitutes a task differ widely. Sometimes the material to be processed is seen as the task (as in Drury & Brill, 1983, p. 339), while in our view the material
processed is an environmental factor. At other times the actions to be carried out by the user are seen as the task (e.g. Ramsey, 1985, p. 121). For these reasons, the task is not discussed separately.

2.3.1 Actions by the user

In the literature, only global descriptions are available of people’s actions, i.e. what people do with a product in terms of manipulations, postures, movements and so on (cf. Kanis & van Hees, 1995; Kanis & Marinissen, 1991). If considered at all, the reliance is generally on self-reported behaviour. Only now and then are people’s actions observed (see for example Branton, 1970; Ramsey et al., 1986; Winseminius, 1965), but in those cases the actions observed are not always documented. And if descriptions are provided, these often consist of value judgements, such as ‘unsafe placing of tools, equipment, or materials’ and ‘unsafe body movements’ (see Ramsey et al., 1986, p. 23-24), thus blurring the findings concerning people’s actual behaviour. Such ‘observations’ are a reminder of the identification of errors.

2.3.2 The product

The appearance of a product may be relevant in the occurrence of accidents (Kreifeldt & Alpert, 1985; Laughery, 1993; Singer, 1993). On the one hand, the product’s appearance may provoke particular ways of use, such as when the product does not provide feedback about its hazards or when it looks safe when it is not (Frantz & Miller, 1993; Laughery, 1993; Norman, 1988). On the other hand, form can alert users and invoke safe ways of use (Singer, 1993, p. 85). Singer (1993) indicates that little is known on product form and safety.

Product features that may influence product use include colour, texture, composition, size, shape, mass, finishing, elasticity, rigidity, reflection, transparency, fragility, graphics, such as signs or symbols, centre of gravity and stability (Drury & Brill, 1983; Gibson, 1977, p. 75; Singer, 1993).

In addition to product appearance, product failures can play a part in accidents (see e.g. Ferry, 1988; Hammer, 1980; Himmelfarb, 1985; Lement & Harwood, 1992; Thygersen, 1986). The properties of materials and of the product as a whole, such as the maximal mechanical forces a product can stand, may contribute to failures (see Hammer, 1980; Lement & Harwood, 1992). During the lifetime of a product, lack of maintenance, stress due to use conditions (e.g. load) and environmental influences (e.g. corrosion), and the inevitable wearing out of the product are factors affecting product failures (Hammer, 1980; Lement & Harwood, 1992).
2.3.3 The environment

**Material environment**

Environmental factors such as obstructions, (working) surface, available workspace, temperature, noise, lighting and weather conditions are indicated as relevant either directly for the occurrence of accidents or for human performance (see e.g. Cohen & Lin, 1991a; Drury & Brill, 1983; Evans, 1991; Farmer, 1932; Feggetter, 1982; Hale & Hale, 1972; Ramsey, 1985; Surry, 1974). In addition, the characteristics of the material processed (for instance, wood or vegetables), such as its dimensions and condition, may be relevant (e.g. Drury & Brill, 1983). Nijsten & Willemsen (1991) investigated whether there is a relationship between the cycles of the moon and the number of accidents brought into the emergency department of a hospital. The authors did not find a relationship.

**Social environment**

Various authors provide evidence for the relevance of the social environment, such as social patterns in road accidents and sociological factors in childhood accidents (see Haddon et al., 1964). More directly, people present near the user of the product may distract or hamper the user. They may even become the one who is injured (as was found by Jaartsveld & Mulder, 1990).

In industrial safety, the role of organisational factors, such as management and the allocation of tasks, in the occurrence of accidents has been stressed (for example, Robinson, 1982; Wagenaar & Reason, 1990).

Life events, such as the death of a spouse, a change of job or a divorce, can be seen as social factors. These events may distress people temporarily (Porter, 1988). Several studies found that people who recently experienced a life event were more frequently involved in accidents (Evans, 1991; Porter, 1988). Others did not find an association between life events and involvement in accidents at work (see e.g. Verhaegen and colleagues, 1976).

2.3.4 The user

Humans apparently have sensory, mental and physical characteristics. In addition, a distinction can be made between temporary conditions, such as fatigue, and people’s more or less permanent characteristics, such as knowledge and personality traits. Thus, the various characteristics of the user are ordered in terms of the temporary condition, and the sensory, mental and physical characteristics (cf. Ramsey, 1985; Surry, 1974; Wilson, 1984). Accident proneness does not fit into one of the above mentioned human characteristics and is therefore discussed separately.
Temporary condition of users
People's temporary sensory, mental and physical condition includes being hurried or irritated, clothing, fatigue, menstruation, attention and distraction (see Cohen & Lin, 1991a; Feggetter, 1982; Hale & Glendon, 1987; Porter, 1988; Ramsey, 1985; Ramsey et al., 1986; Surry, 1974). Some studies found that attention tests are good predictors of accident involvement (Guilford, 1973; Porter, 1988), a finding that could not be confirmed in several other studies (see Porter, 1988). Hale & Hale (1972, p. 42) state:

Inattention has often been cited as a cause of accidents...but those who use the term often treat it as a scapegoat which enables them to avoid delving more deeply...

Drinking alcohol and using drugs is frequently associated - especially in traffic - with accidents (Evans, 1991; Feggetter, 1982; Guilford, 1973; Hale & Hale, 1972; McKenna, 1982; Surry, 1974). Only excessive fatigue has been found as a contributory factor in the occurrence of accidents (Farmer, 1932; Hale & Hale, 1972; McKenna, 1982).
A relationship has been suggested between alertness, or arousal, and performance: the efficiency of people's performance increases to an optimum as arousal increases, but declines again when arousal becomes very high (this is called the 'inverted-U hypothesis', see Brown, 1990, p. 761). According to this hypothesis, accidents are most likely to occur when arousal is low (e.g. when people are bored or drowsy) and high (e.g. when people are anxious or extremely motivated).

Biorhythm theory claims that people's condition is governed by three cycles: a physical cycle of 23 days, an emotional cycle of 28 days and an intellectual cycle of 33 days (see McKenna, 1982; Nijsten & Willemsen, 1991). These cycles start at birth and are regularly repeated until death. The days on which the cycles are changing from positive to negative are supposed to be the critical ones. On these days people are more prone to involvement in an accident. Thus if people knew their critical days, they could behave more carefully. So far, evidence supporting biorhythm theory is practically non-existent (see e.g. Ernst & Brühning, 1988; McKenna, 1982; Nijsten & Willemsen, 1991; Wolcott et al., 1977).

Sensory and physical characteristics of users
Sensory and physical characteristics include the body dimensions, exertable forces, handedness, state of health, the functioning of the senses, and perceptual-motor skills and performance.
The dimensions of the body, such as weight and stature, are put forward as potentially relevant in the occurrence of accidents (see e.g. Hale & Glendon, 1987; Molenbroek, 1994; Ramsey, 1985; Steenbekkers, 1993).
Exertable forces are also suggested as relevant in accidents (see e.g. Daams, 1994; Ramsey, 1985; Steenbekkers, 1993; Surry, 1974). Surry (1974) indicates that
forces incorrectly applied and required forces exceeding a person's exertable forces have been found as contributory factors in accidents. Coren (1989, 1992) found that left-handed people reported a higher accident involvement than right-handed people. An explanation Coren (1992, p. 244) offered for the left-handers' liability to accident involvement is that the world is generally designed for right-handed people.

People's state of health, including (chronic) diseases and impairments, may be associated with accident involvement (see, e.g., Hale & Glendon, 1987; Hale & Hale, 1972; Surry, 1974). The functioning of the senses, including vision, hearing, and touch, has been associated with accidents (see, for example, Evans, 1991; Hale & Glendon, 1987; Hale & Hale, 1972; Surry, 1974). Some authors found that people are well able to compensate for their (temporary) disabilities (Kanis & van Hees, 1995; Surry, 1974).

People's perceptual and motor skills, such as speed of reaction, visual-manual coordination and accuracy of movements, and their involvement in accidents has repeatedly been investigated (see Guilford, 1973; Hale & Glendon, 1987; Hale & Hale, 1972; Porter, 1988; Ramsey, 1985; Steenbeekers, 1993; Surry, 1974). The findings of such studies are mostly contradictory.

People's movements are prone to fluctuations and variations in velocity and accuracy around the ideal path (e.g., Andersson et al., 1978; Branton, 1970; Surry, 1974; Winsemius, 1965), see figure 2.4. In this view, accidents are seen as a result of extreme fluctuations exceeding a particular boundary.

![Figure 2.4](image)

**Figure 2.4**
*The motion of a hand in a machine preceding an accident (source: Surry, 1974, p. 32).*

The question is whether or not people are aware that their actions vary (Sheridan, 1984). Take, for example, attempts to explain the phenomenon of unintended acceleration, as described in police reports (see Schmidt, 1989). People start their car (with automatic gear), press the accelerator, and mistakenly believe that they are braking. Occasionally, it may take up to 12 seconds before the driver notes his
or her error, amounting to a speed of 64 km/h. The incorrect positioning of the foot, which often leads to an accident, is ascribed by Schmidt (1989) to spinal- or muscle-level variability. Brehmer (1990, p. 1231) argues that variability in human performance 'introduces a limit to the extent to which a person will be able to adapt to the environment'. A problem with variable performance is that we cannot predict it. For example, we cannot predict whether our reaction is going to be fast or slow. Accidents are a token of this limited predictability of our performance (Brehmer, 1990).

Mental characteristics of users
Mental characteristics included in this review are cognitions (e.g. experience, knowledge), risk perception, attitude and motivation, personality, intelligence and demographical characteristics. The role of drivers' and workers' (in)experience in accidents has repeatedly been investigated (see for instance Cohen & Lin, 1991a; Evans, 1991; Hale & Hale, 1972; Surry, 1974). On the one hand, inexperienced drivers or workers are found to be more frequently involved in accidents than experienced ones (Farmer, 1932; Hale & Hale, 1972). On the other hand, when people are very familiar with a situation their attention may decrease, thus incurring an accident (Hale & Hale, 1972, p. 42). This is called 'overfamiliarity'. Hale & Hale (1972) remark that it is important to distinguish the type of experience people have, for example, experience in industry, in the firm, with a specific task and so on. Gelderblom (forthcoming) examined the role of cognitions in operating unfamiliar consumer products. In several experiments Gelderblom showed that previous experience with a product may hamper the operation of unfamiliar products, i.e. fixation occurs. Also, people with heterogenous experience have more success in the operation of unfamiliar products than people who have one-sided experience.

In the safety literature, overwhelming attention has been paid to the perception of risks. At least twenty definitions of risk can be found, each including different aspects of risk, such as probability, frequency or severity (Vlek, 1990). Subjective risk or perceived risk, defined as the personal evaluation of risk, can differ from objective risk, which is the risk of becoming involved in an accident according to, for instance, the number of accidents per unit of time or distance travelled (see Brehmer, 1994; Haight, 1986; McKenna, 1987, 1988; Näättäinen & Summala, 1976; Sabey & Taylor, 1980; Summala, 1988). For example, when people are asked to assess the frequency of accidents, infrequent accidents are generally overestimated, while frequent ones are often underestimated (Wogalter et al., 1993). Several factors have repeatedly been identified as influencing the perception and judgement of risks and hazards. These factors include:

- familiarity and experience with a product: the more familiar someone is with a product, the lower the estimated risk of an accident (e.g. Brems, 1986; Leonard & Hill, 1989; Vlek, 1990; Wogalter et al., 1991; Wogalter et al., 1993);
• dread, including the severity of consequences: increasing dread is associated with increasing risk (e.g. Slovic, 1987; Vlek, 1990; Vlek & Stallen, 1986);
• voluntariness of exposure to the risk: voluntary exposure is perceived to be less risky than involuntary exposure (e.g. Vlek, 1990; Vlek & Stallen, 1980);
• the controllability of risks: more controllable means perceived as less risky (e.g. Vlek, 1990; Vlek & Stallen, 1980).

Laughery (1993) gives several possible reasons for peoples’ failure to perceive hazards associated with a consumer product (p. 11-12). For example, when a technology is new people may not yet know the hazards. In addition, accidents are rare events, and therefore we cannot learn about them. Also, people may not correctly understand or perceive the product.

People use particular strategies in making decisions in risky situations (DeJoy, 1987; Slovic, 1987; Slovic et al., 1982; Tversky & Kahneman, 1982). These strategies, also called heuristics, are rules people use in judging complex situations in order to facilitate the perception, structuring and processing of events (Tversky & Kahneman, 1982). Although, as a rule, such heuristics are adequate, they sometimes may result in biased judgements. Availability is the phenomenon by which people judge the frequency or probability of an event based on the ease with which information can be imagined or retrieved from memory (DeJoy, 1987; Slovic et al., 1982; Tversky & Kahneman, 1982). This implies that the riskiness of activities is underestimated when possible dangers do not come to mind easily, and is overestimated when they do, as in the case of frequent events. Overconfidence means that people have excessive confidence in their own assessments and performance (DeJoy, 1987; Slovic et al., 1982). For example, people often believe that they will not be involved in an accident (McKenna, 1993). Suppression bias concerns the tendency to selectively ignore information that conflicts with their existing interpretation of an event (DeJoy, 1987). Consequently, consumers’ pre-existing notions about risks associated with products may lead them to believe that precautions are not necessary (DeJoy, 1987). Some of the heuristics are also at issue in recounting accidents (see § 2.4.3).

Risk perception is often seen as a decision process (see e.g. Slovic, 1987; Wagenaar, 1992). Wagenaar (1992) contends that the approach to risks, as being accepted after conscious decision-making, may not apply to people doing their everyday things. Such activities are automatically controlled. On these occasions, accidents may not be attributable to misperception or conscious acceptance of risk (Wagenaar, 1992, p. 261).

A controversial theory is risk homeostasis, launched by Wilde (1982, 1986, 1989). In this theory, it is assumed that road users strive after a constant, target level of risk, which is embodied by the overall accident rate in a particular society. At any moment, the experienced level of risk is compared to the target level of risk. When there is a discrepancy between the two the behaviour is adjusted. The target level
of risk is supposed to be the unique controlling variable (Wilde, 1986): it is assumed to be independent from characteristics of the vehicle, or the road environment. A basic proposition of risk homeostasis theory is that the actual level of risk is maintained over time through a closed-loop, self-regulating process. An example is the change from driving on the left to driving on the right in Sweden. After the change, the accident rate dropped immediately, returning to the previous rate two years later. In terms of risk homeostasis (see Wilde, 1982), people first overestimated the risks, consequently adjusting their actions. After some time they discovered that the situation was not as dangerous as they expected. Therefore, people’s motivation to adjust their behaviour decreased, and they changed their actions again, but now towards the target level of risk that existed before the change, thus resulting in an increase in the number of accidents. According to Wilde (1982), interventions that do not increase the motivation to adjust actions will not reduce accident rates.

Haight (1986, p. 365) suggests that risk compensation may not only occur for external conditions, such as weather, but also for internal conditions. For instance, people who consider themselves clumsier than others may compensate for their clumsiness by avoiding particular occupations or activities. Wilde’s theory found both support and opposition (see for studies supporting risk compensation for consumer products Viscusi (1984) and Viscusi & Cavallio (1994), and for opposition Walton (1982)). Evans (1986) shows that road accident rates on different roads, over time, per individual etcetera, do not remain constant, as is argued by Wilde. McKenna (1987, 1988) observes that many factors are relevant for the occurrence of accidents, instead of the target level of risk only. In addition, there may be a great many other reasons for the failing of countermeasures, such as the way in which a measure has been implemented. With McKenna, several authors criticise the relevance of risk homeostasis theory when countermeasures are invisible (e.g. Haight, 1986; Hoyes & Glendon, 1993). Furthermore, McKenna doubts whether people always perceive risk, as is assumed by Wilde. Various authors argue that (road) users may have no perception of risk at all (see Näätänen & Summala, 1976; Wagenaar, 1992). McKenna (1988) concludes that risk perception is much more complex than is depicted in risk homeostasis theory.

The major part of the risk perception literature is dedicated to large, complex industries, such as nuclear power and chemical plants (see e.g. the papers in Brehmer & Sahlin, 1994). The extent to which findings from such research can be extended to consumer products may be limited. Studies into common or garden products are generally of the psychometric tradition, using multidimensional scaling techniques. People are confronted with various risk activities, varying from chemical industries to aspirin (see Slovic, 1994). Brehmer (1994, p. 84) points at the following fallacy in the psychometric tradition (see also Kanis, 1993a):
One problem in studies on risk judgement is that the judgements exhibit variance. Following traditional measurement theory, this variance is usually treated as measurement error with different subjects being considered as replications. This assumes that there are no systematic differences among subjects in how they understand the concept of risk and in how they make their judgements.

According to Brehmer (1994), people judge very different things when they judge risk, which puts the majority of research into risk perception into question.

People’s attitude towards hazards, and their motivation to take precautions, are considered relevant to their behaviour (Hale & Glendon, 1987). By some, the fear of injury is seen as a motive for all behaviour (Gibson, 1964). However, as Hale & Hale (1972) remark, safety is only one aspect that motivates behaviour.

Several studies have been undertaken into the role of personality in accident involvement, including aggression (Dahlbäck, 1990), counselling, social maladjustment, distractibility (Hansen, 1989), temperament (Guilford, 1973; Steenbekkers, 1993), attention seeking and repression of emotions (Dahlbäck, 1991). For reviews concerning personality and accidents, see Evans (1991), Hale & Hale (1972), Porter (1988) and Surry (1974). These reviews show that some studies found that personality characteristics are associated with accident involvement, but that other studies did not find a relationship between personality and accidents.

Some authors found that intelligent subjects are less frequently involved in accidents (e.g. Evans, 1991; Guilford, 1973). Apart from the controversies surrounding the concept of intelligence, findings pointing at the significance of intelligence in accident involvement are certainly not overwhelming (see Hale & Glendon, 1987; Hale & Hale, 1972; Porter, 1988; Surry, 1974).

Demographical characteristics of people that have been associated with accident involvement include age, gender, marital status, social class, profession and income (see Guilford, 1973; Hale & Glendon, 1987; Hale & Hale, 1972; Surry, 1974). Obviously, age and gender are closely related to other characteristics of users, such as experience and physical characteristics (see also Hale & Hale, 1972).

**Accident proneness**

Accident proneness (or accident liability) is the phenomenon, still controversial, that some people are more liable to get involved in accidents than others. If the people likely to incur an accident can be identified then they can be trained for or even excluded from particular activities (Porter, 1988, p. 201). Accident proneness has been surrounded by much confusion, partly because it has been defined in various ways (McKenna, 1983; Sass & Crook, 1981), for example, as a unitary trait, as a characteristic which varies with external factors, as a general characteristic (lifelong and across domains, e.g. at home/at work) and as an innate and immodifiable characteristic. In addition, the term ‘accident proneness’ is used
ambiguously: as a description and as an explanation (Cameron, 1975; Haddon et al., 1964, p. 386). As a description, accident proneness refers to the phenomenon that people differ in accident involvement, and as an explanation, it is used to denominite the causes of differences in accident involvement. This double use of the term, as adopted by several authors (see McKenna, 1982; Porter, 1988), gives rise to at least part of the confusion surrounding the concept (Cameron, 1975).

Accident proneness was launched by Greenwood & Woods (1964, first published in 1919) who posited that it was a lasting and fixed trait. They used the curve-fitting technique, in which statistical distributions are compared to the distribution of the number of accidents over individuals, see figure 2.5. Greenwood & Woods found that the distribution of accidents involving women working at a munition factory was better described by the negative binomial, indicating unequal liability, than by the Poisson distribution or the biased liability curve. Thus, the authors conclude, accident proneness is a decisive factor for the distribution of accidents over people.

![Graph showing the distribution of accidents](image)

**Figure 2.5**
The three distributions that are compared to the actual distributions of people's accident involvement are chance, biased and unequal liability. In the chance (Poisson) option the distribution of accidents over people is random. In the biased distribution the assumption is that, after having been involved in an accident, the probability of involvement in a future accident either increases or decreases. In the unequal liability (negative binomial) distribution some people are more liable to get involved in accidents than others (source: Porter, 1988, p. 179; Porter used the data of Greenwood & Woods, 1919).
Much of the discussion centred around the statistical techniques that Greenwood & Woods and their followers used (McKenna, 1983; Porter, 1988). Critics argued that there are many explanations for the negative binomial other than individual liability to accidents. The distribution can also be explained in terms of, for example, differences in exposure (Hale & Glendon, 1987; Koornstra, 1978; McKenna, 1983; Porter, 1988; Sass & Crook, 1981; Suchman & Scherzer, 1964; Walbeehm, 1960) which in turn may be a consequence of differences in environmental factors as well as variation over time (Boyle, 1980; Sass & Crook, 1981). Apart from exposure, the groups compared should be homogenous in order to preclude differential involvement because of differences in, for example, age and experience (Porter, 1988; Walbeehm, 1960). Furthermore, there is a good chance that few people are involved in a large number of accidents (Koornstra, 1978; McKenna, 1983; Porter, 1988; Sass & Crook, 1981; Suchman & Scherzer, 1964; Walbeehm, 1960).

Another statistical technique used to determine accident proneness is to compute the correlation coefficient of the accidents in two periods. The idea is that people incurring accidents in one period will also be involved in the next period. The argument given above, about not accounting for exposure, also applies to the correlation technique (McKenna, 1983; Porter, 1988; Walbeehm, 1960). The findings from studies using statistical approaches are contradictory; some authors identify accident prone people, while others cannot find any (Porter, 1988). Since the statistical approaches do not provide insight into the factors underlying accident proneness, much research has been conducted to find out whether physiological and psychological characteristics of accident prones differ from people who were not identified as accident prone. Such characteristics include psychomotor skills, perception and attention, intelligence, life events and personality (McKenna, 1982; Porter, 1988). People’s characteristics are correlated with the number of accidents they had during a particular period. Again, findings are controversial (McKenna, 1982; Porter, 1988; Surry, 1974). In addition, the correlations found are low (Hale & Hale, 1987; McKenna, 1982; Porter, 1988). As Porter remarks, authors are not always explicit on how the subjects are selected, their exposure and how many accidents the subjects should have had to be typified as accident prone. Various authors note that the definition, the recording and the reporting of accidents have been far from perfect in research into proneness (Boyle, 1980; Sass & Crook, 1981).

Cameron (1975) points out that the reduction of accidents by removing or training accident prones is marginal. Mohr & Clemmer (1988) computed that the removal of individuals with excessive injuries and the replacement of these workers by others leads to a reduction of only 7.4% of the accidents.

Accident proneness - with its inference of ‘carelessness’ - has been criticised because it is used as a ‘licence’ to blame the victim (Sass & Crook, 1981). To conclude with Sass & Cook (1981, p. 175):
For the purposes of industrial accident prevention, however, it would be more appropriate to discard this notion in favor of a more integrated and broader understanding of the nature of the interaction between workers and their socio-technical work environment.

2.3.5 Discussion

In the literature various factors are suggested as potentially contributing to the occurrence of accidents. The review of the factors shows that findings are generally not very convincing and frequently contradictory. It remains to be seen whether the factors suggested in the literature are actually relevant for accidents in the domestic sector. This thesis explores the extent to which factors can be reasonably identified as contributory to the occurrence of accidents with consumer products.

While the factors contributing to product failures seem to be well-understood, little appears to be known about the relevance of the appearance of the product. What little study has been done on the actual use of products is based mainly on the self-reports of users. Obviously, what people say they do can differ substantially from what they actually do (cf. Deutscher, 1973).

Human characteristics, including factors such as personality which are only remotely related to accidents, have been addressed extensively in the literature. Johnson (1973, p. 57) remarks:

Particularly in trying to deal with the exasperating human factor, we must begin with actual behavior rather than with the often vague antecedent concepts of attitude, responsibility, education, or motivation.

As long as the link between human characteristics and the manner in which people use a consumer product remains obscure, the findings obtained in research into human characteristics have little relevance for the design of consumer products.

2.4 Research into accidents

In this paragraph, the literature on the pros and cons of various methods of accident research is described. A distinction is made between:
- retrospective versus concurrent research;
- research into accidents versus near-accidents.

After a discussion of these variants (§ 2.4.1), they are evaluated with respect to their appropriateness for the aim of the present study (§ 2.4.2). Since validity is always a matter of concern in retrospective research, the literature on, for example, the questioning of eyewitnesses is discussed (§ 2.4.3).
2.4.1 Methods in accident research

Retrospective versus concurrent research
The most obvious way to obtain insight into accidents is to study them in retrospect. Conventional methods of accident investigation in the domestic sector are telephone interviews, mail questionnaires and investigations on-site, of which mail questionnaires are most frequently used, at least in the Netherlands. Consumer safety organisations, such as the Dutch Consumer Safety Institute (Stichting Consument & Veiligheid) and the Consumer Product Safety Commission (U.S.A.), have conducted many retrospective studies into domestic accidents. Examples of studies conducted by the Dutch Consumer Safety Institute are the investigation on-site of accidents in cleaning windows (Mertens, 1988), a mail questionnaire among people who were injured in accidents involving chain saws (Jaartsveld & Mulder, 1989) and telephone interviews concerning accidents involving equipment for physical exercise (Dorsman, 1989).

In accident research, nothing is known about the characteristics of people who are not involved in accidents. Haddon et al. (1964, p. 30) pointed out the relevance of including ‘controls’ in accident research, as is customary in the social sciences. Therefore, the people involved in an accident (the cases) should be compared to a reference population (the controls), thus conducting a so-called case-control study (cf. Bouter et al., 1989). The cases are matched with the controls on as many variables as possible, except, of course, with respect to the variable under study (Waller, 1977). Comparing cases and controls is generally limited to general factors, such as type of ski binding (Bouter, 1988), type of residential swimming pool (Rodgers, 1989) and social circumstances (Svensson et al., 1992).

A key word in case-control studies is ‘comparability’. See Bouter and colleagues (1989) for a discussion of the limitations of case-control studies. The variables should be measured in the same way for both cases and controls, which requires standardised questionnaires. Despite standardisation, comparability may be threatened, for example because the cases try very hard to recall the accident, while the controls do not have this incentive (Bouter et al., 1989).

There are several examples of case-control studies into domestic accidents. Svensson et al. (1992) compared the social and medical characteristics of elderly people who had an accident involving a fall with the characteristics of elderly people who did not fall. In another study, the home situation of children who (nearly) drowned in the residential swimming pool was compared to the situation of other children with a residential pool (Rodgers, 1989). In case-control studies large numbers (amounting to hundreds) of respondents are used.

Validity is always a matter of concern in retrospective research (see § 2.4.3). As is known from the literature, people’s accounts may be biased by memory processes and heuristics. These threats to validity may be partly obviated by concurrent
research into accidents, which literally waits for accidents to occur. For example, locations where accidents are expected to occur are observed continuously by camera. By filming the staircases in the lobby of a geriatric complex, Holliday et al. (1990) hoped to record accidents involving falls. In this way, it is not necessary to rely exclusively on a reconstruction of accidents in retrospect. This type of research, however, carries the risk of spending too much time and effort while observing no accidents at all. For instance, Oude Egberink et al. (1988) videotaped a particular traffic junction during one and a half years. Based on the number of accidents during the previous years, about five or six accidents per year were expected. At the end of the observation period only one accident had been observed.

In the domestic area, there is one example of a study yielding no less than 370 accidents, including cuts, burns, bruises and falls (Guilford, 1973). These accidents were observed in a group of 226 women, who performed various tasks in a laboratory kitchen, such as washing dishes, ironing clothes and cleaning the kitchen (total time per subject two hours). Guilford remarks that it had never been necessary to interrupt the tasks longer than the time it took to apply a bandage.

Several types of experimental studies - either in the laboratory or in the field - can be found in the area of safety. In traffic safety, simulators are used in which the user, for example, seated in a real car, is confronted with videotaped accidents or computer generated traffic situations (see Evans, 1991, p. 126). Rubinsky (1977) reports the use of accident simulators, e.g. one simulator imitated the dies of a press. When the fingers are not removed in time, the dies can amputate the finger(s). The machine was changed so that the upper die was made of soft material leaving an ink mark when touched. Thus, when the fingers are hit by the die this leaves an ink impression. Rubinsky (1977) claims that the simulators are valuable for training people in using machines.

**Accidents versus near-accidents**

Because accidents tend to be rare, the study of near-accidents, near-misses or critical incidents has been used as an additional means of obtaining insight into the precursors of accidents (cf. Gerbert & Kemmler, 1986; Grayson & Hakkert, 1987; Kruysse, 1993; van der Schaaf, 1991, 1992). The investigation of human errors also comes under this heading (see e.g. Kruysse, 1992; Reason & Mycielska, 1982).

It is crucial to have a definition of near-accidents. In traffic safety, the traffic conflicts technique is often used for estimating potential collisions (e.g. Brown, 1991; van der Horst, 1990). A traffic conflict is a meeting of road users in which one of them has to take an evasive action to avoid a collision (Brown, 1991).

Measures for rating the conflict are, for example, time to collision (i.e. the time between the beginning of the evasive action to the point at the roadway at which a collision would have occurred without the evasive action), and the risk of collision as judged by observers. Gerbert & Kemmler (1986), who asked pilots to report
Chapter 2

Aircraft incidents, do not provide a definition of what is an incident. In the domestic sector the definition of near-accidents is not as straightforward as in traffic. Coppens & Gentry (1991) video-recorded playgrounds at schools. They defined near-injury as the abrupt contact of a child with the environment, while the child resumes playing. This definition is not as equivocal as Guilford’s (1973, p. 308), who defined near-accidents as ‘unplanned events that logically could have resulted in an accident’. Clearly such a definition leaves much room for interpretation.

A basic premise in the study of near-accidents and errors is that the precursors of accidents and near-accidents are similar (e.g. Reason & Mycielska, 1982, p. 3-4; Van der Schaaf, 1991, 1992). According to Grayson & Hakkert (1987, p. 46) the notion of near-accidents is based on ‘the assumption that there exists a continuum of events that range from normal ‘safe’ driving through to accident and injury’. The assumption that near-accidents are predictors of accidents is under discussion (see Grayson & Hakkert, 1987; Hale & Glendon, 1987; Kruysse, 1993). So far, research has shown that traffic conflicts do not predict the occurrence of accidents very well (Kruysse, 1993).

2.4.2 Discussion

For several reasons, retrospective research into accidents appears to be the most appropriate for application in our exploratory study. To begin with, no insight is available into the factors affecting accidents involving consumer products. Therefore, the study of near-accidents involving consumer products seems too premature; it is not yet clear to what extent near-accidents predict the occurrence of accidents. For the same reason, the use of (accident) simulators does not seem appropriate either. As Haddon et al. (1964, p. 86) remark, simulation requires thorough insight into what is to be simulated. The second reason for conducting retrospective research is that data acquisition is not as uncertain as in concurrent research, although the latter is preferable from the viewpoint of validity. As was explained, concurrent research brings with it the risk of spending much time and money, while no accidents are observed. Thirdly, research into accidents is preferable to experimental and laboratory studies for ethical reasons. To bring subjects deliberately into a situation in which they may be injured, or to provoke accidents in a laboratory, would create ethical problems.

In the present study, no external controls, i.e. people not involved in an accident, will be included. Since this study is not focussed on a particular product or type of accident, an adequate selection of controls is practically impossible. However, when the use of products without accidents remains unknown, the conclusions that
can be drawn are limited. Within this study, several possibilities will be used to find out as much as possible about product use that did not result in accidents.

2.4.3 Validity in retrospective research

In retrospective research, the validity of inferences is threatened by, for example, memory processes. In research into domestic accidents the single precaution usually taken to minimise bias is to limit the time between the accident and the questioning of subjects (see Weegels, 1992a). In this paragraph, the literature on validity in retrospective research is explored to find out whether other precautions can be taken.

Most studies into the validity in retrospective research concern the questioning of eye-witnesses and victims in legal matters. In these studies, subjects witness an enactment of a crime or an accident, on film or live. Afterwards, they are questioned about the incident. The extent to which the subject’s account does not correspond to the actual occurrences can be termed as lack of validity. Lack of validity, or bias, can only be established by a comparison of findings with an external criterion (cf. Carmines & Zeller, 1988; Kanis, 1994).

First, a review is given of the influences of memory processes, heuristics and causal attribution. Possible differences between witnesses are briefly discussed. The paragraph concludes with implications for data collection.

Memory processes and other sources of bias

The processing of details of an event in long-term memory is generally seen as consisting of three stages (cf. Ellis, 1984; Hall et al., 1984; Smyth et al., 1987; Wells, 1988):

- acquisition or encoding: the perception of an event produces changes in the cognitive system;
- storage or retention: the change in the cognitive system is permanent;
- retrieval: the information is retrieved from memory.

In each stage, various factors may contribute to changes in the information. In this thesis, the discussion on what happens to information in the memory if new information is acquired, i.e. replacement or coexistence of information, is not further touched upon (e.g. Bekerian & Bowers, 1983; Hall et al., 1984).

People’s perceptions are selective to a large extent (cf. Wells, 1988). The encoding of an event depends on someone’s prior expectations and knowledge (Wells, 1988). When something is salient or obtrusive to the witness, perception and encoding are more exact (Eisenhower et al., 1991; Hall et al., 1984). High levels of arousal, such as stress, fear or anxiety, may also interfere with information acquisition, since they can disrupt a person’s cognitive functions (Wells, 1988). An example is the so-called ‘weapon-focus’, which is the tendency to direct excessive attention to a drawn weapon (Loftus, 1979). The perception and successive
encoding of an accident into memory become less exact when a situation is familiar, which means that cognitive activity is low (Smyth et al., 1987). During the storage of an experience in memory the view of what has happened can change. People bring up experiences from time to time, as when recalling an accident. Each time the story is brought up, the event is reconstructed in terms of what has been perceived. To this perception new interpretations of why it happened are added (Hall et al., 1984). In interpreting an event, people tend to bring their explanations to perfection (Wells, 1988). In the end, it becomes impossible for people to separate their perceptions from their thoughts and interpretations (Hall et al., 1984). It is generally acknowledged that the alteration of stored information increases with time (Dent & Stephenson, 1979; Eisenhower et al., 1991; Sudman & Bradburn, 1974; Wells & Loftus, 1984). Time per se does not seem to be responsible for this, since no memory losses occur when nothing is happening, for example, when sleeping. Rather, the opportunities for the acquisition of new information, which interferes with stored information, increase with time (Wells, 1988).

Apart from the continuous reconstruction of an event, post-event information and leading questions about what happened can influence people’s recall of events (Wells & Loftus, 1984; Smyth et al. 1987). Leading questions, which are questions with a strong, loaded use of words, may affect what witnesses think they have seen (Loftus, 1975; Loftus & Palmer, 1974; Yarmey, 1979). For example, Loftus & Palmer (1974, p. 587) posed two different questions to different groups of subjects, who saw the collision of two cars on video:

- "About how fast were the cars going when they smashed into each other?"
- "About how fast were the cars going when they hit each other?"

When asked a week later "Did you see any broken glass?", the subjects confronted with the ‘smashed’-question were more likely to answer ‘yes’. Thus, misleading information and leading questions that entail false presuppositions about what happened, may influence people’s account of what happened.

Successful retrieval depends on the availability of the right cues. An example of the search for such cues is that when people have misplaced an object they usually try to recall what they were doing at the time the object was misplaced (cf. Wells, 1988). Providing the witness with cues brings along the risk of these cues being false, thus misleading the witness (Wells, 1988). Therefore, cues should be generated by the witness. The retrieval of an experience from memory is improved if retrieving takes place in the same context or mood as at the time of the actual event (Smyth et al., 1987).

People’s account of events may have been influenced by heuristics, which are rules people use in judging complex situations in order to facilitate the perception, structuring and processing of events (Tversky & Kahneman, 1982). Heuristics may lead to biased judgements (see also § 2.3.4). In narrating an accident, these heuristics may have influenced people’s story as follows:
• availability: mentioning only easy available or readily recalled information of an event (DeJoy, 1987; Slovic et al., 1982; Tversky & Kahneman, 1982);
• suppression bias: selectively ignoring information that conflicts with the existing interpretation of an event (DeJoy, 1987);
• anchoring: sticking to the very first presented information (DeJoy, 1987; Slovic et al., 1982);
• overconfidence: having excessive confidence in the existing interpretation of an event (DeJoy, 1987; Slovic et al., 1982);
• hindsight bias: believing, while having outcome knowledge, that one could have predicted the outcome of an event (Fischhoff, 1975).

Effects of heuristics on stored memories are believed to be irreversible, they can never be cancelled (DeJoy, 1987; Kahneman et al., 1982). Note that the interviewer’s interpretation of a subject’s account can also be distorted as a consequence of heuristics.

Another phenomenon that deserves attention is causal attribution. The account that a subject gives of the causes of an accident may be biased in terms of the extent to which the occurrence of the accident is attributed to the victim, or to external factors. According to DeJoy (1990) and Kouabenan (1985), who investigated causal attribution in accidents, victims attribute the occurrence of an accident to external factors when the accident has severe consequences. When the accident has minor consequences, they tend to blame themselves for the accident.

Inter-individual differences
Witnesses may give a different account of the same occurrence for various reasons. People may differ with respect to the certainty with which they express themselves. The certainty, or confidence, of a witness is generally a poor measure of possible bias in the information given (Wells & Murray, 1984; Yarmey, 1979). This also applies to the comprehensiveness of people’s story. The information provided by people who give a fluent and detailed account of events is not necessarily more likely to be correct than information provided by people who say that they are not sure, or whose information is fragmentary (Leippe, 1994; Wells, 1988). Furthermore, witnesses may differ in their so-called response criterion, which may be lax or strict. A lax criterion is the tendency to also report weak memories, while a strict criterion is the tendency to report only memories of which the witness is absolutely sure (Wells, 1988).

Memory capacity may vary between people. Generally, elderly people and children provide accounts that are more biased than other age groups (Loftus et al., 1992; Smyth et al., 1987; Wells & Loftus, 1984). The difficulty is to distinguish which witnesses are delivering the more biased testimonies from the ones who give less biased accounts (Leippe, 1994).
Implications for data collection

Influences of memory processes of victims or spectators are generally seen as irreversible. Nevertheless, some precautions can be taken in the method of data collection to avoid further deterioration of the description of an accident as it emerges out of any reconstruction. To begin with, subjects should be visited as soon as possible to limit alterations of stored information. As far as can be seen, no maximum is recommended for the elapsed time.

The retrieval of information from memory may be improved if retrieving takes place in the same context or emotional state as at the time of the event. Various authors advise using aided recall in the case of retrospective questions (e.g. Sudman & Bradburn, 1974). For instance, retrieval may be stimulated by asking respondents to use documents or photographs. Dillman & Tarnai (1991) found that recall of seat belt use improved when the respondents were first asked to recall details about their last trip, such as date, destination and duration of the trip.

Sheehy (1981, p. 440) points at the dangers of asking the people involved in an accident to reflect on behaviour 'which was originally performed at a routine, non-reflective level of awareness'. On those occasions, ‘there may be a pronounced tendency to recall what one assumes must have occurred. There is a tendency to recall that which conforms to the expected’ (Sheehy, 1981, p. 440).

In the field of safety, various authors suggest interviewing people on the site of the accident, and asking them to show what happened (e.g. Ferry, 1988; Wilson, 1979; Winsemius, 1969b). To what extent such a demonstration of what happened is prone to the same influences as verbal reporting is not known. In human movement sciences, memory for movements has been extensively studied. These studies have shown that the forgetting of movements increases with time and that retention of movements improves the longer and more frequently these movements have been practised (see, for instance, Adams, 1987; Schmidt, 1988; Smyth, 1984; Stelmach, 1982).

Various authors investigated how the method of questioning witnesses influences the answers obtained. Subjects were confronted with an incident on film, followed by either an open interview or a closed questionnaire. On the one hand, the data obtained in the open interviews showed a closer correspondence with the occurrences presented on film than did the answers to the closed questionnaires. On the other hand, topics that were included in the closed questionnaire remained untouched in the open interviews, for example because respondents considered these topics as irrelevant or self-evident (Dent & Stephenson, 1979; Marquis et al., 1972). In addition, data gained in open interviews may be biased with easy-to-remember information (availability bias, see Marquis et al., 1972). The disadvantages of both open and closed questioning may be eliminated in a combination of the two (cf. Feggetter, 1982; Ferry, 1988). According to Wells (1988), the main principle in questioning witnesses is to start an interview with...
open-ended, general questions, gradually proceeding to more specific questions. Details and sensitive topics should be discussed at the end of the interview to preclude the possibility that people are biased towards particular answers (Loftus, 1975; Loftus & Palmer, 1974; Dent & Stephenson, 1979). Obviously, leading questions should be avoided as much as possible (cf. Loftus, 1979).

To summarise, people involved in an accident should be visited as soon as possible. The literature further suggests that accidents should be reconstructed on the spot, since re-enacting what happened may help in the retrieval of information. In order not to deteriorate people’s account any further, an open interview with a checklist as a backup is recommended. Subjects should first be given ample opportunity to give their own account of what happened.

2.5 Analysis of accidents

In the safety literature, various techniques of accident analysis can be found (see § 2.5.1). These techniques are examined to find out what they have to offer in the analysis of accidents involving consumer products (§ 2.5.2). In fact, the analysis of an accident cannot be dissociated from assumptions on the emergence of accidents. Several of the approaches discussed earlier (in § 2.2.1), such as the concept of deviations and systems approach, are encountered again here.

2.5.1 Techniques of accident analysis

Analysis of deviations
A prevailing method of analysis is to look for deviations, changes or variations in a standard, normal or desired situation, procedure or task (e.g. Kjellén, 1984, 1987). The analysis of human error, featuring the deviation of a prescribed task (cf. Leplat, 1978, 1982, 1984, 1987), also comes under this heading. To establish the standard work procedures to which the actual occurrences at the time of an accident can be compared, task analysis or work analysis may precede the analysis of deviations (see, for instance, Leplat, 1978, 1989; Moyen et al., 1980). The result is a review of (possible or actual) deviations, which serves as a basis for the prevention of accidents.

Multidisciplinary review
Some authors report that the accident data are reviewed in a multidisciplinary team, containing members from various disciplines (Christoffel et al., 1986; Holliday et al., 1990; Sabey & Taylor, 1980; for a review of multidisciplinary teams in traffic, see Grayson & Hakkert, 1987). The accident data are discussed
within the team, each member reviewing the data from the viewpoint of his or her discipline. The review results in conclusions about factors that may have contributed to the occurrence of each accident. The aim of this multidisciplinary review is to obtain a broad view of potentially contributory factors. For instance, video-recorded falls in a home for the elderly were reviewed by a team including industrial designers, physiotherapists and psychologists (see Holliday et al., 1990).

**Systems analysis techniques**
Many techniques have been developed for the analysis of (possible) accidents in complex systems, such as Management Oversight and Risk Tree (MORT), Failure Modes & Effects Analysis (FMEA) and Fault Tree Analysis (FTA). A compendium of techniques is provided by Clemens (1982). For instance, event trees, also called causal trees or causal networks, are widely used for arranging the causes that are identified (e.g. Armstrong, 1989; Hammer, 1980; Wagenaar & Groeneweg, 1987). By organising the events that culminate in an accident into a diagrammatical tree, the co-occurrences and sequence of events are clarified.

**Accident models**
Some authors use models of the accident process (see also § 2.2.1) to organise accident data (e.g. Andersson et al., 1978; Coppens & Gentry, 1991; Corlett & Gilbank, 1978; Tuominen & Saari, 1982; Williamson & Feyer, 1990). For example, Corlett & Gilbank (1978) propose an accident analysis procedure in which the stages of human information processing are explored. Each stage in the occurrence of the accident is studied to find out whether events, their environment, the condition and the experience of the person involved, influenced the perception of the situation and the decisions made.

**Causal checklists/taxonomies**
In this approach the causes of accidents are categorised by means of a checklist, classification or taxonomy, see for example Rouse & Rouse (1983), and Wagenaar & Groeneweg (1987), who use the checklist of Feggetter (1982) for classifying causes. Generally, such checklists or taxonomies are based on ‘existing knowledge’ (e.g. Feggetter, 1982, p. 1070). The checklists contain classes of possible causes of accidents or, in a human centred approach, possible human factors/errors. The causes of each accident are then classified according to the checklist.

**Scenario analysis**
In this type of analysis, accidents are clustered into scenarios in order to organise the findings into manageable subproblems (e.g. Cohen & Lin, 1991b; Drury & Brill, 1983; Stoop, 1990).
For example, a scenario description for accidents involving windows is: victim is male, glass is defective and injury is to upper leg (Drury & Brill, 1983, p. 334). Cohen & Lin (1991b) use descriptives for scenarios of accidents involving falls from ladders such as: slips on rungs, overreaches, stands on top rung.

**Preventive measures**

One method of analysis is to take preventive measures as a starting point, either to evaluate the effectiveness of a proposed countermeasure or to avoid the identification of causes (e.g. Ayres et al., 1991; Friedman et al., 1991). For example, Ayres et al. (1991) examined, on the basis of in-depth investigation reports, to what extent accidents involving All Terrain Vehicles could have been prevented if there had been a conspicuous flag.

**Combinations**

The methods and techniques that are distinguished so far do not preclude combinations of approaches. For example, Masson (1989) combines the concept of deviation with event trees. Armstrong (1989), Moyen et al. (1980) and Wagenaar & Groeneweg (1987) first arrange the causes of each accident in an event tree and then categorise these causes.

2.5.2 Discussion

A common flaw of most techniques discussed is that they are not explicit on how causes or contributory factors are, or should be, derived from accident data. The inference of causes is a crucial step in accident research, since the plausibility and falsifiability of findings depend on the extent to which the identification of causes can be made explicit. That the inference of causes remains untouched in the techniques described is most surprising, given the fact that these all involve human judges or experts. Except in the analysis of deviations and preventive measures, such judges are called in to identify the causes of accidents. Although it has been repeatedly remarked that the establishment of causes is subjective, i.e. that judges may reach different conclusions to a certain extent (e.g. Grayson & Hakkert, 1987; Groeneweg, 1992; Rasmussen, 1985; Sabey & Taylor, 1980), the reasons for these differences have rarely been questioned. Often, the problem of differences arising between judges is solved by continuing the analysis until agreement is reached (see e.g. Coppens & Gentry, 1991; Friedman et al., 1991; Williamson & Feyer, 1990). Indeed, in the multidisciplinary review, the assumption that there are differences between people from various disciplines is the pivot of the method. The different disciplines serve as a guarantee for the inclusion of all factors. However, the considerations judges used in identifying contributory factors still remain obscure.
2.6 Conclusions

The shortcomings of the current perspectives on the emergence of accidents make it unattractive to choose a single approach as a starting point for the observation of accidents involving consumer products. In the next chapter an approach is introduced that is attuned to accidents with consumer products. This approach includes the common perspective in the literature that accidents are the result of consecutive interactions between man and machine in an environment (cf. Lehto & Salvendy, 1991).

Many factors have been associated with accidents. In general, the evidence for the relevance of factors is not very convincing and often contradictory. The various possible contributory factors are included in the method of data collection in order to find out to what extent these factors can be reasonably identified as contributory to the occurrence of accidents with consumer products. The relevance of product appearance in accidents has hardly been explored, while human characteristics have received excessive attention, seemingly at the expense of actual behaviour. However, it is the actual product use that can be influenced via the design of the product, while the significance of human characteristics is limited to the extent that these characteristics can be linked up with how and where products are being used.

The evaluation of prevailing methods of accident research shows that for various reasons retrospective research into accidents is most appropriate. Since validity is always at issue in retrospective research, the literature on the influence of, for instance, memory processes has been explored. Various precautions can be taken to minimise bias, such as the reconstruction of the accident on-site and the combination of an open interview with a checklist.

A common flaw in current approaches to accident analysis is that they are not explicit on how the causes of accidents are identified. So far, little attention has been given to the identification of causes, although it has repeatedly been remarked that differences may arise in conclusions reached by judges and experts. As long as little is known about how causes are inferred from accident data, the outcomes of accident analysis can never be justified. Therefore, this thesis includes a study into this topic.
3. Observation of accidents

The approach serving as a starting point in the observation of accidents is described in § 3.2. Data were collected in an investigation on site (§ 3.3). A video-recorded reconstruction was made, followed by an interview and various measurements. Subjects (n=42) were recruited via hospitals, general practitioners and public calls. Indications for bias are explored (§ 3.4). The chapter concludes with a discussion of the method for the observation of accidents (§ 3.5).

3.1 Introduction

Insights derived from accident data may assist industrial design engineers in their efforts to set criteria for a safer product. A prerequisite for this is that the data are sufficiently comprehensive and that all possible precautions are taken to minimise bias. The method for the observation of accidents has been attuned to these aspects.

When precautions have been taken to minimise bias, it is important to monitor the results of these precautions, as they may have negative consequences. Therefore, the accident data are examined with respect to indications of lack of validity. For this purpose, various issues that might give indications of lack of validity are included in the method of data collection.

As was concluded in the previous chapter, existing perspectives on the emergence of accidents are not an attractive choice as a starting point. Therefore, an approach is introduced which is attuned to the observation of real life accidents involving consumer products. This approach is described first.

3.2 Approach

The approach introduced in this paragraph serves as a guiding principle for the observation and description of accidents involving consumer products. Before passing on to some basic premises, one remark should be made.

In the present study, theoretical insights derived from the literature served as input for the method of data collection. Subsequently, the data gathered with this method gave rise to new suppositions, which then were included in the investigation of ensuing accidents. Thus, suppositions, the method of data collection and the data eventually obtained are inevitably intertwined.
Chapter 3

In this study, an accident is seen as a consequence of the functioning of the product. In a technical/physical sense, this functioning is the result of the co-occurrence in time and place of a product, use activities (how a product is used) and situational characteristics (where a product is used). In the case of an accident the consecutive interactions culminate in injury. Obviously, only empirically observable co-occurrences are at issue.

How and, to some extent, where products are being used reflect human interference and thus may be linked with the temporary condition and sensory, mental and physical characteristics of the user. In addition, the role of the user comes to the fore in the evaluation of the functioning of a product. To the extent that this functioning does not match the user’s intentions and expectations, the user may adjust or change subsequent use activities, thus tuning accomplishments to intentions.

Accidents can be prevented by (re)designing the product in such a way that use activities and situational characteristics fall within safety margins (e.g. a safety valve on a pressure cooker), or that particular use activities and the choice of situational characteristics are blocked or discouraged. An example of the latter is provided by Mauro (1978), who discusses electrocution accidents as a result of hair dryers falling into bathtubs. To prevent these accidents, the powered parts of the redesigned hairdrier are fixed to the wall, while the hot air is led to the blower by means of a hose.

Characteristics of the user and some situational characteristics, such as the presence of bystanders, cannot be influenced or changed via the design of a product. However, industrial designers can attempt to attune their product to characteristics of the user, for instance, by matching the forces required in operating the product to the users’ exertable forces; of course, this only makes sense when there is evidence that force is exerted during the use of the product.

Possibly relevant characteristics to be included in the method of data collection are based on the literature, see the previous chapter (§ 2.3). Some factors are not, or at least not in detail, further considered for various reasons. These factors include biorhythm, the functioning of the senses (e.g. visual acuity), perceptual-motor skills (e.g. reaction time), intelligence and personality traits. Apart from the fact that the measurement of these factors is often surrounded by controversies, most of these factors seem to be only remotely related to accidents, which leaves their relation with people’s actions a matter of speculation.

Besides, if they are relevant in one way or another, they will become evident in other things, such as the temporary condition. For example, when someone is easily distractable, this reappears in the fact that he/she was possibly distracted at the time of the accident.

All other factors discussed in § 2.3 will be considered in the present study.
Functioning of the product
The technical/physical functioning of the product, which is conditioned by the use activities and the situation, comes to the fore as the output of the product. The primary output, i.e. the effectiveness of the product, may be accompanied by additional output, such as noise, vibrations, waste matters, energy released and so on. An injury may be the result of primary output (e.g. sustaining an incision with the blade of a knife) or additional output (e.g. heat, energy that is suddenly released). Additional output can be important in the prevention of accidents. For instance, noise produced by the product may serve to alert the user that the product is activated.
For the functioning of the product at least some human effort is needed. In addition, physical matter, such as energy and materials, may serve as input for the product.

Use activities
Use activities include all activities directed at the functioning of the product. These include physical actions as well as perceptual and cognitive activities. In order to use a product, users must employ their sensory perceptions as well as their mental and physical abilities. Obviously, a prerequisite for the use of a product is that the product is, or can be, perceived. The user may not perceive something because the visual field is obstructed, or because he/she is not looking at or not noticing something. The user’s understanding of the functioning of the product, i.e. what can be done with the product, may also affect the use actions. Perceptual and cognitive activities may influence physical activities. They cannot be directly relevant to the occurrence of injury, at least not in the case of the physically operated products in this study. Consequently, the products involved cannot be activated without a physical action from the user. Such physical actions concern in the first place what is done with the product, including what is not done (omitted actions). By detailing what is done with the product, how the product is used is described. The product and, if applicable, the material processed are in one way or another contacted with the hands or other parts of the body. Often, some amount of force exertion in a particular direction is needed to activate a product. The orientation and distance of the product in relation to the user, and the position of the product and/or the user in the environment, describe the location of product, user and environment with respect to each other. Some actions may proceed out of the user’s control, such as slipping with a product, inadvertently hitting or contacting the sharp parts of a product, or falling with or off a product. On these occasions, the user has no time to adjust his or her actions.
Obviously, the distinction between what is done with the product and how the product is used is a relative one.
Product
Characteristics of the product are relevant insofar as they are perceivable by the user, and, as such, affect use activities. Generally, these characteristics concern external features, such as colour, shape and texture. Incidentally, they may comprise internal aspects that are perceptible, e.g. when a product is powered. Product features that may influence product use include colour, texture, composition, size, shape, mass, finishing, elasticity, rigidity, reflection, transparency, fragility, graphics, such as signs or symbols, centre of gravity and stability (Drury & Brill, 1983; Gibson, 1977, p. 75; Singer, 1993). In addition, it seems obvious to include other factors, such as material, presence of breakages, state of maintenance and wear. As was indicated, the user’s role becomes important in the perception and cognitive evaluation of the functioning of the product. Consequently, the feedback that the product provides about its condition may be important for the evaluation of the accomplishments so far (e.g. Norman, 1988).

Situation
The characteristics of the situation are divided into material and social characteristics. Material characteristics include not only factors such as temperature and noise but also the material processed by the help of the product, e.g. the wood that is chopped or the cheese that is sliced. The space available, the floor or working surface, objects present, the working height and distance and so on describe the surroundings of the user. Material characteristics may influence the functioning of the product directly, such as the material processed, and indirectly via the user’s reaction to, for example, temperature or noise. Social characteristics of the situation concern people or animals present near the user. They may affect the use activities carried out, for example, in the case of physical hindrance, or the user’s mental state, e.g. distraction caused by bystanders.

User
How and where products are used may be linked with the characteristics of the user. Possible relevant characteristics of the user include the temporary condition at the time of the accident and sensory, mental and physical characteristics. The temporary condition of the user encompasses factors such as fatigue, cold hands and being hurried. Apart from asking subjects whether they were wearing their reading glasses at the time of the accident, perceptual characteristics are not measured, since this would be far too intricate for the aim of the present study. Mental characteristics concern the awareness of risks, experiences in the use of the product and with previous accidents (i.e. accident liability), and preferences and reasons for using a product in a particular situation for a particular application. Physical characteristics include stature, exertable forces and dimensions of the hands.
Deviations
Accidents may be seen as originating from deviations from some kind of norm. As the concept of deviations is a prevailing notion in the field of safety, this study examines to what extent deviations can be identified as relevant in the occurrence of accidents. For various reasons deviations are based on the user’s self-reports concerning their habitual use of the product.

3.3 Method

Accident data were collected in an investigation on the site of the accident. This makes it possible to collect detailed accident data on the product, use activities and the situation, see Weegels (1991, 1992a) for a comparative study into the data obtained in various methods of accident investigation. A protocol was developed for conducting the on-site investigations (see § 3.3.1). For any investigation on the spot, the cooperation of people who have been involved in an accident is essential. The data sources used in the recruitment of subjects are elucidated in § 3.3.2.

3.3.1 Protocol for the on-site investigation

First, a brief summary of the protocol is given, followed by an explanation of the design of the protocol. The investigation on-site proceeded as follows:
• Introduction:
  - check for changes in the product and situation since the accident;
• On the site (video-recorded):
  - first demonstration of what happened;
  - second demonstration of what happened;
  - pursue matters brought forward by the subject;
  - demonstration of habitual use;
• Open interview with the use of the checklist (sound-recorded), including:
  - details concerning the occurrences preceding the accident;
  - topics concerning the history of the product, social elements and the characteristics of the user;
  - the subject’s evaluation of the accident;
• On the site (video-recorded):
  - third demonstration of what happened;
• Video-recordings of the situation, the product, the position of the wound and the dimensions of the hands;
• Measurements of situational characteristics;
• Measurements of exertable forces by the subject;
• Inspection of the product.
Chapter 3

The detailed protocol, including all procedures for making video-recordings and for the measurements, as well as the instructions for conducting the interview, is given in appendix 1.

On average, the investigation on-site took one and a half hour.

The investigations on-site were conducted by two researchers, one being responsible for conducting the interview, one for operation of the equipment. Accordingly, the interviewer could focus entirely on the interview.

Reconstruction and interview

Subjects were visited as soon as possible after the accident. After arriving at the subject's home and making the necessary preparations, we asked the subject to take us to the location of the accident. In order to ensure that the registration of the reconstruction would be similar to the situation at the time of the accident, the subject was first asked whether things had since been changed. If so, the subject was asked to rearrange things as they were during the accident. In making the appointment for the on-site investigation by phone, the subject had already been asked whether any material such as vegetables or bread was being processed, so an example of the material could be brought along, if necessary. This was done in order to make sure that the reconstruction would not be hampered by the absence of the material processed.

The subject was asked to demonstrate what happened and to describe it. Apart from the beneficial effects on the retrieval of information from memory, a demonstration of the use of the product avoids a situation where people are suddenly forced to verbalise actions which are often routine. At this stage, no questions were asked. After the first demonstration, the subject was requested to show again what happened (the reason for this is given later). When the subject had finished his or her demonstration and account of what happened, matters brought forward by the subject were pursued.

Then, the subject was invited to compare the use of the product at the time of the accident with his or her habitual use, and, if possible, to demonstrate this use. This was done to gain insight into deviations. Note that the subjects' habitual use may coincide with their use of the product at the time of the accident.

Subsequently, the accident was recapitulated while using the checklist. Thus, as is recommended in the literature, subjects were first given ample opportunity to tell their own story. The checklist was used as a guarantee for the inclusion of possible relevant factors. Using the checklist - as opposed to a questionnaire with a fixed sequence and formulation - allows for specific questions on the product and the situation encountered on-site. In addition, the follow-up of details brought forward spontaneously by the subject is enhanced. Leading questions were avoided as much as possible. Aided recall was used whenever this was possible. In those cases, first a general question was posed, and this was followed by probing. For example, when the subject answered the question 'Were you involved in any accidents in or

40
around the home during the last six months?’ with ‘no’, recall was stimulated by probing, e.g. ‘You did not sustain any cuts? Bruises? Scalds? . . .?’.

Data recording
The reconstruction of the accident was recorded on video and the interview was sound-recorded. Observation with recording equipment has both advantages and disadvantages. An advantage of recordings is that they can be scrolled through repeatedly. Since the factors that may contribute to the occurrence of accidents are not fully known in advance, the possibility of repeated analysis is essential. Also, recordings preclude a priori selection and interpretation by the observer. However, the camera position and resolution imply a selective view. A further disadvantage of making video- and sound-recordings is that people may start to behave differently when they are conscious of the fact that they are being observed (cf. Fowler & Mangione, 1990, p. 129-130; Weick, 1968). Indications in this study for interference of recording equipment are discussed in § 3.4.1.

Sequence of measurements
Topics that were brought forward by the subject were first addressed, followed by a discussion of details concerning the occurrences preceding the accident as established in the checklist. Only after discussing the ins and outs of the accident were more general topics brought forward, such as the history of the product and the subject’s involvement in other accidents. At the end of the interview, the subject’s evaluation of the factors that contributed to the occurrence of the accident was obtained. Finally, the subject was asked to demonstrate again what happened. Video-recordings and measurements of the situation, the product, the position of the wound and the dimensions of the hands were made after the interview, in order to preclude the provision of any clues about the factors considered as relevant by the investigator. If the subject was prepared to exchange the product for a new one, the inspection of the product took place in the laboratory. Ten subjects were prepared to hand over the product. The remaining thirty-two subjects did not or could not put the product at our disposal. Of sixteen products a new product of the same brand and type number could be purchased. For sixteen accidents the product involved could not be made available; these products were inspected on-site.

Indications for effects of memory processes
Various issues that might give indications for effects of memory processes were included in the protocol. As effects of memory processes generally increase with time, the number of days that passed between the accident and the investigation on-site was registered. In addition, subjects were asked to indicate how often they had described the accident to others and what they had told them. Each time that people bring up experiences, as in talking about an accident, new interpretations
are added. Thus, a higher frequency of talking about the accident might imply a more distorted account.
People's perceptions and actions vary intra-individually (see e.g. Brehmer, 1990; Sheridan, 1984). Therefore, subjects were asked to show what happened three times: twice at the beginning of the visit, and once after the interview. By monitoring if and when differences in demonstrations occur, indications might be obtained as to the extent to which the subject's notion of what happened changed while demonstrating what happened and/or talking about the accident. The results are presented in § 3.4.2.

Characteristics included in the protocol
The various factors mentioned in the literature have been included in the protocol for the investigation on-site. In addition, possibly relevant factors have been accumulated during the initial phase of the project. After the investigation of each accident, the protocol was evaluated. If factors had not yet been included in the protocol, these were added to the checklist and investigated in subsequent accidents.
In addition to the characteristics mentioned in the literature and accumulated as indicated above, various other factors were established. For example, the characteristics that are also registered in PORS, the home accident surveillance system of the Dutch Consumer Safety Institute, have been included. These comprise - among others - gender, age, type of injury and treatment of injury. Also, subjects were invited to compare the circumstances at the time of the accident with the habitual use of the product, in order to gain insight into possible deviations.

After the on-site investigation
The first step in processing the raw data was to transcribe the sound-recordings. These transcriptions comprise everything that is said by those present during the investigation on-site. The accidents are all described in terms of defined characteristics in order to obtain comparable descriptions. On average, it took one day per accident to complete the transcription of the sound-recordings and the description of the accident.

3.3.2 Data sources

Sources
A prerequisite for the recruitment of subjects was that the time between the accident and the investigation should be as short as possible. Another requirement was that the recruitment of subjects had to be portioned, since sequential data collection gives rise to the possibility of adjusting the protocol.
Various data sources were probed. The results of the recruitment via the various sources are shown in table 3.1. In total, forty-two accidents were investigated. An obvious way of contacting subjects is recruitment via the emergency department of a hospital, as this is the most common place to go when injured in an accident. Two hospitals cooperated. The recruitment via hospital 1 resulted in four responses over five months. Possible reasons for this low response rate may have been a recent reorganisation of the hospital and nationwide strikes of the medical staff during the period that subjects were recruited. Recruitment via hospital 2 was more successful.

**Table 3.1**
*Number of subjects (n=42) recruited by various sources.*

<table>
<thead>
<tr>
<th>Source</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency department</td>
<td>38</td>
</tr>
<tr>
<td>Public calls</td>
<td>11</td>
</tr>
<tr>
<td>Practitioners</td>
<td>1</td>
</tr>
<tr>
<td>Panel</td>
<td>0</td>
</tr>
</tbody>
</table>

1. Eight responses were not pursued (see further down).

In addition to recruitment via the hospital, public calls were made at the university and in local newspapers. Calls at the university resulted in ten responses. One person responded to a call in the local newspaper.

Also, six general practitioners were asked to report the names of patients who had been treated for injury sustained in an accident involving a consumer product. After two months, one accident had been reported. The practitioners indicated that people tend to visit the emergency department of a hospital instead of their practitioner.

Finally, thirty-four persons who regularly participate in user's trials were phoned twice, with an interval of 1 month between calls. Each time, they were asked whether they had been involved in any accidents in the preceding month or whether they knew of someone else who had been involved in an accident. Two people reported a friend who had had an accident involving a consumer product. However, these two refused to participate.

**Recruitment via the emergency department**

The recruitment via the emergency department of hospital 2 proceeded as follows. The emergency department was provided with letters on behalf of the university. When entering the hospital, patients were asked what had happened. The staff members, who were informed about the aim of the project and the products of
interest, asked people whether a consumer product was involved in the accident. If so, the patient received a letter, containing a request to participate. Participants received twenty-five guilders. They were invited to respond by mail (free of charge) or to phone the university. Staff members were instructed also to provide letters to people if they were not sure whether the product involved in the accident was relevant to the project. The staff members of the emergency department regularly received feedback about the results of their efforts.

Response rates
Recruitment via the hospital took place in 1991 from January to April, and from July 1992 to February 1993. During the first period thirteen of the twenty-five letters that were distributed (52%) were answered. During the second period twenty-five of the fifty-five distributed letters (45%) were answered. Some staff members explained that they did not give a letter to people who were very distressed about their accident. They also said that some people refused to accept a letter. This implies that the response rates found may be exaggerated. Because of the legislation on privacy in the Netherlands, it was not possible to obtain data on the accidents involving patients who did not want to participate or who did not return the response form.

Procedure after responding
As soon as the response form was received, the respondents were phoned by the investigator. The respondent was asked to tell very briefly what happened in order to check whether the product involved in the accident was relevant for the project. It was then explained why and how the investigation on-site would be conducted. Participants were asked to preserve the product and, if applicable, the material processed. Some had already used or thrown away the product or material processed, the latter because they were angry that it had happened or because it was blood stained. Eight responses were not pursued further, because the respondent did not have the time for an investigation on-site or because the accident did not fit into the project, such as in case of a man who had slipped in dog’s urine.

3.4 Indications for lack of validity

First, some general issues are discussed, such as interference caused by making recordings, and missing data (§ 3.4.1). The findings concerning indications for influences of memory processes are presented in § 3.4.2.
3.4.1 General issues

Interference of making recordings
Now and then, interference caused by the making of video- or sound-recordings was observed. Although intervention was limited as much as possible, circumstances sometimes forced the video operator to intervene, for example, by asking the subject to turn. Two subjects made remarks concerning the recordings. The user of a grater said that she moved the cheese faster during the actual use of the grater than in front of the camera. Another subject realised only after a while that sound-recordings were made of the interview. She then exclaimed that she should have said things more clearly.
Most subjects did not show any interest in the video camera or the sound-recorder. At the very most they joked about it at the beginning of the investigation, an observation that is also mentioned by Weick (1968).

Difficulties in demonstrating what happened
Various difficulties were encountered in demonstrating the accidents.
In ten cases it was difficult to show the use activities carried out with the product, for example, when the product broke down at the time of the accident or when the subject fell off a stepladder. In such cases, recordings were made of the situation, and - if the user was willing - of the use activities carried out before the accident. The gas and electrical appliances, such as the planing machine, were in most cases (8 out of 10) not activated during the demonstrations in order to prevent the accident happening again. This may, however, limit the extent to which the demonstrations correspond to the actual occurrences.
In four cases, the situation had been irreversibly changed since the time of the accident, which hampered the demonstration of the accident. An example is the user of a hobby knife who was cutting mastic in a drainpipe. By the time of the investigation the drainpipe had already been fixed.
Six subjects still wore bandages at the time of the investigation. In four of these cases, the bandages made it difficult to show what happened. One of these subjects instructed and supervised her daughter in showing what happened; others had difficulties in performing particular actions.

Missing data
Data are missing for various reasons. Due to circumstances on-site, parts of the sound-recordings are sometimes inaudible or unintelligible. Some fragments of interviews are missing because the apparatus was not yet started. Usually, missing fragments are limited to a few minutes. Obviously, what is missing in these cases is unknown. Data are also missing because topics in the checklist were not explicitly touched upon.
An inventory of the transcriptions showed that almost all subjects said at least once that they did not remember a particular thing. In general, this concerned topics that do not seem directly relevant to the occurrence of an accident, such as the price of the product or what they had been doing before they started to use the product. However, when probed in more detail about how the accident occurred, eleven subjects stated that they did not remember things precisely. For instance, the user of a scraper, who slipped in replacing a protective cover on the blade, indicated he could not recall exactly how he held the cover.

Not remembering exactly what happened may be associated with a relatively long period between the accident and the investigation. However, no systematic differences were found in the median number of days since the accident for subjects who say they do not remember the occurrences in detail versus subjects who do not indicate not remembering details (median test, p=0.673).

3.4.2 Indications for effects of memory processes

Time between accident and investigation
As distorting effects of memory processes generally increase with time, the time which elapsed between the accident and the investigation on-site was registered. The median number of days between the accident and the investigation on-site was twelve days, with a minimum of one day and a maximum of forty-two days. Some subjects phoned directly after coming home from the hospital, but most used the response form. Apart from urging people to contact us as soon as possible, the time taken to contact the researcher could not be influenced.

Frequency of narrating the accident
Subjects were asked how often they narrated the accident, since this might give an indication of the extent to which a story was biased. The frequency of talking about the accident to others, as reported by subjects, varied from one to fifty times, with a median of ten. Most of the subjects who had told of the accident more than ten times, only gave a rough estimation of the frequency of telling, rounding it off to tens. In particular, subjects who had a conspicuous injury were frequently asked to tell what happened, 'ad nauseam'. Some subjects even stopped wearing bandages so as to prevent questions about it. Generally, subjects explained to other people what happened only very briefly, such as: 'I cut myself with a bread-knife'. In telling the story to others, at least three subjects showed the product to other people. None of the subjects had actually demonstrated what happened. It is conceivable that the number of times the story has been told to others increases with a longer period between the accident and the on-site investigation. There seems to be a moderate relationship between the two on a p=0.07 level (Spearman Rank Correlation Coefficient: r_s=0.2869;).
Within-subject differences in demonstrations
Subjects were asked to demonstrate what happened three times, to find out if and when differences between demonstrations occur. The outcomes of the analysis of the within-subject differences in demonstrations obviously depend on the resolution of the analysis (cf. Sheridan, 1984). The analysis focuses on differences in use actions, such as the way of contacting the product and the material processed, the posture, the direction of movements and so on. Some of the differences are obvious, such as standing versus sitting, or moving to the left versus to the right. Sometimes, however, the distinction of differences in actions is less apparent. The analysis of differences is therefore illustrated by means of some examples, see figures 3.1 and 3.2.

Figure 3.1 a to d
Figures a and b show the use of a handsaw in making the surrounding of a television smaller, trying to make it fit into a cupboard. The saw hits the little finger of the hand holding the box. In figure a, the distance of the free hand (circled) to the blade of the saw is smaller than in figure b. This is considered as a difference in the way of contacting the material processed. The user in figures c and d is separating frozen meat with a knife. The knife slipped and gashed the hand that was holding the meat. The way of holding the meat (circled) is considered as similar.
Figure 3.2 a to d
Figures a and b show the use of a scraper, which is used to scrape paper off the wall. The user is replacing the protective cover on the blade. The scraper slipped and cut the palm of the hand holding the cover. Here, the ways of holding the cover while replacing it, i.e. holding the cover from underneath (in figure a) and above (in figure b) are considered as different. The user in figures c and d was removing the cap of the handlebar of her bicycle. The screwdriver slipped off the cap and pierced the palm of the hand. In this case, the way of contacting the screwdriver in figures c and d is considered as similar.

In the interests of completeness, several things should be noted. Firstly, the analysis is not based on whether these differences would lead to different conclusions concerning the relevance of a particular action for the occurrence of the accident. Thus, the analysis is conducted from an outsider’s perspective, which implies that the findings do not indicate whether the subject is aware of these differences. Secondly, the observation of differences in demonstrations may be partly blurred because differences can arise due to a variety of conditions. For example, the viewpoint of the camera may differ for the three demonstrations. Thirdly, users’ trials have shown that within-subject differences in use actions often occur when a task has been interrupted (Weegels, 1992b). Consequently, differences may have arisen from the interruptions between demonstrations.
In fifteen cases the third demonstration - after the interview - was omitted for several reasons: when the accident was difficult to reconstruct (e.g. falling with the product), when the situation had changed so that the demonstration was severely hampered, or when the subject was reluctant to show what happened, afraid it might occur again. In twenty-seven cases demonstrations were made before as well as after the interview. These cases are included in the presentation of the findings. The results of the analysis of within-subject differences in demonstrations are given in table 3.2. More than half of the subjects show differences in more than one of the specified use actions, with a maximum of four. For example, a subject may show differences in posture, in the way of contacting the product and in the direction of moving. The number of differences in use actions does not systematically vary over demonstrations. For example, the number of differences between D1 and D2 is not systematically higher in comparison to the differences found between D2 and D3, and vice versa (D stands for 'Demonstration'). Therefore, the results in table 3.2 only show whether differences were observed or not.

Table 3.2

<table>
<thead>
<tr>
<th>Similarities and differences</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1 ≈ D2; D1 ≈ D3; D2 ≈ D3</td>
<td>11</td>
</tr>
<tr>
<td>D1 ≈ D2; D1 D3; D2 D3</td>
<td>2</td>
</tr>
<tr>
<td>D1 D2; D1 ≈ D3; D2 D3</td>
<td>0</td>
</tr>
<tr>
<td>D1 D2; D1 D3; D2 ≈ D3</td>
<td>6</td>
</tr>
<tr>
<td>D1 D2; D1 D3; D2 D3</td>
<td>8</td>
</tr>
</tbody>
</table>

Δ demonstrations are considered as different
≈ demonstrations are considered as similar

In eleven cases the demonstrations are considered as similar. In two accidents, the demonstrations before the interview (D1 and D2) are similar, while the demonstration after the interview (D3) differs from D1 and D2. One of the subjects realised only during the third demonstration that she had performed a particular action with the product.

Six subjects show differences in the demonstrations before the interview (between D1 and D2), while the third demonstration (D3) resembles D2. A tentative explanation for this situation (see fourth row) may be that during the first demonstration people do not yet have a clear picture of what happened. The retrieval of information may have reached completion by the time of the second
demonstration, which is then taken as the ‘right’ one and repeated throughout the third. In eight cases, each reconstruction is different (fifth row). These differences might also be explained in terms of the retrieval of new details. By D1 the retrieval of information may not yet have reached completion, resulting in differences between D1 and D2. Then, during the interview, new details may come up again, leading to a D3 different from D2.

The situation that D1 resembles D3 while D2 differs from both D1 and D3 (third row) was not found. This might indicate that none of the subjects in the end (at D3) ‘comes back’ to the first demonstration once they have retrieved new details during D2 and/or during the interview.

When the line of reasoning followed above is carried through, we might have to worry about the situation where the three reconstructions are similar. It may mean that these subjects have relived or talked about the occurrences so many times before the investigation on-site, that they are fixated on one interpretation of what happened. However, no systematic differences in the median number of times of telling were found for the subjects who showed differences and the subjects who did not (median test: $p=0.226$). Computation of Spearman’s Rank Correlation Coefficient of the frequency of narrating with the number of differences in use actions per subject did not reveal significant differences either ($p=0.319$).

Obviously, the extent to which differences are a result of random variation or systematic variation (bias) is not known.

In total seven of the twenty-seven subjects say that they cannot recall what exactly happened; six of them show differences in the demonstrations. This finding suggests that there may be a relation between subjects’ statements on their remembrance of what happened and differences between demonstrations.

There may be a relationship between the time that passed since the accident and differences in demonstrations. An increasing number of days may be associated with differences in demonstrations, for example because subjects’ remembrance of what happened may have decreased. No significant differences in the median number of days were found for the subjects who showed differences and those who did not (median test: $p=0.352$). Computation of Spearman’s Rank Correlation Coefficient of the number of days with the number of differences in use actions per subject did not reveal significant differences either ($p=0.347$).
3.5 Discussion and conclusions

In this chapter an approach was introduced which is attuned to the observation of accidents involving consumer products. This approach should not be seen as something completely new. After all, the concept of accidents emerging in consecutive interactions of man and machine/product in some environment is a general perspective in the literature (cf. Lehto & Salvendy, 1991). A basic difference from many existing approaches is the view that influences of human characteristics only assume importance by way of actions taken by the user. Furthermore, a one-sided approach is precluded by taking the co-occurrence of the product, use activities and the situation as a starting point for the observation of accidents.

An attempt has been made to explore indications for lack of validity. However, in retrospective research into accidents it remains largely unknown to what extent data are actually biased. Nevertheless, it is important to take note of anything that may point to lack of validity.

With respect to the investigations on-site, observing subjects and making video- and sound-recordings may sometimes have interfered with how the subjects behaved. The majority of the subjects did not seem to pay any attention to the recorders.

In several cases, evidence is available that the demonstrations may differ from the unknown actual occurrences, for example, because the bandages that subjects were still wearing hampered a demonstration of what happened, or because it was too dangerous or even impossible to demonstrate what happened.

The analysis of differences in demonstrations shows that in more than half of the accidents within-subject differences can be observed in these demonstrations. In fact, the extent to which differences are a result of random variation or systematic variation (bias) remains unknown.

The analysis of the differences was not based on whether these differences would lead to different conclusions on the relevance of a particular action for the occurrence of an accident. Probably, not all differences lead to different conclusions.

Practically all subjects said at least once that they could not remember something. This generally concerned topics that do not seem directly relevant to the occurrence of the accident. Yet, when questioned about exactly what happened, a quarter of the subjects indicated that they did not remember. The findings suggest that there is a relation between the subjects' statements concerning the remembrance of the exact occurrences and differences in consecutive demonstrations. In a methodological sense, this implies that when subjects state
that they do not remember things exactly, probing should be avoided, since this paves the way to guessing in order to satisfy the interviewer (cf. Sheehy, 1981). Furthermore, if subjects indicate that they are not certain about what happened, this sets a limit to the possible meticulousness of the analysis.

As is known from the literature, people can differ in regard to the certainty with which they express themselves, which may also be the case in this study. Some subjects may have been more apt to indicate their uncertainty in showing what happened, by saying they did not remember exactly what happened. Without meaning to do so, subjects may have altered their account or demonstration of what happened in order to avoid appearing foolish (cf. Sheehy, 1981). Such 'selective memory' may result in socially desirable accounts.

In conclusion, this chapter describes the method for the observation of accidents, which consists of the reconstruction of accidents on-site. Although due attention was paid to the minimisation of distortions, e.g. as a consequence of memory processes, the findings obtained in the reconstructions may be biased to some extent. Nevertheless, the data collected in the present study compare favourably with those obtained in current research practices, which generally rely on self-reports only.
4. Judging the causes of accidents

The aims and questions of a study into the inference of the causes of accidents are given in § 4.1. The design of this study is described in § 4.2. The findings, which are presented in § 4.3, are discussed in view of the literature from social psychology and philosophy (§ 4.4). What these two disciplines have to offer in judging the causes of accidents is explored. Implications for accident analysis are presented (§ 4.5). The analysis of the accidents is explained and illustrated. Conclusions are given in § 4.6.

4.1 Introduction

A review of the safety literature shows that the inference of causes by human judges or experts has rarely been addressed, despite the fact that identifying causes is a crucial step in accident research. Clearly, the causes of accidents constitute the foundations of countermeasures. In designing a product, the inference of insights from accident data is essential in formulating the criteria that should be met by the design. The inference of causes is also relevant when searching for patterns in accidents. A prerequisite for this is that the analysis of the various accidents proceeds in a similar way. Thus, the considerations and criteria governing the selection of causes must be made clear.

For these reasons, an additional study into the possibilities of establishing causes by means of human judges was conducted. The aim of this study was to gain insight into the identification of the causes of accidents. These insights should be applicable in the analysis of accidents, so that the inference of causes can be clearly shown. The research question addressed in this exploratory study is: 

To what extent can similarities and differences in the causes identified by different judges be related to the use of particular criteria and/or types of reasoning?

In order to answer this question, judges were confronted with accident data that were collected as described in the previous chapter. Initially, the focus of this study was to examine whether it is possible to identify the causes of an accident by means of human judges. To what extent do judges agree on the causes of an accident? As agreement on the causes of the same accident appeared to be limited, the question arose as to why various judges indicate different causes. Therefore, the focus shifted towards a means for the identification of contributory factors, which would clearly show the way in which conclusions are reached.
4.2 Design of the study with judges

4.2.1 Introduction

The data of four accidents were presented to twelve judges. The outcomes of accident analysis conducted by these judges are phrased in terms of:
• the causes of an accident;
• the importance assigned to causes;
• the recommendations given for a redesign of the product;
• the considerations, criteria and types of reasoning used in arriving at causes. Differences in outcomes may be related to how - i.e. on the basis of what type of reasoning - judges reach conclusions on the causes of an accident. How judges infer causes was established by asking for an explanation of their considerations in identifying causes.
In preparing the study four pilots were carried out. These pilots showed that the judges repeatedly referred to their own experiences with the products involved in the accidents, or with similar products. Therefore, experience in using a product was also included.
In § 4.2.2, the selection of the accidents presented to the judges is explained. The selection of the judges is addressed in § 4.2.3. The procedure during the sessions with the judges is presented in § 4.2.4. Finally, the analysis of the judges' responses is described (§ 4.2.5).

4.2.2 Accident data presented to judges

Selection of accidents
The pilots showed that four accidents is the maximum number that can be presented within two hours, given the limits of people's time and concentration. Thus, four of the forty-two accidents had to be selected. As a basis for this selection the results of a first analysis of the data by the investigator were used. The causes initially identified by the investigator were ordered in terms of the product, the use activities, the situation and the characteristics of the user. In selecting the accidents, differences in type as well as in number of causes were sought. One accident was selected in which no product features were identified as causes by the investigator. Also, products were selected that can be used in different types of activities, such as do-it-yourself and household activities.
A picture and a concise description of the four accidents is given on the next page. Note that the judges had a much more comprehensive description at their disposal.
Planing machine
The user was planing a short piece of plywood with the planing machine in the stationary position. The wood was grasped by the revolving cutters. He slid into the cutters with both middle fingers. The user explained that he had sawed the piece of wood before planing it; usually he first planes the wood and then saws it into pieces.

Fitness-stick
The subject noticed her son and a friend coming in with a fitness-stick. As she had heard of a serious accident with the stick, she wanted to warn the children by giving a demonstration of the use of the stick. While bending the strong spring, she kept the left handle closer to the body. One handle slipped out of her - possibly damp - hand, and smashed against the chin, thus injuring the lower jaw and the tongue.

Pump screwdriver
The subject was fixing a telephone rig, with two screws, to the wooden wall of his garage. He had not pre-drilled the holes. He was working above his head. The user had positioned one foot on a machine, and the other on a cupboard. In pumping for the first time, the bit slipped upwards out of the cross-slotted screw. The turning bit pierced the middle finger of the hand that held the screw.

Food processor
The subject was removing the protective covers from the sickle-shaped knives of a food processor. The knives slipped out of the wet hand. In trying to catch the knives, the tendon of the ring finger was severed by the uncovered knives. According to the subject, the covers stick when removing them. She also indicated that the functioning of her arm has decreased due to an operation, and that her force exertion may not have been well controlled.
Chapter 4

Accident data

The data were presented in their most original form, with the exception of the sound-recordings of the interview; these would have taken too much time. Hence, the data provided consisted of:

- Video-recordings of the reconstruction of the accident and of the environment. Faces were made unidentifiable.
- The product involved. In the case of the pump screwdriver the specimen involved in the accident was available. Of the other products a new one of the same type as that used at the time of the accident was purchased.
- A description of the accident, including the data of the interview and the outcomes of measurements. This description was arranged in terms of the use activities, the product, the situation and the characteristics of the user. Where applicable, the operation manual of the product was provided.

4.2.3 Judges

In total twelve judges participated in the study. Since the findings in this thesis are intended to have relevance to the design process, it seemed obvious that designers should be included. Six judges were industrial design engineers, who graduated at the Faculty of Industrial Design Engineering of the Delft University of Technology, and who were working for at least 50% of their working time in professional practice. The six remaining judges were academics employed at the Faculty. In order to provide diversity, these academics did not have a degree in industrial design engineering, but came from various other disciplines, such as psychology and physics.

4.2.4 Procedure

Judges were welcomed individually. The sessions consisted of an introduction, the analysis of the accidents and a debriefing in which the judges were questioned by the experimenter.

Introduction and individual part

During the introduction the judges were told how the accident data had been obtained. Pictures of the measurement of forces were shown. After the introduction all judges had to analyse the data of a ‘dummy’ accident in order to give them, as much as possible, a common history. The results of the analysis of this dummy accident were not used for further analysis. After viewing the dummy accident the judges were asked to examine the video-recordings, the product and the description of the four accidents. They then had to write down the causes of each accident. The question posed was:

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What, in your opinion, are the causes of this accident?
The judges were allowed to answer freely, without restrictions on the number or
types of causes. This is an important point in the design of the study. Although
allowing judges this freedom makes the comparability of answers more difficult,
the alternative, i.e. to supplement a list of causes beforehand, would make it
difficult to obtain insight into the manner in which people reach their conclusions.
The participants may learn during the session. Therefore, they were told that they
could review the data as often as necessary, and that they could re-examine a
formerly analysed accident. The time available for analysis was unlimited. Judges
were told to stop the analysis of an accident if and when they felt that their list of
causes was complete. The order in which the accidents were given to the judges
was varied. The order of viewing the video, reading the description or examining
the product was determined by the judges themselves.
Paper and various writing and sketching materials were made available. After the
instruction and the dummy-accident, the experimenter left the judge alone.

Debriefing
In order to shed light on how judges reach conclusions on causes during the
analysis of the accidents, a debriefing was held. The debriefing was recorded on
video. The judges were asked to explain the causes they indicated. In asking for a
clarification in retrospect the answers may be biased as a result of memory
processes. Indeed, some judges complained that they could no longer remember
what their considerations had been in deciding on the causes of the accidents.
Thinking aloud concurrently, i.e. thinking aloud during the accident analysis, may
interfere with what judges are doing. In this study it was thought preferable not to
disturb the judges during the analysis of the accidents.
Apart from the issue of asking questions retrospectively or concurrently, a basic
question is to what extent people can express their considerations (see Nisbett &
Wilson, 1977). However, in the pilots it appeared that the judges spontaneously
began to elaborate on the considerations they had had in reviewing the data.
The debriefing included the following topics:
• Elucidate causes.
  Each cause was read aloud. The judge was then asked to explain why he or she
  thought this was a cause of the accident. An elucidation of the relation between
  a cause and the occurrence of the accident was then requested.
• Rank causes according to importance.
  Judges were asked to rank the causes according to importance. Some maintained
  that the accident was the result of a combination of causes, making it impossible
to rank the causes.
• Give recommendations for a redesign of the product.
  Judges may be apt to think in terms of how an accident can be prevented rather
  than in terms of the causes of an accident. By asking them to indicate the causes
of an accident, they may be forced to adopt a way of thinking which they normally 'shortcut'. In order to give judges the opportunity to bring up solutions, they were asked to give recommendations for a redesign of the product that would prevent the accident. Following the review of the four accidents, questions were asked concerning the judge's experiences in the use of the products involved in the four accidents.

4.2.5 Analysis of responses

The conversations during the debriefing were literally transcribed. These transcriptions and the causes written down served as a basis for further analysis. The analysis of the transcriptions proceeded as follows.
In the inventory of causes, the extent to which the causes indicated could be denoted as 'the same' was examined. As judges state matters in different ways, interpretation is unavoidable. Causes were categorised as the 'same' cause if it was impossible to conceive of these causes as concerning different topics. For example, in the case of the food processor, expressions such as the cover is too tight around the knives and protective covers get stuck are both contained in the cause protective covers stick. Another example is stands unsteady and uses a bad step in the case of the pump screwdriver. Both expressions are contained in the cause stance unstable. During the analysis, each time that a judge's response could not be included in an already identified cause, this cause was added as a new topic. For example, type of wood, named in the case of the planing machine, could not be included with any of the other causes that were identified, and thus was added as a new cause. With regard to the number of causes, the absolute numbers are not comparable between accidents, as the categorisation of causes may not be similar in the four accidents. For example, the sentence because the man was hasty, he did not pre-drill the hole may be divided into two causes: hasty and did not pre-drill the hole. This may equally well be regarded as one cause. In the analysis such causes were split in two if several judges named only one part of the sentence. If most judges named both parts of the sentence it was considered as one cause.
In order to check whether judges emphasise particular aspects, causes were categorised in terms of whether they related to the product, use activities, the situation or the characteristics of the user.
As to the importance of causes, judges occasionally indicated that the accident was a result of a combination of causes. In these cases, all causes involved were rated as the most important cause. Sometimes causes were not explicitly evaluated in terms of importance, therefore the findings concerning importance are presented in general terms.
Regarding recommendations, only ideas for what should be changed (e.g. improve the protective cover of the planing machine) were included in the analysis. Ideas
on how the product should be changed, which can be done in various ways (e.g. fix cover, make cover transparent, make cover adjustable) were excluded, as these would have favoured the designers. Compared to the other judges, the designers brought forward a substantially larger number of ideas on how to change the products. Obviously, the distinction between what and how the product should be changed is a relative one. The transcriptions of the debriefing were analysed with regard to the considerations used by the judges in the inference of causes. On the basis of their statements, various criteria for deciding on what is a cause could be distinguished.

4.3 Results

The similarities and differences in the causes mentioned by the twelve judges are presented first (§ 4.3.1). Where possible, the differences in causes are related to the experience and occupation of the judges. The various criteria the judges use in arriving at causes are addressed in § 4.3.2.

4.3.1 Agreement among judges

Experience
Table 4.1 shows the number of judges who had previously used the products involved in the accidents, or similar products.

<table>
<thead>
<tr>
<th>Product</th>
<th>Previously used product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump screwdriver</td>
<td>8</td>
</tr>
<tr>
<td>Food processor</td>
<td>8</td>
</tr>
<tr>
<td>Fitness-stick</td>
<td>7</td>
</tr>
<tr>
<td>Planing machine</td>
<td>2</td>
</tr>
</tbody>
</table>

Causes
From three to eight causes per accident (median: 4) are mentioned by more than six judges. No cause is mentioned by all judges. The level of agreement on the remaining causes of the four accidents is low. A large proportion of the causes indicated for each accident is mentioned by only one or two judges.
To illustrate the findings, the accident with the planing machine is used as an example. Figure 4.1 depicts the number of judges who mentioned a cause of the accident with the planing machine. Most judges agree that *piece of wood too small, insufficient grip on wood and holds wood with bare hands* are causes of the accident with the planing machine. Thus, the total number of causes on which at least seven judges agree is three. The overall picture gained in the case of the planing machine resembles the findings in the remaining three accidents.

Judges were asked to indicate how a cause was related to the occurrence of the accident. Mostly they differ in what they indicate as the consequences of a cause. For instance, in the case of the planing machine, nine judges mention three different consequences of the cause *piece of wood too small*. These judges indicate the following consequences:

- the wood provided insufficient grip (eight judges);
- the wood was grasped by the revolving cutters (three judges);
- the user used the wrong grip (one judge).

It would seem that judges do not agree on the way in which causes influence the occurrence of an accident.

No systematic inter-individual differences are found in the number of causes indicated. Designers do not appear to stress different aspects of the accidents from the other judges. For example, designers do not lay more emphasis on aspects of the product. Although judges repeatedly refer to their experiences with the products involved, those who have used the products in the past do not yield more or different types of causes from those with little or no personal experience of them.

**Importance**

Causes mentioned by more than six judges are, in general, classified as the most important causes. Some causes mentioned by a majority of the judges are indicated by only a minority of them as one of the most important causes. This is illustrated again with the results of the accident involving the planing machine. Ten judges find *piece of wood too small* one of the most important causes of the accident. On four occasions *insufficient grip on wood* is indicated as one of the most important causes. This is followed by *uses small piece deliberately*. Three judges think this is one of the most important causes. Other causes are incidentally listed as the most important.

In general, no systematic inter-individual differences in the listing of importance were found. An exception was a designer who indicated in every case that product aspects were the most important causes, because he could change the product, but could not influence other aspects, such as the situation or the user (this designer uses the criterion of mutability, see § 4.3.2).
### Causes of Accidents

<table>
<thead>
<tr>
<th>Causes</th>
<th>Number of Judges</th>
</tr>
</thead>
<tbody>
<tr>
<td>piece of wood too small</td>
<td>12</td>
</tr>
<tr>
<td>insufficient grip on wood</td>
<td>10</td>
</tr>
<tr>
<td>holds wood with bare hands</td>
<td>10</td>
</tr>
<tr>
<td>no instructions for stationary use</td>
<td>8</td>
</tr>
<tr>
<td>no guideway</td>
<td>6</td>
</tr>
<tr>
<td>cutters grasp wood</td>
<td>6</td>
</tr>
<tr>
<td>stands twisted behind plane</td>
<td>4</td>
</tr>
<tr>
<td>uses short piece deliberately</td>
<td>2</td>
</tr>
<tr>
<td>unsuitable for stationary use</td>
<td>2</td>
</tr>
<tr>
<td>unusual sequence</td>
<td>2</td>
</tr>
<tr>
<td>positioning of fingers</td>
<td>2</td>
</tr>
<tr>
<td>no transit aid</td>
<td>2</td>
</tr>
<tr>
<td>overconfident</td>
<td>2</td>
</tr>
<tr>
<td>feed table too small</td>
<td>2</td>
</tr>
<tr>
<td>fingers too close to cutters</td>
<td>2</td>
</tr>
<tr>
<td>depth adjustment of plane incorrect</td>
<td>2</td>
</tr>
<tr>
<td>protective cover inadequate</td>
<td>2</td>
</tr>
<tr>
<td>does not follow instructions</td>
<td>2</td>
</tr>
<tr>
<td>works too low</td>
<td>2</td>
</tr>
<tr>
<td>turned away protective cover</td>
<td>2</td>
</tr>
<tr>
<td>works too quickly</td>
<td>2</td>
</tr>
<tr>
<td>plywood</td>
<td>2</td>
</tr>
<tr>
<td>much force needed to handle wood</td>
<td>2</td>
</tr>
<tr>
<td>working bench unstable</td>
<td>2</td>
</tr>
<tr>
<td>just back from lunch</td>
<td>2</td>
</tr>
<tr>
<td>control cannot be locked</td>
<td>2</td>
</tr>
<tr>
<td>too experienced</td>
<td>2</td>
</tr>
<tr>
<td>hampered by clothing</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 4.1

Indicated causes of the accident with the planing machine.

**Recommendations**

In general, the recommendations involve the causes considered as most important by the judges. Note that the judges were asked to give recommendations for improvements of the product only.

Figure 4.2 gives the recommendations mentioned in the case of the planing machine. Seven judges indicate that the instructions for use should be improved,
six advise adding a guideway. On other recommendations no more than four judges were in agreement.

As to the kind of recommendations, other than recommendations for the product - only in the case of the screwdriver are recommendations for the user given, such as choosing a better working environment and rough-drilling the hole. In the remaining three accidents, judges only give recommendations for the product and its attributes, such as the operation manual.

![Figure 4.2](image)

*Indicated recommendations for the prevention of the accident involving the planing machine.*

No systematic inter-individual differences can be found with respect to the recommendations given. For example, none of the judges recommend changes to use instructions or the product on every occasion. In all four accidents, the designers give more recommendations than the other judges.

*In summary*

From three to eight causes per accident (median 4) are indicated by at least seven judges. No cause is mentioned by all twelve judges. The remaining causes of the four accidents are indicated by at most six judges, but usually by only one or two. Little agreement appears to exist on what is viewed as the consequences of a cause.
Differences in the causes and their importance, and differences in recommendations, can be related only incidentally to differences in background, such as occupation and experience.

4.3.2 Criteria used in arriving at causes

During the debriefing judges were asked to explain the causes they indicated. The judges' considerations in deciding whether something is a cause or not a cause can be categorised in three different criteria. The criteria that can be identified are described in this paragraph. The terms used to label these criteria are derived from the literature.

**Deviations**

When the judges consider that a condition deviates from what they see as normal, they regard this condition as a cause. Conditions that are not viewed as a deviation are not considered as a cause. In the elucidation of their answers, the judges refer to what can be called norms, such as:

- what they consider as normal, usual, logical or proper;
- how the product should be used according to the operation manual;
- the habitual use of the product by the victim;
- their own experiences with this or similar products;
- the intended function of the product according to the judges;
- the abilities of other people the judges know, such as an aunt or grandmother.

Some of the norms that judges use are based on external evidence, such as the operation manual or the data on the habitual use of the product by the victim. Most norms seem to be based on the judges' own internal standards and norms.

An example of how the judges reason is as follows: the user of the food processor dropped the knives. This user stated that probably her hands were wet. Because the judges consider wet hands in a kitchen to be normal, they do not indicate wet hands as a cause.

In the case of the planing machine, the user did not use the planing machine as was prescribed in the operation manual, therefore these judges consider planing a small piece of wood to be a cause.

Note that the analysis of deviations is a prevailing method of accident analysis.

**Counterfactual reasoning**

In the literature, a counterfactual statement - or a contrary-to-fact conditional (see Walters, 1967) - is defined as a statement 'about what would happen if something were the case that in fact is not the case.' (see White, 1990, p. 5). Judges appear to apply this type of reasoning in arriving at causes. They ask themselves whether the accident would still have happened given the presence or absence of particular
conditions. A condition is considered a cause if the accident would not have happened in the absence of this condition. Here, the actual conditions are replaced by imaginary alternative conditions in order to 'investigate' the effect on the consequences.

For example, in the case of the planing machine, the judges consider holding the wood with bare hands as a cause, because the accident would not have happened if a transit aid had been used.

In some cases the judges cannot imagine alternative conditions or circumstances. For instance, in the case of the screwdriver, the way of holding the screw is not a cause according to the judges, because they think the user could not have held the screw in any other way.

**Mutability**

Conditions that judges consider to be immutable are not indicated as causes. Judges use this criterion only in indicating why a condition is not a cause. For example, several judges say that revolving cutters are an inherent component of a planing machine and cannot be changed. These judges therefore do not regard this feature as a cause.

**Relationship between criteria and causes indicated**

Different criteria do not necessarily lead to different conclusions on whether or not something is a cause. For example, judges who consider keeping the small piece of wood as a cause of the accident with the planing machine, may have reached this conclusion by looking at deviations, and via counterfactual reasoning.

Applying the same criterion to the same condition does not necessarily lead to the same conclusion. In the case of the planing machine, the man had turned away the protective cover. Most judges do not consider this as a cause, because the accident would also have happened if he had not turned away the cover. One judge believes that the accident would not have happened if the man had not turned away the cover, as the cover might have snapped back in time. Here, the assumptions that are implicitly made, such as what would (not) have happened if the cover had not been turned away, may result in different conclusions.

When the criterion of deviations is used, the different norms that judges have may lead to different conclusions. For example, in the case of the accident with the food processor, the knives slipped out of the hand. One judge concludes that the grip on the cylinder of the knives is sufficient, as he tried it himself. Another judge, however, concludes that the grip on the cylinder is insufficient, as his food processor at home provides a much better grip.

No inter-individual differences were found in applying the criteria. In general, all criteria are applied by all judges. Although some judges refer to their experiences with the product, not all judges with experience do this.

It was found that the use of counterfactual reasoning was the most frequently applied criterion. This was followed by the criterion of deviations, while the
criterion of mutability was used less often. These findings should be regarded with some caution as they are the result of spontaneous and interpreted remarks by the judges, and some judges are more verbose than others!

In summary
Judges appear to use different criteria in the identification of causes, of which counterfactual reasoning seems to be used most frequently. The same criterion can lead to different conclusions, and different criteria can lead to the same conclusion. Judges do not interindividually differ with regard to the criteria they use.

4.4 The criteria revisited

The findings of the study are recapitulated briefly (§ 4.4.1). As the criteria used by judges can also be found in social psychology and some areas within philosophy, the related literature from these fields is discussed (see § 4.4.2 and § 4.4.3). The paragraph will conclude with a discussion of the different ways in which counterfactual reasoning is addressed in philosophy and in social psychology (§ 4.4.4). The aim of this review is to find out what these two disciplines have to offer in judging the causes of accidents.

4.4.1 Recapitulation of findings

From the analysis of the transcriptions of the debriefing it appears that the judges' considerations in the inference of causes could be categorised into three criteria. The finding that various criteria are used in deciding whether or not something is a cause was not anticipated at the beginning of this study. As a result, the findings with respect to who uses which criteria, and when, are fragmentary. It is conceivable that, if this had been known in advance, the design of the study would have been somewhat different. For example, judges could have been asked to think aloud during the analysis. Nevertheless, coming across this kind of 'spontaneous findings' is an inherent feature of exploratory research. The criteria that judges use seem to correspond to some extent with findings in the field of social psychology. In this area research has been carried out into the mental simulation of alternatives to events resulting in dramatic outcomes. In some parts of the philosophical literature, counterfactual reasoning has been extensively discussed. Therefore, the literature in these areas is discussed and related to our study.
4.4.2 Social psychology

Kahneman & Tversky (1982) introduced the simulation heuristic, i.e. the phenomenon that people evaluate events by mentally simulating alternatives to these events. Mental simulation is present in a range of psychological phenomena, such as perception of causes, blame assignment and feelings of regret. This simulation appears to be governed by various rules and constraints, which will be discussed later.

The experimental design that is generally used in research on mental simulation consists of providing different descriptions of a story to different groups of people. The stories vary with respect to, for example, the order of events (e.g. Wells et al., 1987) or the extent to which events are labelled as normal/exceptional (e.g. Wells & Gavanski, 1989) or as controllable by the actor (e.g. Girotto et al., 1991). The subjects are instructed to undo the outcome of the story by listing (a maximum number of) ways in which the outcome could have been avoided. In this case they have to finish the following sentence: If only . . . (e.g. if only John had (not) done this or that). In some studies the subjects are (also) asked to indicate causes, causal significance, legal responsibility or the amount of compensation that should be given to a victim.

A basic assumption in these experiments is that people use mental simulation. Mental simulation is usually represented as a process in which - after receiving a stimulus, such as a story - first a norm is generated by means of counterfactual reasoning, followed by a comparison of this norm to the stimulus. When the stimulus differs from the norm, the stimulus is labelled by people as a deviation and, consequently, as a cause (Kahneman & Miller, 1986; Zwier, 1992).

A prerequisite for mental simulation of alternatives to reality is that events can be mutated or influenced. Immutable characteristics of events cannot be mentally altered (Kahneman & Miller, 1986; Wells & Gavanski, 1989). Consider the example of Wells & Gavanski (1989, p. 161):

... following a suicide in which a man leapt from a window, people would not cite the presence of gravity as a cause of his death. Although it is true that an absence of gravity would have undone the outcome, the presence of gravity is an immutable characteristic of life on Earth.

The availability of alternatives to events is relevant in mental simulation in the sense that, in the absence of alternatives to a particular event, no norm can be generated. Wells & Gavanski (1989) provided subjects with information about alternatives to the factual event preceding the outcome. These are called default events. Default events are those that most readily come to mind when a factual event is mentally mutated. The authors use the story of a woman who died of an allergic reaction to a meal ordered by her boss (p. 161):
When the boss was described as having considered another meal without the allergic ingredient, people were more likely to mutate his decision and his causal role in the death was judged to be greater than when the alternative meal was also said to have the allergic ingredient.

Miller & McFarland (1986) found that subjects recommended more (financial) compensation for victims of a robbery in a shop, when alternatives, such as the information that the victim usually visits another shop, are easily available.

Mackie (1974a) suggests that abnormal conditions are more likely to be judged as a cause. In the area of safety, Rasmussen (1990b, p. 451) remarks that often normal and usual conditions are taken for granted. Only the unusual is included in the analysis of accidents.

Following Mackie, various authors examined people’s tendency to perceive exceptional or abnormal events as more mutable than normal or usual events (Einhorn & Hogarth, 1986; Kahneman & Miller, 1986; Kahneman & Tversky, 1982; Macrae, 1992; Miller & McFarland, 1986; Wells et al., 1987). Thus, it seems easier for people to generate alternatives to exceptional events rather than to normal events. For example, when someone incurs an accident on an unusual route home, subjects tend to alter the unusual route in undoing the accident (example from Kahneman & Tversky, 1982).

Several authors found that people tend to focus on the first event in a chain of events (Girotto et al., 1991; Johnson et al., 1989; Miller & Gunasegaram, 1990; Wells et al., 1987). A study of Johnson and colleagues (1989) indicates that the first event in a causal chain is blamed, rather than the second event.

As far as can be seen, Girotto et al. (1991) are, with Bagnara et al. (1992), the only authors who are concerned with safety. Girotto et al. (1991) investigated the relevance of controllability by the actor in the perceived mutability of events. The controllability of an event is defined as the extent to which an event depends on the actor’s decision. People consider events that are controllable by the actor as more mutable than surrounding events.

Given the relationship between counterfactual thinking and perceived causality, Girotto and colleagues (1991) discuss the implications of their findings for man-machine studies. Because human actions that precede an accident tend to be regarded as the event that could have been avoided and modified, designers may focus on human actions as the easiest factor to modify (Girotto et al., 1991; see also Bagnara et al., 1992).

Alicke (1992) investigated the influence of blameworthiness on people’s perception of causes. People appear to select the most blameworthy act as the most important cause. For example, subjects are provided with a story about John, who drives home at high speed and collides with another car. The motives for driving at high
speed vary in different versions of the story. Either John needs to hide cocaine from his parents before they see it, or he wants to hide a present for his parents before they see it. John’s causal role is considered greatest when he is driving home to hide cocaine.

To summarise, a basic assumption in social psychological experiments into mental simulation appears to be that people use counterfactual reasoning, which is the simulation of alternatives to reality, in evaluating events with dramatic outcomes. An event should have mutable characteristics, and in order to be able to complete the process of mental simulation alternatives to the event should be available. How people select the events that are mutated seems to depend on various factors, which include the extent to which an event is considered as a deviation, the order of events, the controllability of events by the actor and the blameworthiness of the actions.

4.4.3 Philosophical literature

In the philosophical literature, it is generally assumed that there is a link between counterfactual and causal statements, i.e. that counterfactuals confirm that there is a relation between antecedent and consequent (Goodman, 1947, republished in 1991; Mackie, 1974b). Counterfactuals play an important role in causal analysis in areas such as history (cf. Dray, 1957; Elster, 1983; Frankel, 1957; Gerschenkron, 1968).

Counterfactual conditionals, or contrary-to-fact conditionals, such as ‘If the vase had fallen, it would have broken’ (example from Walters, 1967), point at imagined situations. The example given suggests that the vase did not fall, i.e. the antecedent did not actually happen (Mackie, 1974b). This is the characteristic of counterfactuals which poses problems for philosophers. Much of the discussion centred around the truth of counterfactuals, which resulted in various theories (e.g. Kvart, 1986; Lewis, 1973; Sanford, 1989) which are far too intricate for the scope of this review.

Several authors circumvent the ‘truth-problem’ by proposing that counterfactual statements are neither true nor false; they can only be sustained (Dummett, 1978; Elster, 1983; Mackie, 1974b). The basis for the plausibility of counterfactual statements - what would have happened in the absence of a condition - is existing knowledge. This knowledge may comprise scientific laws (Walters, 1967), facts (Dummett, 1978), a connecting principle (Goodman, 1947), something that we know or believe (Mackie, 1974b), or, as Elster (1983, p. 37) puts it:

A counterfactual statement is warranted or assertible if the consequent can be deduced from the antecedent together with some suitably chosen theoretical statements.
The use of counterfactuals assumes a ceteris paribus clause, e.g. in the absence of the antecedent the consequent would not have occurred, *ceteris paribus*. According to (Mackie, 1974b, p. 31), the connection between X and Y in the statement ‘X occurred and Y occurred and Y would not have occurred if X had not’ only holds given certain conditions. This is illustrated by Goodman (1947, p. 13):

When we say

If that match had been scratched, it would have lighted,

we mean that conditions are such, i.e. the match is well made, is dry enough, oxygen enough is present, etc., that ‘That match lights’ can be inferred from ‘That match is scratched’.

In conclusion, it is generally acknowledged that counterfactuals confirm that there is a relation between an antecedent and a consequent. Various attempts have been made to analyse the prerequisites for the truth of counterfactuals. Some philosophers have accepted that counterfactuals are neither true nor false, but can only be supported by existing knowledge.

4.4.4 Discussion

In social psychology and philosophy several differences in the treatment of counterfactuals can be observed. Philosophers, as may be expected, mainly stick to philosophising about the problems of counterfactuals; social psychologists provide empirical evidence on people’s actual use of counterfactual thinking (see also White, 1990). Furthermore, the philosophers mentioned have mainly been concerned with the truth, or the sustenance of counterfactuals, while social psychologists have been concerned with the role of counterfactual thinking in people’s evaluation of events with negative outcomes. Philosophers have also addressed the knowledge that can be used in sustaining counterfactuals, whereas social psychologists have looked into the factors that govern the selection of events in people’s evaluation of dramatic events (see White, 1990). This is reflected in the questions that social psychologists ask their subjects, and the questions that philosophers pose to themselves. Subjects in social psychological experiments are asked to indicate what could have been done to avoid an event, in order to find out which (type of) events are mentally alternated. Which events are singled out is left to the subjects. In our study, too, judges were free to select causes. The philosophical discussion centres around the knowledge used in supporting counterfactual statements. Thus, each discipline seeks to answer different questions.

The problem of supporting counterfactuals, as dealt with in the philosophical literature, seems to be related to the focus of our study. The incentive was to
obtain insights into the inference of contributory factors, so as to render the identification of factors explicit. However, the findings of the study presented in this chapter correspond, at least to some extent, to findings in social psychology. Note that the design of the study presented in this chapter differs from the experiments described in social psychology in several respects:

- the accident data provided to the judges in our study are far more detailed than the stories used in the literature, which generally consist of a short description comprising a causal chain of about four events;
- in our study judges were asked to indicate causes, while in the literature subjects are often asked to indicate mutations;
- the findings in our study with respect to the criteria used were ‘spontaneously’ obtained during the debriefing, whereas in the literature subjects are instructed to indicate mutations that would undo the outcome, thus more or less being forced to use counterfactual thinking.

As in the literature, counterfactual reasoning, deviations and mutability are criteria that were used by the judges in our study. The order of events, the controllability of events by the actor and the blameworthiness of actions might also have played a role in the judges’ interpretation of the data. According to the literature, the first event in a causal chain of events is assigned a greater causal significance. In our study, agreement on the consequences of causes, i.e. the way in which a cause is linked up with the occurrence of an accident, appears to be limited. Hence, no clear effect of event order could be discerned. To what extent judges assigned greater causal importance to the events that are controllable by the actors can also be checked. In our study this might mean that judges put greater emphasis on use actions carried out. Our findings suggest that they do not seem to emphasise particular kinds of causes.

In addition, the role of the blameworthiness of actions was looked into. In general, judges did not express themselves in terms of who was to blame. Nevertheless, some of them indicated that the user was ‘lax’ or ‘nonchalant’, expressions that can be seen as indicators of blame. Following the literature, one might expect that greater causal significance is assigned to these causes. However, the judges who indicated these causes only incidentally consider these causes as (the most) important causes.

In psychology, mental simulation is represented as a process. It is not clear whether the judges in our study used the various criteria sequentially, since the judges were asked to indicate their considerations retrospectively. Consequently, how the judges were thinking at the time of the analysis remains unknown.

To sum up, the influence of event order, controllability and blameworthiness cannot be clearly retrieved in our findings. Counterfactual reasoning, mutability and deviations, criteria also found in the literature, were all used by the judges in our study. This observation is of particular interest because the design of our study was not directed at finding these criteria.
4.5 Implications

The applicability of the various criteria in the analysis of the accidents is assessed in § 4.5.1. The steps in the analysis are then described and illustrated (§ 4.5.2).

4.5.1 Appraisal of the criteria

The aim is to provide starting points for the analysis of accident data, so that the inference of contributory factors is made explicit. Most of the norms used by the judges, as a basis for establishing deviations, seem to rely on implicit considerations referring to experience and knowledge of the judges themselves. The judges’ norms are only incidentally explicit, e.g. when they refer to the operation manual. Since people’s norms may not be retrievable most of the time, the criterion of deviations does not seem operable for the analysis of accident data.

Some of the norms used by judges betray an observer’s perspective, which may be completely at odds with the user’s perspective of what is normal or reasonable use of a product (see also Hale et al., 1990, p. 1379).

The study with judges indicates that conclusions reached with counterfactual reasoning may depend on the judges’ assumptions of what would (not) have happened in other circumstances. A problem in counterfactual reasoning is the plausibility of these assumptions. This problem can be solved to some extent. Philosophers emphasise that counterfactuals should be sustained by existing knowledge. For our aim, explication of the assumptions, i.e. the knowledge used to support a counterfactual statement, renders conclusions arguable. Therefore, counterfactual reasoning is applied in the analysis.

According to social psychological literature, a prerequisite for counterfactual reasoning is that factors can be mutated or influenced in some way. Immutable factors are not subject to this type of reasoning. Thus, gravity is usually not considered as a cause. What is considered as mutable seems to depend on the alternatives that people can imagine. For instance, it is possible to have a location where gravity is low, such as the moon, which implies that in this perspective gravity can be considered as mutable. In short, mutability appears to be an elastic concept.

Since mutability may shift with people’s perspective, this perspective should be made clear. In our analysis, the perspective introduced in § 3.2 makes it possible to define mutability: what can be affected - in one way or another - by the design of the product is seen as mutable. The designer of a product establishes the features of the product and its possible functioning. Both the product and its functioning can affect the use activities and, in some cases, the choice of the situation.
Something needs to be said about the relation between counterfactual reasoning on the one hand and the concept of deviations on the other. As will be explained in the next chapter, deviations are established on the basis of the users’ self-reports. The point to note here is that the factors identified as contributory by means of counterfactual reasoning may or may not be a deviation in the eyes of the user, and that factors not considered as contributory may or may not be a deviation according to the user. To what extent the findings obtained with counterfactual reasoning and the concept of deviations actually overlap is examined in § 5.4.

4.5.2 Analysis of the accidents

The analysis of each accident proceeds in the following steps:
1. Examination of the data: what happened?
2. Searching for contributory factors using counterfactual reasoning.
3. Making explicit the evidence used in sustaining counterfactuals.
4. Ordering of contributory factors according to sequence and co-occurrence.
5. Graphical presentation of the contributory factors in factor trees.
These steps are subsequently described and illustrated.

1. Examination of the data

The data, consisting of the video-recordings, transcriptions of the interview and outcomes of measurements, are examined to reconstruct what happened. Figure 4.3 gives the accident involving the planing machine as an example.

2. Counterfactual reasoning

Reasoning backwards from the occurrence of injury, the possible impact of characteristics is investigated by means of counterfactual reasoning. For this, the available accident data are reviewed, while asking, "If this condition had been absent, would the accident still have happened?". A characteristic is considered as a contributory factor if it can be presumed that the accident would not have happened in its absence, ceteris paribus. In order to ascertain that in all accidents corresponding characteristics are considered, all possibly relevant characteristics included in the study are checked for each accident.
Each counterfactual (if not ... then ...) specifies the sequence of factors, i.e. what is the consequence of a contributory factor. The sequence of factors follows the approach introduced in § 3.2. Thus, perceptual and cognitive use activities and some aspects of the material situation (e.g. light, temperature) can only affect physical actions. The functioning of the product is always a result of the co-occurrence of product characteristics, physical actions and/or the situational characteristics.
Figure 4.3
Illustration of the accident involving the planing machine. The user moves the short piece of plywood towards the cutters (A). In moving the wood, a force forward ($F_f$) and a force downward ($F_d$) is exerted. The instant that the cutter exerts force on the wood ($F_c$), the moments [$F_c \times a$] and [$F_d \times b$] are obtained, with the corner of the feed table as the turning point (B). The user repeatedly states and shows that the wood canted. Since the wood canted, [$F_c \times a$] must have been larger than [$F_d \times b$], perhaps because the cutters wedged themselves into the soft plywood, pulling the piece of wood down. The subsequent, complicated interplay of forces depends, among other things, on the angle between the wood and the feed table and the reaction time of the user, which in turn determines the extent to which the user can adjust his forces. The fingers slid into the revolving cutters (C). It is not clear whether the wood then canted further or was flung away.

3. Evidence used in supporting counterfactuals

The evidence used in supporting counterfactuals may be existing knowledge, outcomes of measurements and user’s statements. Such evidence always concerns the relation between two factors. Although some of the evidence may seem trivial, such ‘common sense’ is nevertheless evidence.

Firstly, existing knowledge may consist of physical or psychological regularities. An example is the knowledge used in analysing an accident involving a thermos
and a coffee filter. The empty thermos was positioned on a sloping floor, and tipped over when the user filled the filter with boiling water. The conclusion is that the accident might not have happened if the floor had been level. See figure 4.4 for physical knowledge used to support this conclusion.

Figure 4.4
Comparison of the thermos and filter positioned on a flat floor and on a sloping floor. The thermos was empty, while the filter was completely filled with coffee and hot water. $F_g$ indicates the gravitation for the unit of filter and thermos; the mass centre is the point of application of $F_g$. In case of a flat floor (A) the gravitation is in the centre of the unit. When an object is positioned on a sloping plane (B), the working line of the gravitation may fall beyond the crossover point, resulting in the toppling over of the filter and thermos.

Secondly, what might have happened in the absence of a condition can sometimes be measured. For example, the relevance of the sloping floor in the case of the accident with the thermos can also be measured by varying the angle of the floor. In the third place, subjects’ statements can provide support for counterfactuals. The influence of some factors, e.g. required effort, temperature, noise and bystanders, on the user’s activities and condition can only be retrieved by asking the user. For example, it is concluded that if the radio had not been playing during planing the piece of wood, the accident would still have happened. This conclusion is based on the user’s statements; he said that the radio did not bother him.
Thus, the user's perspective constitutes at least a part of the evidence used to support counterfactuals.

Table 4.2 shows the results concerning the relevance of the material situation in the case of the planing machine. A description is given of each characteristic. Also, the evidence used to support the counterfactuals is provided.

The length of the piece of wood is considered as contributory, and the type of wood (plywood) is seen as possibly relevant. The remaining factors could not be identified as relevant. Figure 4.5 shows the basis for the conclusion that the length of the wood is a contributory factor.

![Figure 4.5](image)

**Figure 4.5**

Planing a small piece of wood (A) is compared to a long piece (B), assuming that with a long piece the hands are positioned further from the cutters. When the cutter exerts force on the wood, two moments are obtained: \([F_d \times b]\) and \([F_c \times a]\) with the corner of the feed table as the turning point. The user can do two things to prevent the wood from canting, either increase the distance to the turning point, i.e. position the fingers farther from the cutters (as in B), which would require a longer feed table or a completely different way of holding the wood, or exert more force. In other words, case A has to exert much more force than case B in order to prevent the piece of wood from being pulled down.

4. The ordering of contributory factors

Once the contributory factors are identified, they can be ordered according to their sequence and co-occurrence. This ordering is constrained as follows. Perceptual and cognitive use activities, user characteristics, the temporary condition of the user and some situational characteristics only affect physical actions. The functioning is always a result of the co-occurrence of, on the one hand, the product and, on the other hand, the physical use actions and/or situational characteristics. Furthermore, an accident is seen as a consequence of the consecutive interactions in time and place of the product, the use activities and the material situation, which implies that these factors are never relevant in isolation for the occurrence of an accident.
Table 4.2
Material characteristics of the situation in the case of the planing machine: description and relevance, including the evidence used to support the counterfactuals.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
<th>Contributory?</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions of wood</td>
<td>Piece of plywood of 10 by 6 cm</td>
<td>Yes</td>
<td>If the piece of wood had been longer, it might not have canted. See figure 4.5 for evidence supporting this conclusion.</td>
</tr>
<tr>
<td>Type of wood</td>
<td>Plywood</td>
<td>Probably yes</td>
<td>Plywood consists of several layers of soft material. The cutters can easily wedge it and pull it down. Since the user had thrown away the piece of wood, it is impossible to draw firm conclusions.</td>
</tr>
<tr>
<td>Floor covering</td>
<td>Paving stones</td>
<td>No</td>
<td>The investigation on-site showed that the work bench did not wobble as a result of possible unevenness of the stones.</td>
</tr>
<tr>
<td>Space available</td>
<td>About 1 by 1 meter</td>
<td>No</td>
<td>The user said that he had enough space.</td>
</tr>
<tr>
<td>Sitting height</td>
<td>Not applicable</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Working height</td>
<td>108 cm</td>
<td>No</td>
<td>According to the user, the working height (always the same) is fine.</td>
</tr>
<tr>
<td>Reaching distance</td>
<td>Not applicable</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Objects present</td>
<td>Lots of objects surrounding user</td>
<td>No</td>
<td>The user said that the objects, which are always present, did not hamper him.</td>
</tr>
<tr>
<td>Lighting</td>
<td>Lighting clear, from various</td>
<td>No</td>
<td>The user indicated that there was enough light.</td>
</tr>
<tr>
<td></td>
<td>directions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sound/noise</td>
<td>The radio was playing</td>
<td>No</td>
<td>According to the user, the radio, which is usually playing, did not bother him.</td>
</tr>
<tr>
<td>Weather</td>
<td>Not applicable (inside)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Temperature</td>
<td>Fresh</td>
<td>No</td>
<td>According to the user the cold, in which he usually works, did not bother him.</td>
</tr>
</tbody>
</table>

For the accident involving the planing machine, table 4.3 provides a review of the factors that are found to be relevant, including the counterfactuals and the evidence for their relevance. The upper rows of the table concern the factors which are nearest to the injury. The factors between the lines are interactions, they jointly lead to the factor in italics.

At this point, the causes indicated by judges (see figure 4.1) can be compared to the contributory factors obtained by counterfactual reasoning. Most factors indicated in table 4.3 are mentioned as a cause by at least one, and generally more, judges. Why are the remaining causes indicated by judges not identified as a contributory factor?
### Table 4.3
**Contributory factors, counterfactuals and evidence in the accident involving the planing machine.**

<table>
<thead>
<tr>
<th>Contr. factor</th>
<th>Counterfactual</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fingers slide into</td>
<td>The fingertips would not have been cut off if</td>
<td></td>
</tr>
<tr>
<td>cutters</td>
<td>the fingers had not slid into the cutters or</td>
<td>When fingers get within reach of sharp, revolving parts, they are cut off.</td>
</tr>
<tr>
<td>Cutters are</td>
<td>the cutters had not been revolving.</td>
<td>When blades are revolving, fingers entering their path can be cut off.</td>
</tr>
<tr>
<td>revolving</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fingers close to</td>
<td>The fingers might not have slid into the cutters if</td>
<td></td>
</tr>
<tr>
<td>cutters</td>
<td>the user had not positioned his fingers so close to the cutters or</td>
<td>When the distance of fingers from cutters is small, the time taken to slide into the cutters is short, making it impossible to reposition the fingers. When fingers are positioned on a canted plane, they slide off.</td>
</tr>
<tr>
<td>Wood cants</td>
<td>the wood had not canted or</td>
<td></td>
</tr>
<tr>
<td>Opening for</td>
<td>the opening for the cutters had not been accessible to fingers.</td>
<td>When an opening is larger than fingers, fingers can get into the opening.</td>
</tr>
<tr>
<td>fingers large</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$[F_d \times b]$ larger than $[F_c \times a]$, i.e., the wood might not have canted if</td>
<td>See figure 4.3.</td>
<td></td>
</tr>
<tr>
<td>Exerted force not</td>
<td>the user had exerted enough force or</td>
<td>A larger force means a larger moment $[F_d \times b]$.</td>
</tr>
<tr>
<td>enough</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fingers close to</td>
<td>the distance of the fingers to the turning point had been larger or</td>
<td>A larger arm means a larger moment $[F_d \times b]$.</td>
</tr>
<tr>
<td>turning point</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance cutter-</td>
<td>the distance from cutter to turning point had been smaller or</td>
<td>With a smaller arm, the moment $[F_c \times a]$ will be smaller.</td>
</tr>
<tr>
<td>turning point</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cutters pull down</td>
<td>the cutters had not exerted this much force on the wood.</td>
<td>With a smaller force, the moment $[F_c \times a]$ will be smaller.</td>
</tr>
<tr>
<td>wood forcefully</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piece of wood short</td>
<td>the piece of wood had not been so short.</td>
<td>The longer an object, the more room for positioning the fingers.</td>
</tr>
<tr>
<td>Cutters wedge into</td>
<td>The cutters might possibly not have pulled down the wood if</td>
<td>When a pointed object is hooked into soft material, it can pull the material down.</td>
</tr>
<tr>
<td>wood</td>
<td>the cutters had not wedged themselves into the soft plywood</td>
<td></td>
</tr>
<tr>
<td>Plywood</td>
<td>The cutters might possibly not have wedged into the wood if</td>
<td>When soft, layered wood meets a pointed object, the pointed object may wedge itself into the wood.</td>
</tr>
<tr>
<td></td>
<td>the wood had not been plywood.</td>
<td></td>
</tr>
</tbody>
</table>
Several contributory factors indicated by judges are rejected because there is no evidence pointing at the relevance of these factors, i.e. supporting the counterfactuals (e.g. stands twisted behind plane, just back from lunch, no lock for starting button, hampered by clothing). Sometimes causes mentioned by judges point at solutions (e.g. no instructions for stationary use, no guideway, no transit aid). In addition, judges now and then indulge in fictions: they name factors that were not or cannot be investigated, i.e. for which no data are available (e.g. one judge speculated as to whether the user of the fitness-stick was pregnant). They also incidentally phrase causes in terms of value judgements (e.g. the user is overconfident, the product is unsuitable for stationary use, protective cover inadequate). Several times, judges identify product characteristics that - according to the judges - may result in accidents other than the accident for which the video was provided.

To summarise, our analysis includes the following premises. One, considerations in the identification of contributory factors have to be supported by external evidence. Two, no conclusions are drawn beyond the data available. When something is or was not investigated, this is not considered any further. No value judgements are made. Neither are possible solutions considered. Three, as far as factors are not identified as contributory to the accident investigated, they are left out of consideration, no matter how evident it is that other accidents than the one investigated may occur.

5. Factor trees

The contributory factors for each accident are graphically presented in a so-called ‘factor tree’. The factor tree depicts the combinations and sequences of contributory factors. The purpose of presenting the findings in ‘trees’ is that it is easier to grasp the occurrences in comparison with the presentation of findings in, for example, tables.

The concept of a tree is borrowed from the literature, where event trees and fault trees are distinguished. These are used in analysing possible accidents as well as in the analysis of accidents that actually happened (Clemens, 1982). Of course, the latter applies to our case. The difference between event trees and fault trees is that the former start with a fault or an end event, reasoning backwards to causes, while the latter begin with an initiating event, reasoning forwards to consequences (Clemens, 1982). One of the principles of event and fault tree analysis is that a condition, event or factor can be described as being in one of two states (Hammer, 1980). When the probability of each factor is known, the probability of the top-event can be computed. Like Wagenaar & Groeneweg (1987), we will use trees to portray the factors that contributed to the occurrence of accidents. Consequently, several differences between the factor trees as used in the present study and as used in the literature should be kept in mind.
To begin with, the identification of causes is not exclusively based on an expert’s or observer’s perspective, as in the literature (e.g. Czernakowski & Müller, 1993), but also on the user’s statements and self-reports. Thus, an observer’s perspective is exchanged, at least in part, for a user’s perspective.

Secondly, event and fault trees originated in industry, where the system is generally fully known, making it possible to compute the probability of particular events. Our trees, however, are interspersed with uncertainties, as the examination of the accident with the planing machine shows. Groeneweg (1992, p. 114) puts it as follows:

No matter how carefully the accidents are analysed, the only result is a tree in which events are graphically represented. The events are conjoined but not connected.

Groeneweg’s remark that the events in a tree are ‘conjoined but not connected’ may have something to do with the fact that most authors, including Groeneweg (1992), remain silent on how to identify the causes to be positioned in the trees. As long as it is not clear why events are positioned in a tree, events may indeed seem conjoined instead of connected.

Thirdly, in the literature event trees seem to be used as a tool in finding causes, while in our analysis these have already been identified by means of counterfactual reasoning. The purpose of factor trees in our study is merely to present the contributory factors graphically.

Figure 4.6 depicts the factor tree obtained for the accident with the planing machine. The tree is based on table 4.3. The end event, depicted as the star at the top, is the fingertips being cut off. From the injury the reasoning moves backwards in time. For example, the fingertips being cut off is a result of the fingers sliding into the revolving cutters.

The background is added to emphasise that the factors are contributory within a particular context, i.e. the use of a product in a particular situation. Thus, the background indicates the characteristics of the planing machine, use activities and of the situation that were present but not identified as contributory.

The time arrow indicates that factors at the bottom precede the other factors in time. Note that blocks being on the same horizontal line does not indicate that the time passed is equal for those blocks. Some things may happen very quickly, while others do not.

Dotted lines indicate that it is not clear whether a factor was influenced by the previous factor (e.g. the relevance of the use of plywood to the cutters wedging themselves into the wood). Of the factors in italics it is not clear whether they actually occurred (e.g. the cutters wedging themselves into the wood). The shortness of the piece of plywood is twice in the tree (‘repetitive’ factor, cf. Groeneweg, 1992, p. 66-67). In appendix 3, the factor tree of each accident is shown in addition to a short description and a picture of what happened.
An accident is prevented by the elimination of at least one contributory factor (e.g. remove cutters), but may also be averted by, for example, reduction (e.g. lowering the voltage of hair dryers) or isolation (e.g. protective cover or place out of reach, as in Mauro, 1978) of a relevant factor (see also Stoop, 1990, p. 53-54; Hale & Glendon, 1987, p. 214-217). For instance, the accident with the planing machine may be prevented by eliminating the possibility of sliding into the cutters or by covering the revolving cutters.

Figure 4.6
Factor tree for the accident with the planing machine. Dotted lines indicate that it is not clear whether a factor was influenced by the previous factor. Of the factors in italics it is not clear whether they actually occurred.
Wagenaar & Groeneweg (1987, p. 589) remark that the making of event trees can be ‘tricky’, because one and the same accident can be represented in various ways. They asked two judges to create trees for fourteen accidents. In some cases, the number of causes differed considerably between the two judges (see also Groeneweg, 1992). Groeneweg (1992) concludes that differences in the event trees result from subjective considerations. He also suggests that the number of causes identified is a reflection of the severity of the accident and the amount of money and time invested in the analysis. However, in the experiments of Groeneweg (1992) no effort is made to find out what were the considerations of judges in compiling the trees.

Various authors point at the issue of the time horizon (Groeneweg, 1992; Rasmussen, 1990b, 1990c; Wagenaar & Groeneweg, 1987): when should the search for causes stop? Groeneweg (1992, p. 112) concludes that:

there is no theoretical limitation as to the extent in time or space the backward search for causes should go: the length of the event tree is therefore infinite in all directions.

In our analysis, the outcomes are constrained in several respects. As was pointed out, the outcomes regarding the sequence and interaction of factors should be in accordance with the approach in this thesis. The perspective chosen concerning mutability is another limitation of the ‘horizon’. Also, the factors that should be considered in the analysis work as constraints.

4.6 Conclusions

The study discussed in this chapter shows that judges use various criteria in identifying the causes of accidents. Of these, counterfactual reasoning is found to be applicable in the analysis of the accident data. Counterfactuals can be supported by external evidence, thus allowing evaluation of conclusions. Although this type of reasoning does not guarantee that different judges identify the same causes, the considerations in the selection of causes are at least made clear. This enables a comparison of the outcomes of different accidents, which is necessary in order to ascertain whether patterns in accidents can be identified.

The evidence supporting counterfactuals includes existing knowledge, outcomes from measurements and user’s statements. Some of the evidence used may seem trivial. By founding a part of the evidence on the user’s statements, the observer’s perspective has been partly exchanged for a user’s perspective.

Mutability, seen in the literature as a prerequisite for counterfactual reasoning, is considered from a designer’s perspective. This perspective serves, in the analysis, as a limitation on which factors can be changed and accounted for, and thus which factors are subjected to counterfactual reasoning.
Despite all efforts made to affirm counterfactuals, conclusions drawn about causes can never be 'true' or 'sure'. Consequently, some authors consider it more appropriate to speak of probable causes (e.g. Cook & Campbell, 1979; Eells, 1990; Einhorn & Hogarth, 1986). Apart from these considerations, the use of the term 'cause' brings with it the notion of monocausality (see Evans, 1991, p. 60; Surry, 1974, p. 20-21). Therefore, 'contributory factor' is considered as preferable to 'cause'. The factors identified as contributory still concern possible contributory factors, since the counterfactuals have been made plausible and were not proven to be 'true'.
5. On patterns in accidents

The extent to which characteristics of the product, use activities and the situation can be considered as contributory is explored (§ 5.2). The contributory factors serve as a basis for the examination of regularities in sequences and combinations of factors preceding the occurrence of accidents. The characteristics of the user are described and, as far as possible, compared to other people (§ 5.3). Then, the extent to which deviations can be related to accidents is addressed (§ 5.4). Discussion and conclusions are found in § 5.5.

5.1 Introduction

When no evidence is retrievable on possible accidents involving a product yet to be designed, industrial design engineers may profit from general insights into the occurrence of accidents. This chapter explores to what extent such general insights can be given. For this, the accident data are examined to find out whether patterns in the occurrence of accidents can be detected. These patterns may consist of a dominant contributory factor, regularities in the sequences and combinations of contributory factors, or particular relations between user characteristics and how and where products are being used.

The accidents included in the study can be briefly characterised as follows. The average age of the participants was 42 years, with a range of 20 to 69 years. Nineteen women and twenty-three men participated in the study. Most accidents took place indoors (37), during housekeeping and do-it-yourself activities. A major part of the accidents happened during the actual use of the products, while a minority of the accidents occurred during repairing, storing or cleaning the product. Most products had been newly bought by the subject and were less than 5 years old. The age of the products varied from 10 days to 30 years. In six accidents, the product broke down at the time of the accident. The most frequently occurring injury was an incision. The part of the body that was most often injured was the hand. In three-quarters of the accidents the subject had to be medically treated. In a quarter of the accidents the severity of the injury did not seem too serious. Nevertheless, these subjects did experience some inconvenience. In appendix 2, a more detailed characterisation of the accidents can be found.
Synopses and pictures of the accidents, including the factor trees, are given in appendix 3. The accidents are alphabetically ordered according to the product(s) involved.

5.2 Regularities in the occurrence of accidents

To begin with, the extent to which characteristics of the product and its functioning, the use activities and the situation can be identified as contributory to the occurrence of accidents is explored (§ 5.2.1). The possibility of identifying regularities in the sequences and combinations of contributory factors is examined in § 5.2.2. The contributory factors can always be further divided into new factors, which would finally result in idiosyncratic findings. In the other direction the resolution of the analysis can be blurred, which might, in the end, lead to trivialities. The point to note here is that the resolution of the analysis has implications for the findings obtained.

In two accidents, the product that inflicted the injury was not actually in use, but was placed in the environment. In addition, the use activities were not directed at the functioning of these products. These two accidents involved the scissors, which were lying between newspaper sheets, and the needle, which was lying in a chair. In these two cases, the product is seen as a part of the environment.

5.2.1 Contributory factors

Note that tables 5.1 to 5.5 include the number of accidents in which a particular factor was found to be relevant. Incidentally, these numbers may be smaller than the number of times that a factor could be identified as contributory, because a factor can be indicated as relevant more than once in one and the same accident. For example, the user of the food processor gripped the cylinder of the sickle-shaped knives with wet hands. Also, she tried to catch knives after having dropped them. Both are subsumed under the heading of ‘what is done’.

Functioning of the product

The number of accidents in which functional aspects can be considered as relevant are given in table 5.1. Examples of accidents in which a particular aspect could be identified as contributory are included. Functional aspects that cannot be indicated as relevant in any of the accidents are vibration, waste-matters and smell (see § 3.2).
Table 5.1
Functioning: number of accidents in which functional aspects can be identified as contributory, including examples.

<table>
<thead>
<tr>
<th>Contributory factor</th>
<th>Number</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Additional output</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat</td>
<td>5</td>
<td>The tip of the iron was burning hot.</td>
</tr>
<tr>
<td>Kinetic energy suddenly released</td>
<td>3</td>
<td>The bottle of soft drink suddenly exploded.</td>
</tr>
<tr>
<td>Noise</td>
<td>1</td>
<td>The stair gate creaks when opened.</td>
</tr>
<tr>
<td><strong>Human input</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Required forces</td>
<td>3</td>
<td>It required much force to tighten the blades on the blender.</td>
</tr>
<tr>
<td>Effort</td>
<td>1</td>
<td>The stair gate was difficult to open with one hand.</td>
</tr>
</tbody>
</table>

*Use activities*

Table 5.2 and 5.3 shows in how many accidents the various use activities have been recognised as relevant. Table 5.2 gives the perceptual and cognitive use activities, table 5.3 gives the physical use actions. See § 3.2 for an explanation of the use activities distinguished.

When a use activity is considered as contributory to the occurrence of an accident, this does not imply that the subject concerned is conscious of what he or she does, or that activities are performed deliberately.

Table 5.2
Perceptual and cognitive use activities: number of accidents in which perceptual and cognitive use activities can be identified as contributory, including examples.

<table>
<thead>
<tr>
<th>Contributory factor</th>
<th>Number</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Could not see what he/she was doing</td>
<td>4</td>
<td>The user of the grater could not see the fingers at the bottom of the cheese.</td>
</tr>
<tr>
<td>Was not looking at what he/she was doing</td>
<td>4</td>
<td>The user of the stepladder 2 was not looking when he stepped off the wrong side.</td>
</tr>
<tr>
<td>Perceived product as sturdy</td>
<td>1</td>
<td>The children’s table gave the user an impression of solidity.</td>
</tr>
<tr>
<td>Did not notice something</td>
<td>1</td>
<td>The user did not notice the lamp indicating that the hot plate was still hot.</td>
</tr>
</tbody>
</table>
Table 5.3
Physical use actions: number of accidents in which physical use actions can be identified as contributory, including examples.

<table>
<thead>
<tr>
<th>Contributory factor</th>
<th>Number</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is done, e.g. stood on the product, particular motions made, gripped the</td>
<td>20</td>
<td>The user of the razor tried to catch it when she dropped it; the user of the stair gate</td>
</tr>
<tr>
<td>product with wet hands</td>
<td></td>
<td>climbed over the gate.</td>
</tr>
<tr>
<td>Amount of exerted force</td>
<td>15</td>
<td>The user of the small knife exerted great force to separate frozen meat.</td>
</tr>
<tr>
<td>Way of contacting the material processed</td>
<td>14</td>
<td>The user of the metal saw kept his thumb close to the blade.</td>
</tr>
<tr>
<td>Slipping, e.g., the product slipped out of the hand, the user slipped with the</td>
<td>14</td>
<td>The fitness-stick slipped out of the hand; the small knife slipped on the meat.</td>
</tr>
<tr>
<td>product on the material processed in relation to the user</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orientation of the product or material processed in relation to the user</td>
<td>11</td>
<td>One handle of the fitness-stick was kept close to the body.</td>
</tr>
<tr>
<td>The user hit/contacted the product</td>
<td>9</td>
<td>The user of the can hit the sharp edge of the lid.</td>
</tr>
<tr>
<td>Way of contacting the product</td>
<td>9</td>
<td>The user of the large knife used two hands while cutting.</td>
</tr>
<tr>
<td>The user fell through, with or off the product</td>
<td>6</td>
<td>The user of stepladder 1 fell with the ladder.</td>
</tr>
<tr>
<td>Small distance between user and product</td>
<td>5</td>
<td>The thermos was near the user's feet.</td>
</tr>
<tr>
<td>Posture</td>
<td>5</td>
<td>The user was leaning over on the plane.</td>
</tr>
<tr>
<td>Direction of exerted force</td>
<td>4</td>
<td>The user of the pump screwdriver did not exert force in line with the screw.</td>
</tr>
<tr>
<td>Position of user on the product</td>
<td>2</td>
<td>The user of the children's table was not standing in the middle of the tabletop.</td>
</tr>
<tr>
<td>Position of the product in the environment</td>
<td>2</td>
<td>The stool was positioned on the grate of the underfloor heating.</td>
</tr>
<tr>
<td>Omitted action</td>
<td>1</td>
<td>The user of the thermos omitted to hold it with one hand.</td>
</tr>
</tbody>
</table>

Product characteristics
Table 5.4 shows the number of accidents in which characteristics of the product can be identified as contributory. Examples are given of accidents in which a particular product characteristic was relevant. Product characteristics that were included in the method of data collection, but which cannot be identified as contributory in any of the accidents, are mass, reflection, colours and graphics (see § 3.2).
### Table 5.4

Product characteristics: number of accidents in which characteristics of the product can be identified as contributory, including examples.

<table>
<thead>
<tr>
<th>Contributory factor</th>
<th>Number</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharp, moving or revolving parts</td>
<td>28</td>
<td>The sharp points of the handsaws tore the skin; the revolving blade of the circular saw amputated the fingers.</td>
</tr>
<tr>
<td>Feedback</td>
<td>5</td>
<td>The hot plate did not reveal that it still contained heat; the children’s table gave an impression of solidity.</td>
</tr>
<tr>
<td>Dimensions</td>
<td>5</td>
<td>The safety holder of the vegetable slicer is too small for vegetables.</td>
</tr>
<tr>
<td>Product breaks</td>
<td>4</td>
<td>The user of the step lost balance when the clothesline broke.</td>
</tr>
<tr>
<td>Amount of force exerted by product</td>
<td>4</td>
<td>The planing machine pulled down the plywood forcefully.</td>
</tr>
<tr>
<td>Texture</td>
<td>3</td>
<td>The cylinder of the sickle-shaped knives of the food processor provided poor grip.</td>
</tr>
<tr>
<td>Flexibility</td>
<td>2</td>
<td>The blade of the hobby knife is flexible while pulled out.</td>
</tr>
<tr>
<td>Material</td>
<td>2</td>
<td>The user of wastepaper basket did not touch the gleaming metal so as to prevent leaving fingerprints.</td>
</tr>
<tr>
<td>Product worn down</td>
<td>2</td>
<td>The flints of the gas lighter were worn down.</td>
</tr>
<tr>
<td>Product deforms</td>
<td>2</td>
<td>The blade of the hobby knife folded during cutting mastic.</td>
</tr>
<tr>
<td>Pressure is built up</td>
<td>1</td>
<td>High pressures had built up in the bottle of soft drink, resulting in explosion.</td>
</tr>
<tr>
<td>Composition</td>
<td>1</td>
<td>The tabletop of the children’s table was fixed to the frame with too few screws.</td>
</tr>
<tr>
<td>No brace</td>
<td>1</td>
<td>Stepladder 2 did not have a brace, i.e., was symmetrical.</td>
</tr>
<tr>
<td>Transparency</td>
<td>1</td>
<td>The user walked into the corner of the transparent, smoked glass table.</td>
</tr>
<tr>
<td>Product is powered</td>
<td>1</td>
<td>The plug was still in the socket when the user activated the blender.</td>
</tr>
<tr>
<td>Breakability</td>
<td>1</td>
<td>The cylinder of the retractable clothesline had been glued together.</td>
</tr>
</tbody>
</table>
**Chapter 5**

**Situational characteristics**
The relevance of situational characteristics is given in table 5.5. Table 5.5 also includes social elements. Three subjects were looking at the people present, one subject indicated that she was distracted by talking with the person near her. In one accident, a dog caused a movement of fright from the user. Thus, the presence of people or animals influences the functioning of the product indirectly, i.e. via the user’s reaction.

Light, climate, i.e. temperature and humidity, and noise are situational characteristics that were expected to have possible relevance in designing this research, but which cannot be indicated as contributory in any of the accidents (see § 3.2).

**Table 5.5**
*Situational characteristics: number of accidents in which situational characteristics can be identified as contributory, including examples.*

<table>
<thead>
<tr>
<th>Contributory factor</th>
<th>Number</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material situation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material processed moves</td>
<td>6</td>
<td>The metal strip moved during sawing.</td>
</tr>
<tr>
<td>Material processed is tough</td>
<td>5</td>
<td>The mastic cut with the hobbyknife was tough.</td>
</tr>
<tr>
<td>Dimensions of material processed</td>
<td>5</td>
<td>The slat that was chopped to kindlings with the axe was small.</td>
</tr>
<tr>
<td>Material processed is stuck/sticky</td>
<td>4</td>
<td>The cork removed with the cork screw was firmly stuck in the winebottle.</td>
</tr>
<tr>
<td>Type of floor</td>
<td>3</td>
<td>The stool was positioned on the grate of the underfloor heating.</td>
</tr>
<tr>
<td>Floor inclines</td>
<td>2</td>
<td>Stepladder 1 was positioned on a sloping floor.</td>
</tr>
<tr>
<td>Dimensions of location</td>
<td>2</td>
<td>The room available in the case of the glass table was small.</td>
</tr>
<tr>
<td>Objects present</td>
<td>2</td>
<td>The user of the gas lighter had to reach beneath a heat diffuser to light the gas.</td>
</tr>
<tr>
<td>Liquid processed is hot</td>
<td>2</td>
<td>The pan contained boiling water that gushed out.</td>
</tr>
<tr>
<td>Material processed is rough</td>
<td>1</td>
<td>The user of the plane scraped his finger along the rough plank.</td>
</tr>
<tr>
<td>Type of material processed</td>
<td>1</td>
<td>The user of the planing machine used plywood.</td>
</tr>
<tr>
<td><strong>Social elements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of people or animals</td>
<td>5</td>
<td>The user of stepladder 2 was looking at his wife and daughter while stepping down; the user of hand saw 2 was scared by a dog.</td>
</tr>
</tbody>
</table>
Discussion
Eight factors are relevant in a quarter to two-thirds of the accidents (9 to 28 accidents). The remaining factors are contributory in, at most, six accidents. Obviously sharp, moving and revolving parts of a product are involved in a majority of the accidents. The findings do not point at other factors as being dominant.
The number of contributory factors per accident, as derived from the factor trees, varies from two to thirteen. The median number of factors per accident is 6. The unravelling of factors by presenting the contributory factors in isolation is clearly in contradiction to the perspective that accidents are a consequence of the co-occurrence of factors. No insight is obtained into the context in which factors are relevant, how they influence the subsequent occurrences culminating in injury, or how they came about. In the next paragraph the contributory factors will be viewed in relation to each other.

5.2.2 Combinations and sequences of factors

In this paragraph an attempt is made to find regularities in the combinations and sequences of the factors culminating in injury. The factor trees in appendix 3 constitute the basis for these analyses. Since none of the factor trees are similar, it is unnecessary to analyse patterns in the entire trees. This leaves us looking for repeatedly occurring combinations and sequences of factors.

Combinations of factors
In table 5.6 the combinations of factors preceding the injury are given, including the number of accidents, and examples, in which each combination was found. Injury in most cases is preceded by a fall of the user, the user hitting sharp or hot product parts, or slipping with the product on, off or out of the material processed or the product. Apart from the combinations mentioned in table 5.6, one combination is found in two accidents. This concerns the product slipping out of the hand while much energy is stored in a spring, a combination found in two accidents. The remaining combinations are found in one accident. Given the enormous variety, a presentation of all the combinations is omitted here, since this would lead to lengthy, insignificant enumerations.

Sequences of factors
Findings concerning the sequence of factors can be approached from two directions, i.e. the precursors of factors and the consequences of factors. The precursors of injury can be found in table 5.6, so they are not discussed here.
### Table 5.6
Combinations of factors preceding injury, including the number of accidents in which a particular combination was found, and examples of these accidents.

<table>
<thead>
<tr>
<th>Combinations of factors preceding injury</th>
<th>Nr.</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>The user contacts or hits - often very forcefully - the sharp/turning part of the product with the hand holding the material processed/product.</td>
<td>14</td>
<td>Grater, can, razor</td>
</tr>
<tr>
<td>The product (part) slips on/out/off the material processed/product while the hand contacting the product or material processed is in the path of sharp, turning or moving product parts.</td>
<td>9</td>
<td>Metal saw, small knife</td>
</tr>
<tr>
<td>User falls through, with or off product, in one case moving along a sharp part.</td>
<td>6</td>
<td>Stool, stepladders</td>
</tr>
<tr>
<td>The user touches a hot part of the product.</td>
<td>4</td>
<td>Iron</td>
</tr>
<tr>
<td>A large amount of kinetic energy is released at once in the direction of the user.</td>
<td>3</td>
<td>Fitness-stick</td>
</tr>
<tr>
<td>Hot substance pours out of fallen or moving product over the user.</td>
<td>2</td>
<td>Thermos</td>
</tr>
<tr>
<td>The blade of the product folds, thus cutting the hand holding the material processed.</td>
<td>2</td>
<td>Hand saw 2</td>
</tr>
<tr>
<td>The user proceeds to work with the product while the orientation of the product is such that the blade hits the hand holding the material processed.</td>
<td>2</td>
<td>Breadknife</td>
</tr>
</tbody>
</table>

The precursors of, as well as the consequences of, factors are found more than once in at most six accidents. Some examples are:

- the amount of force exerted in reaction to the material processed being stuck (n=5);
- slipping with the product follows a large amount of exerted force (n=6);
- the way of contacting the material processed in reaction to characteristics of the material, such as the dimensions (n=3) or the stability of the material (n=5).

The findings show that product characteristics are almost never preceded by other factors. This also applies to environmental factors; generally they do not have any precursors. That the characteristics of the product and the situation are seldom found to have precursors is a consequence of the fact that the analysis stopped at those instants. This is different with use activities. Approximately half of the use activities originated from the user. In particular the posture, omitting to look and the orientation and position of the product in relation to the user are generally a choice of the user; these factors are mostly not preceded by other factors. The other half of the use activities are prompted by situational factors and product characteristics. For instance, characteristics of the material processed provoked the users to perform particular activities. As to the product, the feedback provided about its condition is in all cases followed by an action that is relevant to the occurrences.
In summary
The variety in combinations and sequences of contributory factors is enormous. Only in combinations preceding the injury can a few patterns be found. When looked at further back in time, the occurrences seem to fan out, leaving hardly any regularities to be detected.

5.3 Characteristics of the user

Characteristics of the user are divided into the temporary condition of the user at the time of the accident and the user’s sensory, mental and physical characteristics. In this paragraph an examination is made of the extent to which these characteristics may be related to how and where products are being used. As was explained in the previous chapter, the characteristics of the user are considered as immutable from a designer’s point of view. Designers can, however, attune their product to the users’ characteristics, including the variability therein. In that case there should be evidence for particular user characteristics being related to how and where the product is used.

A limitation of research into accidents is that no insight is obtained into the characteristics of people not involved in an accident. Therefore, as far as possible, the characteristics of the 42 subjects are compared to those of other people. Data was available on physical characteristics and accident involvement.

The user’s temporary condition
Subjects were asked if they were in a normal state of mind and general condition at the time of the accident. Fifteen subjects indicated that they were in a particular mood, e.g. feeling hurried, tired, drowsy, irritated, distracted, lazy or careless. In these cases the subject’s state of mind may have affected his or her use activities. The remaining subjects said that they were in a normal state of mind at the time of the accident.
Furthermore, the type of clothing worn at the time of the accident was involved in one accident. In this case, the user reached over a burning gas ring with a tea kettle on it, while wearing a housecoat with wide sleeves. The housecoat caught fire.
In addition, three subjects gripped the product with wet or damp hands. In combination with the poor grip provided by the product, the product slipped in or out of the hands.
For the remainder, there are no indications that the user’s temporary condition was relevant.

Mental characteristics of the user
In order to capture the subjects’ perceptions of risk, they were asked whether they had been aware of running the risk of injuring themselves while they worked with
the product. Table 5.7 shows the reasons that subjects give for (not) being aware of running the risk of injuring themselves.

Thirty-one subjects said that they were not aware of running any risks, for example, because it just never occurred to them that an accident could happen or because they believed themselves to be sufficiently cautious. Eleven subjects said that they were aware of running the risk of injuring themselves with the product, because they had previously had accidents with the product or knew that the product was not meant to be used the way they were using it. Four of these subjects said they realised that they were taking risks, but that they took no action to avoid these risks, because, for example, they found it too much effort to apply a proper tool.

Table 5.7
Reasons given for being aware or not aware of running the risk of injury (n=42).

<table>
<thead>
<tr>
<th>Awareness of running the risk of injury</th>
<th>Number of subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not aware, because</td>
<td></td>
</tr>
<tr>
<td>- the probability of an accident never occurred to the subject</td>
<td>10</td>
</tr>
<tr>
<td>- the subject believed he/she was cautious in using the product</td>
<td>8</td>
</tr>
<tr>
<td>- the product looked safe</td>
<td>4</td>
</tr>
<tr>
<td>- it never went wrong before</td>
<td>4</td>
</tr>
<tr>
<td>- the subject paid attention to other hazards</td>
<td>4</td>
</tr>
<tr>
<td>- it seemed logical to do it this way</td>
<td>1</td>
</tr>
<tr>
<td>- the subject did not know that someone else had been using the product</td>
<td>1</td>
</tr>
<tr>
<td>- the subject did not think it would happen to him</td>
<td>1</td>
</tr>
<tr>
<td>Aware, because</td>
<td>11</td>
</tr>
<tr>
<td>- the subject knew that the method of use was risky</td>
<td>6</td>
</tr>
<tr>
<td>- the subject had heard of accidents with the product</td>
<td>2</td>
</tr>
<tr>
<td>- the product looked dangerous</td>
<td>2</td>
</tr>
<tr>
<td>- the subject had had former accidents with the product</td>
<td>1</td>
</tr>
</tbody>
</table>

1. Two subjects gave two reasons for not being aware of the probability of an accident.

To find out more about subjects’ experience with the products involved, they were asked how frequently they had previously used the product for the purpose that the product was used for during the accident. For example, the children’s table is used daily by the children, but it was used two or three times as a step. Table 5.8 shows the frequency of use reported by subjects.

Three subjects used the product for the first time for the purpose it was used for during the accident. The remaining thirty-nine subjects used the product fairly frequently. In these cases, the frequency of use varies from several times per day, e.g. in the case of the hot plate and the gas lighter, to a few times per year, in the case of the hedge-trimmer and the circular saw. The latter products, with a low
frequency of use, are generally used for a longer period, which means at least a few hours.

Table 5.8
Frequency of use of the products for this purpose (n=42).

<table>
<thead>
<tr>
<th>Frequency of use</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>9</td>
</tr>
<tr>
<td>Several times per week</td>
<td>6</td>
</tr>
<tr>
<td>Several times per month</td>
<td>9</td>
</tr>
<tr>
<td>Several times per year</td>
<td>12</td>
</tr>
<tr>
<td>Every year</td>
<td>1</td>
</tr>
<tr>
<td>Every few years</td>
<td>1</td>
</tr>
<tr>
<td>In total a few times</td>
<td>1</td>
</tr>
<tr>
<td>Never used before</td>
<td>3</td>
</tr>
</tbody>
</table>

Another indication for the subjects’ experience with the product may be their experience with previous accidents. Therefore, subjects were asked whether they had previously been involved in accidents with the product concerned or with similar ones. Table 5.9 gives the results.

The majority of the subjects (26) had never been involved in an accident with this or similar products. Ten subjects reported having had an accident with a product similar to the one involved in this accident. Eight subjects indicated that they had previously had accidents with the product involved in the accident. No medical treatment was necessary for the injuries sustained in these accidents.

Table 5.9
Previous involvement in accidents with the product or with similar ones (n=42).

<table>
<thead>
<tr>
<th>Involvement in accidents with the product or with similar ones</th>
<th>Number of subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never had accidents with the product or with similar ones</td>
<td>26</td>
</tr>
<tr>
<td>Previously had accidents with similar products</td>
<td>10</td>
</tr>
<tr>
<td>- maybe once</td>
<td>7</td>
</tr>
<tr>
<td>- recently</td>
<td>1</td>
</tr>
<tr>
<td>- four or five years ago</td>
<td>1</td>
</tr>
<tr>
<td>- thirty years ago</td>
<td>1</td>
</tr>
<tr>
<td>Previously had accidents with the product involved in this accident</td>
<td>8</td>
</tr>
<tr>
<td>- maybe once</td>
<td>6</td>
</tr>
<tr>
<td>- one accident</td>
<td>1</td>
</tr>
<tr>
<td>- two accidents</td>
<td>1</td>
</tr>
</tbody>
</table>
An attempt was made to find out whether the subjects can possibly be typified as ‘accident prone’. Table 5.10 shows the subjects’ involvement in accidents in or around the home during the six months preceding the accident.

Table 5.10
The subjects’ involvement in home accidents during the six months preceding the accident (n=42).

<table>
<thead>
<tr>
<th>Involvement in accidents</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>One accident</td>
<td>4†</td>
</tr>
<tr>
<td>Now and then</td>
<td>11</td>
</tr>
<tr>
<td>Not more than usual/others</td>
<td>3</td>
</tr>
<tr>
<td>Never</td>
<td>24</td>
</tr>
</tbody>
</table>

1. Two of these had to be treated medically.

Four subjects described a particular accident that they had had during the past six months. Two of these subjects were medically treated. Eleven subjects indicated that they ‘rarely’, ‘regularly’, ‘often’ or ‘maybe sometimes’ had had an accident. Three subjects said they did not believe they had more accidents than usual or than other people. These fourteen subjects could not describe particular accidents, but made such statements as: ‘I possibly cut myself in shredding onions’. In general, these subjects considered the accidents of minor importance. In addition, most subjects could not indicate the exact number of times they had had an accident in or around the home. Twenty-four subjects did not remember being involved in any accidents.

The question is to what extent the subjects can be seen as ‘accident prone’. If the participants in this study have had significantly more accidents than other people, they may be characterised as ‘accident prone’.

It is estimated that approximately 800,000 people are medically treated for an accident in or around the home in the Netherlands each year (Mulder et al., 1995). This estimation is based on accidents reported by a sample of 67,000 people. Mulder and colleagues do not provide data on the number of accidents per individual, which would have enabled us to compute the probability that individual subjects would have been involved in accidents other than the one included in this study. This leaves us with a comparison on group level. On the basis of the estimations of Mulder and colleagues, the number of persons involved in an accident that can be expected within a sample of 42 persons can be computed. In a group of 42 people at least one person can be expected who needed to be medically treated during the previous six months. This is estimated as follows: per 15,000,000 inhabitants 400,000 people are involved in a home accident each half
year. In a group of 42 persons, one person is expected to be involved in an accident.

The results show that two subjects needed to be medically treated as a consequence of an accident in or around the home. Given the roughness of the estimations, this does not convincingly portray our subjects as being 'accident prone'.

Physical characteristics of the user

Some authors hypothesise that people who deviate from the rest of the population with respect to physical characteristics, such as dimensions and exertable forces, are more liable to get involved in an accident (e.g. Daams, 1994, p. 12; Steenbekkers, 1993, p. 33). Thus, people who are extremely strong, tall, heavy and so on, may be more prone to accident involvement. Therefore, the extent to which the physical characteristics of the subjects can be typified as deviating from those of other people is examined. Several studies are available in which characteristics were measured in way similar to this study. The studies referred to all concern adults coming from different countries.

Subjects were asked to report their stature. In table 5.11 the percentile scores of $P_5$, $P_{50}$ and $P_{95}$ from the present study and from various other studies (CBS, 1995; Lange et al., 1988; Molenbroek & Dirken, 1986, who provide the DINED table; Woodson et al., 1992) are presented. It should be noted that in our study the stature was based on the subject's self-report, while in other studies the stature was actually measured. Comparing self-reported stature and weight of children with the data obtained by measurements showed that there are no systematic differences between results from both methods (CBS, 1983). The smallest subject in our study reported to be 150 cm, the tallest person 200 cm. The subjects involved in our study, especially the men, seem to be somewhat larger than subjects in other studies.

There are no indications that the subject's stature is relevant to the actions carried out at the time of the accidents.

Table 5.11

<table>
<thead>
<tr>
<th>Authors</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$P_5$</td>
<td>$P_{50}$</td>
</tr>
<tr>
<td>This study</td>
<td>150</td>
<td>167</td>
</tr>
<tr>
<td>DINED (1986)</td>
<td>154.3</td>
<td>165.1</td>
</tr>
<tr>
<td>Lange et al. (1988)</td>
<td>151.0</td>
<td>161.9</td>
</tr>
<tr>
<td>Woodson et al. (1992)</td>
<td>149.9</td>
<td>159.8</td>
</tr>
<tr>
<td>CBS (1995)</td>
<td>-</td>
<td>167.1</td>
</tr>
</tbody>
</table>

1. Estimated as follows: $\bar{x} \pm 1.65 \times \sigma$, assuming a normal distribution (cf. Molenbroek, 1994).
Chapter 5

Subjects were asked to report their body weight. In table 5.12 the percentile scores of P₅, P₅₀ and P₉₅ from the present study and from various other studies (CBS, 1995; Molenbroek & Dirken, 1986 (DINED); Woodson et al., 1992) are given. The smallest body weight is 51 kg, the heaviest subject weighs 100 kg. Our subjects seem slightly heavier than subjects in other studies. In one case the body weight of the subject may have been relevant to the breakdown of the product. This concerned the children’s table, which apparently could not withstand the weight of the subject. It is not known whether this particular weight exceeded the load that the table could resist or whether any adult would have crashed through the table.

Table 5.12
Body weight (in kg) of subjects in this study compared to subjects in other studies, for P₅, P₅₀ and P₉₅.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Women</th>
<th></th>
<th></th>
<th>Men</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P₅</td>
<td>P₅₀</td>
<td>P₉₅</td>
<td>P₅</td>
<td>P₅₀</td>
<td>P₉₅</td>
</tr>
<tr>
<td>This study</td>
<td>51</td>
<td>65</td>
<td>93</td>
<td>64</td>
<td>82</td>
<td>95</td>
</tr>
<tr>
<td>DINED (1986)</td>
<td>49 ¹</td>
<td>65</td>
<td>82 ¹</td>
<td>60 ¹</td>
<td>76</td>
<td>93 ¹</td>
</tr>
<tr>
<td>Woodson et al. (1992)</td>
<td>47.2</td>
<td>63.1</td>
<td>94.4</td>
<td>56.3</td>
<td>76.2</td>
<td>101.6</td>
</tr>
<tr>
<td>CBS (1995)</td>
<td>-</td>
<td>66.2</td>
<td>-</td>
<td>-</td>
<td>78.4</td>
<td>-</td>
</tr>
</tbody>
</table>

1. Estimated as follows: 8 ± 1.65 * σ, assuming a normal distribution (cf. Molenbroek, 1994).

The dimensions of the hands were measured by positioning the hand, with the fingers joined, on a grid of 1 by 1 cm, see figure 5.1.

Figure 5.1
Measurement of the dimensions of the hands.
Only a global comparison is made between the dimensions of the hands of our subjects and subjects in other studies. The comparison indicates that the dimensions of the hands of the men in our study seem to be somewhat larger than in other studies (Lange et al., 1988; Molenbroek & Dirken, 1986 (DINED); Woodson et al., 1992). The dimensions of the hands do not seem relevant for subjects’ use actions in any of the accidents.

The forces exerted by subjects seem relevant in the occurrence of accidents (Daams, 1994; Ramsey, 1985; Steenbekkers, 1993; Surry, 1974). The maximal forces are measured for squeezing, pushing and pinching. These forces were selected as they are expected to have possible relevance in the handling of products. The measurements of the force exertions are depicted in figure 5.2.

![Force exertions](image)

**Figure 5.2**
*Measurement of forces exerted by subjects.*

Forces were measured for both hands. While exerting force, subjects were seated at a table. The upper arm was held alongside the trunk, and the elbow was flexed about 90 degrees. Subjects were instructed to build up their maximal force slowly and then to prolong it for several seconds (see appendix 1 for instructions). Forces were not measured if the product was not handled, such as in the case of a stepladder. Various measurements are missing because the injured hand could not be used. The forces exerted by subjects can be compared with the findings of several other studies (Imrhan & Loo, 1989; Kanis, 1993b; Mathiowetz et al., 1985; Schoorlemmer & Kanis, 1992). The findings in the various studies are presented in table 5.13 (women) and in table 5.14 (men), including the number of subjects and the median/average age of the subjects participating in each study. Except for the pinch grip, the forces exerted by subjects in our study are significantly larger than those in other studies. These differences arise partly from differences in measurement conditions. Also, the subjects’ age may be a relevant factor in differences between the studies (cf. Kanis, 1993b; Mathiowetz et al., 1985).
Table 5.13
Comparison of maximum forces (in N, in brackets the standard error of the mean), exerted by the women in this study and by women in other studies.

<table>
<thead>
<tr>
<th>Force (in N)</th>
<th>This study</th>
<th>Kanis</th>
<th>Schoorlemmer &amp; Kanis</th>
<th>Mathiowetz et al.</th>
<th>Imrhan &amp; Loo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of women</td>
<td>9-14</td>
<td>18</td>
<td>15</td>
<td>295</td>
<td>30</td>
</tr>
<tr>
<td>Median/average age</td>
<td>45 (median)</td>
<td>55 (median)</td>
<td>49 (average)</td>
<td>45 (average)</td>
<td>28 (average)</td>
</tr>
<tr>
<td>Handgrip strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preferred hand</td>
<td>320.6 (13.3)</td>
<td>239.8 (14.5)</td>
<td>275.0 (19.4)</td>
<td>270 (4)</td>
<td>314 (11.4)</td>
</tr>
<tr>
<td>non-preferred hand</td>
<td>291.0 (17.0)</td>
<td>214.2 (14.5)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Push with thumb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preferred hand</td>
<td>82.1 (6.8)</td>
<td>72.0 (5.5)</td>
<td>73.8 (8.1)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Push with forefinger</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preferred hand</td>
<td>66.8 (6.2)</td>
<td>61.0 (5.2)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pinch grip</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preferred hand</td>
<td>49.6 (3.3)</td>
<td>60.3 (4.2)</td>
<td>-</td>
<td>50.7 (0.7)</td>
<td>70 (2.3)</td>
</tr>
<tr>
<td>non-preferred hand</td>
<td>45.0 (3.4)</td>
<td>60.3 (3.8)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lateral pinch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preferred hand</td>
<td>82.3 (4.5)</td>
<td>74.8 (2.4)</td>
<td>69.9 (3.0)</td>
<td>72.5 (0.8)</td>
<td>65 (1.7)</td>
</tr>
</tbody>
</table>

Table 5.14
Comparison of maximum forces (in N, in brackets the standard error of the mean), exerted by the men in this study and by men in other studies.

<table>
<thead>
<tr>
<th>Force (in N)</th>
<th>This study</th>
<th>Kanis</th>
<th>Schoorlemmer &amp; Kanis</th>
<th>Mathiowetz et al.</th>
<th>Imrhan &amp; Loo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of men</td>
<td>16-20</td>
<td>16</td>
<td>4</td>
<td>288</td>
<td>40</td>
</tr>
<tr>
<td>Median/average age</td>
<td>38 (median)</td>
<td>55 (median)</td>
<td>47 (average)</td>
<td>45 (average)</td>
<td>25 (average)</td>
</tr>
<tr>
<td>Handgrip strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preferred hand</td>
<td>510.8 (18.4)</td>
<td>391.2 (19.8)</td>
<td>412.5 (54.5)</td>
<td>465 (7)</td>
<td>497 (17.6)</td>
</tr>
<tr>
<td>non-preferred hand</td>
<td>469.3 (18.1)</td>
<td>374.6 (23.5)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Push with thumb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preferred hand</td>
<td>167.6 (9.4)</td>
<td>123.8 (5.9)</td>
<td>89.9 (14.2)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Push with forefinger</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preferred hand</td>
<td>111.2 (6.4)</td>
<td>92.5 (5.2)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pinch grip</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preferred hand</td>
<td>70.8 (4.0)</td>
<td>81.1 (4.3)</td>
<td>-</td>
<td>75.6 (1.0)</td>
<td>94 (2.2)</td>
</tr>
<tr>
<td>non-preferred hand</td>
<td>73.9 (3.6)</td>
<td>74.8 (3.1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lateral pinch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preferred hand</td>
<td>125.3 (4.9)</td>
<td>99.7 (4.2)</td>
<td>96.7 (11.5)</td>
<td>110 (1)</td>
<td>94 (3.5)</td>
</tr>
</tbody>
</table>

1. The pinch grip is called 'chuck' by Imrhan & Loo (1989) and 'tip pinch' by Mathiowetz et al. (1985).
2. The lateral pinch is called 'key pinch' by Mathiowetz et al. (1985).
Kanis (1993b) ascribes the relatively low forces to the relatively high age of his subjects as compared to the age of subjects in the studies of Imrhan & Loo (1989) and Mathiowetz and colleagues (1985). The median age of our subjects approaches the average age of subjects in the studies of Mathiowetz et al. (1985) and Schoorlemmer & Kanis (1992), and yet the exertable forces of our subjects appear to be significantly higher.

That only the pinch grip forces turn out to be low compared to other studies is puzzling. To what extent the differences between our study and other studies may be ascribed to our subjects actually being stronger, or to differences in measurements, perhaps because our subjects may have been allowed more freedom in their posture, remains unknown.

In the accident involving the corkscrew, the exertable forces of the subject might have been relevant to the amount of force he exerted on the bottleneck of the winebottle, which broke in two and cut his little finger.

Handedness was included, as various authors suggest that left-handed people are more liable to be involved in accidents than right-handers, because, for example, the environment is not designed for left-handed people (e.g. CBS, 1986; Coren, 1992). As is known from the literature, handedness varies over activities (Coren, 1992, p. 37; Coren, 1993; Porac, 1993). Therefore, handedness was established by asking subjects which hand they used in writing, in throwing a ball and in the operation of controls. In addition, they were asked which hand they used for holding a match and which hand for operating the control in lighting the gas (cf. Coren, 1993; Porac, 1993, p. 356).

Thirty-nine subjects indicated that they were right-handed, of which five subjects used their right hand for both holding the match and operating the control. Three subjects were left-handed. CBS data (1986) show that approximately 10% of the adults reports to be predominantly left-handed. In this study 7.1% of the subjects were left-handed, which means that the group of subjects did not contain more left-handed people than would be expected.

Problems in the use of products may be expected when people use the non-preferred hand in handling the product. In the case of products that are manipulated with one hand (19), most subjects used their preferred hand for carrying out manipulations, while the non-preferred hand held still the material processed or the/another product. In the remaining cases, the subjects handled the product or the material processed with two hands. In one case, it may have been relevant that the subject had to use both the preferred and the non-preferred hand. This concerned the accident with the fitness-stick. The user kept the left, non-preferred hand closer to the body than the right hand, which may be related to the fact that the right hand is preferred in exerting force.
People with physical limitations may have more difficulties in the manipulation of products (Kanis, 1993b). The subjects were asked whether they had any limitations in moving their hands and arms. The user of the food processor indicated that she had difficulties with force exertion. According to this subject, the knives may have slipped out of her hands because her force exertion may not have been well-controlled.

Subjects' views of the causes
Subjects were asked what, in their opinion, were causes of the accident. They were first asked to consider product-related causes of the accident. Only then were they asked to mention other causes. This was done because it appeared that the first three subjects, who were not explicitly asked to consider product characteristics as a cause, did not consider the product at all.
Table 5.15 shows the number of subjects who mentioned particular causes. Most subjects indicated several causes of the accident.

<table>
<thead>
<tr>
<th>Causes of accident related to</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>19</td>
</tr>
<tr>
<td>Use activities</td>
<td>14</td>
</tr>
<tr>
<td>Situation</td>
<td></td>
</tr>
<tr>
<td>material</td>
<td>9</td>
</tr>
<tr>
<td>social</td>
<td>4</td>
</tr>
<tr>
<td>Temporary condition of subject</td>
<td>6</td>
</tr>
<tr>
<td>Subjects' own fault</td>
<td>18</td>
</tr>
<tr>
<td>Could not mention causes</td>
<td>3</td>
</tr>
</tbody>
</table>

Causes related to the product included 'red glow of plate disappears too quickly' (hot plate), 'makes a lot of noise' (stair gate), and 'cover is not handy' (scraper). Use activities mentioned as causes by subjects were, for instance, keeping the hand close to the blade (metal saw), swapping planing and sawing (planing machine) and putting the iron too nearby. Limited space, characteristics of the material processed and the presence of others were causes related to the situation. The temporary condition concerned, for example, working too quickly and being drowsy. Almost half of the subjects thought the accident was their own fault, qualifying themselves as having been 'foolish', 'stupid' or 'careless'. Of these, six subjects blamed themselves exclusively for the accident. Three subjects could not mention any causes of the accident.
5.4 Deviations

As the concept of deviations is a dominant perspective in the field of safety, the extent to which deviations can be identified as relevant in the occurrence of accidents is explored. As the analysis of deviations requires some kind of norm, various norms are examined to find out which ones are applicable to the analysis of accidents involving consumer products.

Norms in the literature
According to Kjellén (1987), four types of norms can be found in the accident literature: (1) a standard, rule or regulation, or a judgement of what is (2) adequate or acceptable, (3) planned or intended, or (4) normal or usual.

Explicit standards, rules or regulations (ad 1) for the use of consumer products are not available in the private sector: there is great freedom in how, where, when and by whom products are used. What is judged as adequate or acceptable (ad 2) may differ among people, and is therefore not suitable for use as a norm (see Kjellén, 1987, see also § 4.5.1). Judgements of what is planned and intended (ad 3) refer to the plans and intentions to achieve a particular goal. A prerequisite for this norm is that these plans and intentions have actually been established, and communicated to users (cf. Kjellén, 1987). According to Kjellén these conditions are rarely met.

The norms mentioned so far are norms from an outsider’s perspective. Deviations established by observers can differ from what are deviations according to the user, which questions the appropriateness of judging deviations externally. It seems preferable to establish deviations on the basis of the user’s intentions and/or habitual do’s and don’ts. Here, two options are left for identifying deviations from the point of view of the user: the user’s intentions and what is considered as normal or usual by the user. In this study, subjects recounted their intentions only in global terms, such as ‘I wanted to saw these tree trunks’, which reduces the usefulness of the user’s intentions as a norm for judging deviations.

Therefore, what is experienced as normal or usual (ad 4) by the subjects seems the most appropriate norm for the identification of deviations, as the subject is the only one who can define what is a deviation and what is normal in that particular case (cf. Leplat, 1984, p. 84-85).

Identification of deviations
In this study, the habitual use of the product, as reported by subjects, was taken as a reference in identifying deviations: when the subject indicated that something was unusual, this was identified as a deviation.

Questions were posed on the habitual use of the product, in terms of how, where and when the product is usually used. In addition, they were invited to compare their habitual use with the product use at the time of the accident. Also, they were asked to show the habitual use of the product, if possible.
Chapter 5

Findings
Table 5.16 shows the number of times that particular factors were considered as deviations by subjects.

Table 5.16
Number of times that particular characteristics were reported to be deviations by subjects.

<table>
<thead>
<tr>
<th>Deviating condition</th>
<th>Number of times</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use activities deviate</td>
<td>19</td>
</tr>
<tr>
<td>Material circumstances unusual, e.g. type of floor, presence of objects,</td>
<td>12</td>
</tr>
<tr>
<td>noise</td>
<td></td>
</tr>
<tr>
<td>No deviations identified</td>
<td>10</td>
</tr>
<tr>
<td>Unusual mental/physical state of subject, e.g. rushed, tired</td>
<td>8</td>
</tr>
<tr>
<td>Material processed unusual for that subject</td>
<td>6</td>
</tr>
<tr>
<td>Presence/absence of people/animals is unusual</td>
<td>6</td>
</tr>
<tr>
<td>Condition of the product unusual</td>
<td>4</td>
</tr>
<tr>
<td>Social circumstances unusual e.g. death of relative</td>
<td>3</td>
</tr>
<tr>
<td>Time of day deviant</td>
<td>3</td>
</tr>
<tr>
<td>Unusual division of tasks</td>
<td>2</td>
</tr>
</tbody>
</table>

The number of reported deviations per accident varies from 0 to 6. In 10 accidents, the subjects did not report any deviations; in the view of these subjects everything appeared to be normal at the time and place of the accident. In the remaining 32 accidents, 63 deviations are indicated by the subjects. The median number of deviations is 2.

The overlap between deviations and contributory factors is shown in table 5.17. The number of contributory factors is based on the number of times that a factor could be identified as contributory.

Table 5.17
The extent to which deviations - established on the basis of the users' self-reports - could be identified as contributory factors established with counterfactual reasoning, and vice versa.

<table>
<thead>
<tr>
<th>Deviation?</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contributory factor?</td>
<td>46</td>
<td>234</td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>
Most of the deviations (46) are also identified as a contributory factor. Sometimes (17 times) subjects indicate a deviation that is not identified as a contributory factor. An example is the time of day in the case of the vegetable slicer. According to the subject, he was cooking a meal at an unusual time of day. But the time of day as such cannot be pinpointed as contributory to the occurrence of this accident. A vast number of contributory factors (234), identified by counterfactual reasoning, were not reported by subjects as being a deviation. In fact, the number of factors that is neither contributory nor a deviation is infinite.

5.5 Discussion and conclusions

**Contributory factors**
The findings show that a few factors are relevant in a quarter to half of the accidents, but that the majority of the factors is relevant in only a small number of accidents. There is not one factor that can be considered as dominant. Regularities in the sequences and combinations of factors are sparse. The sequences of factors greatly diverge. Combinations of factors that were found repeatedly are:
- the body hit or contacted cutting or hot parts of the product;
- the product slipped off or onto the material processed in the direction of a part of the body;
- the user fell off or with the product.
These combinations all preceded the injury. Looking further back, the occurrences seem to fan out, leaving hardly any detectable patterns.

**User characteristics**
In fifteen accidents, the user reported being drowsy, rushed, irritated and so on. One wonders whether this relatively large number is the result of the long-standing prejudice that accidents are always the fault of the user because of, for example, being careless or not paying attention. The use of such qualifying statements implying blame coincide with the attitude of self-accusation found in this study (see also Norman, 1988; Torell & Bremerberg, 1995).

Taking the frequency of use as an indicator of people’s familiarity with the product, subjects cannot be classified as being unfamiliar with the products involved. The absence of the awareness of running the risk of being injured in three quarters of the accidents may be related to the subjects’ familiarity with the products. When people use products regularly, it is doubtful whether they use these everyday products after conscious decision making, as is widely assumed in risk-taking theories (cf. Wagenaar, 1992). Wagenaar’s conclusion is that people doing their everyday things rarely anticipate accidents: ‘they run risks, but they do not take them’ (p. 279).
The present study revealed that people's perceptions may be relevant to what is done with a product. Several subjects indicated that the product looked safe. As a result, they thought particular use activities could do no harm. For example, in the case of the children's table the subject might not have used the table if it had looked fragile. In several accidents the product did not give feedback about its condition (see also Norman (1988, 1992) for a discussion on the relevance of feedback in the use of products). An example is the hot plate. The plate does not show that it is still hot. Here, the user might not have removed the crumbs with her bare hand, if it had been obvious that the plate was still hot. However, even if people are aware of the risk of injury, this does not mean that they will take precautions to avoid this risk.

The findings further indicate that subjects did not seem 'accident prone', in the sense that they were more frequently involved in accidents than other people. Our subjects seemed to deviate slightly from other people with respect to the physical characteristics measured in this study. However, in only a few accidents the physical characteristics of users could be identified as relevant to how and where products were used.

Deviations
In an attempt to explore the significance of the concept of deviations in describing and explaining the occurrence of accidents involving consumer products, it was argued that the identification of deviations should be based on the subjects' self-reports. In ten accidents the subjects could not identify any deviations at all. The findings further show that not all deviations, established on the basis of the subject's self-report, can be considered as contributory factors, which were established by means of counterfactual reasoning. In addition, the vast majority of contributory factors cannot be identified as deviations.

Apart from the difficulties with the concept of a norm, the findings imply that the concept of deviations can only partly explain the occurrence of accidents involving consumer products.

In conclusion, the occurrence of accidents with everyday products appears to be largely unpredictable on the basis of the characteristics included in this study, which narrows the perspective of generally available guidelines that industrial designers can effectively apply in their efforts to anticipate accidents.
6. General discussion

6.1 The objectives

The exploratory study in this thesis is intended as a contribution to the provision of means to anticipate future product use that may result in accidents. In their efforts to anticipate accidents, designers may be confronted by at least two situations. In the first situation, accidents are known to occur with forerunners of the product to be (re)designed, and methods for the observation and analysis of accidents may assist industrial design engineers in their efforts to set criteria for safer products. In the second situation, the product to be designed is suspected of being prone to involvement in accidents, but no empirical evidence is retrievable. Here, general insights into the occurrence of accidents may provide starting points for criteria that should be met by the design. This thesis covers both situations. The aims of the present study are:

- to generate methods for the observation and analysis of accidents;
- to gain general insights into the occurrence of accidents involving consumer products.

The findings obtained should be directed towards application in the design process. This general discussion begins with the limitations of the study (§ 6.2). The extent to which the aims of the study have been accomplished is then discussed. Implications of the findings, including their applicability in the design process, are considered (see § 6.3 and § 6.4). Finally, directions for further study are suggested (§ 6.5).

6.2 Some disclaimers

The study is directed at accidents involving existing consumer products. Factors that turned out to be contributory in only a small number of accidents may already have been considered in the design of the products. For example, the limited number of accidents in which the users' physical dimensions were found to be relevant, may imply that the designers have already taken these dimensions into account. Since most factors included in this study appear to be contributory in only a few accidents, this might imply that designers have already thought of these factors. However, according to the designers who participated as judges in the study into the inference of causes, this is definitely not the case. They suggested a variety of factors that the designers of the products involved in the four accidents did not consider.
A limited relevance of particular factors may also point to the fact that these factors simply occur infrequently. One example is the accident in which a dog scared the user of a hand saw by sticking its head between the subject’s legs. It seems more likely that dogs simply do not pass by very frequently while someone is sawing, rather than that designers have already taken the probability that dogs pass by into account in designing handsaws. In any event, there is the possibility that the inclusion of existing products may (not) have generated particular findings.

Another limitation is that only accidents were studied. In the present study, the product use at the time of the accident was compared to the user’s self-reports on their habitual use. In addition, the subjects’ accident involvement and their physical characteristics were compared to those of other people, but for many factors such comparisons could not be made due to lack of data. For example, the majority of the subjects in our study indicated that they had no idea at all that an accident could occur at the time they were working with the product. It is therefore conceivable that people not involved in an accident make a different appraisal of the possibility that an accident may happen.

An additional consequence of studying accidents is that no insight is gained into the extent to which people compensate for their mental, physical and sensory abilities. For example, heavy people may not use a fragile table as a step knowing that it will not withstand their weight (see also Haight, 1986). Nor is insight gained into people’s abilities to successfully correct their actions when they discover that these may have negative consequences.

Most subjects appeared to blame themselves for the accident. Other people readily confirm the injured person’s view that the accident is indeed a consequence of his or her inappropriate behaviour (cf. Torell & Bremberg, 1995). The tendency to accuse the person injured for what happened is characterised by Laughery (1993, p. 10) as follows:

... we seem to have a predisposition in our culture to believe that when an accident occurs, it is because someone screwed up, usually the person who was injured.

It is conceivable that some of the people who received our letter requesting their cooperation did not consider participation because they would then have to acknowledge how ‘foolish’ they had been. It is not known to what degree this possible self-selection led to bias in the type of accidents included in the study.

The findings from the investigations on-site were analysed with respect to indications for lack of validity. In some cases, evidence is available that the demonstrations may differ from the unknown actual occurrences, e.g. because the bandages that subjects were still wearing hampered a demonstration of what
happened, or because it was too dangerous or even impossible to demonstrate the occurrences. The analysis of the within-subject differences in demonstrations showed that more than half of the subjects displayed differences in the three demonstrations. These differences might have arisen from the retrieval of new details during subsequent demonstrations. However, to what extent the within-subject differences in demonstrations concern random variation or systematic variation (bias) remains unknown.

6.3 The observation and analysis of accidents

6.3.1 A fresh outlook

In existing accident research in the domestic sector, the only precaution usually taken to minimise bias is to limit the time between the accident and the interview or questionnaire. In addition, the findings from the methods used - generally mail questionnaires - commonly entail self-reported behaviour. The method developed in this thesis differs from current research practices in the sense that a variety of precautions for minimising bias were taken, and that an interview was combined with observations on the site.

The review of the literature revealed that excessive attention has been paid to human characteristics. The perspective adopted in the observation of accidents differs from many existing approaches in its view that the influence of human characteristics is only seen in use activities. Unlike human characteristics, the use activities can be influenced via the design of the product. Consequently, the present study focussed on the actual use of products.

The obscurity surrounding the way in which human judges infer causes from accident data has been illuminated in the study with the judges. Although the identification of causes is essential in the analysis of accidents, only a handful of publications in the area of safety include this issue. The study showed that the various criteria the judges use in the identification of the causes of accidents appear to correspond to criteria described in social psychology and philosophy. In our analysis counterfactual reasoning (if not . . . then . . . ) is used, since, as is argued by some philosophers, this type of reasoning can be supported by existing knowledge.

Compared to existing ways of accident analysis, where reliance is placed on implicit considerations of judges, the contribution of counterfactual reasoning is that the inference of causes can be made tractable and arguable by explication of the evidence used. Since counterfactuals are to be sustained by evidence, the explanation of considerations cannot be avoided. It must be noted that
counterfactual reasoning in no way guarantees that judges identify the same contributory factors. Its major virtue is that the considerations in identifying factors at least become discussible.

The evidence used to sustain counterfactual reasoning is based partly on the user's statements and self-reports, since internal references, such as whether people are annoyed by noise, cannot be perceived by external observers. Thus, as opposed to some of the existing techniques of accident analysis, the identification of causes is also based on self-reports of users.

The use of counterfactual reasoning is not limited to the identification of the causes of accidents. It is widespread in everyday life, as well as in sciences such as history. Counterfactual reasoning may also be applied to findings from users' trials. It cues designers in terms of how best to avoid and prevent problems, inconveniences and accidents with their product, and may therefore be widely applicable in the design process rather than to accident analysis alone.

6.3.2 Applicability in the design process

The applicability of the approach proposed in this thesis has not yet been empirically studied in design practice. Inevitably, the feasibility of any tool is determined to a large extent by, on the one hand, the costs and time required and, on the other hand, the benefits (see Bias & Mayhew, 1994).

For any on-the-spot investigation the cooperation of victims is crucial. The widespread attitude of self-accusation creates a possible obstacle to this cooperation. Hence, finding victims can be time consuming, especially when looking for accidents involving a particular product. Given the small probability of coming across an accident with the product aimed at, the recruitment of subjects via an emergency department, as in this study, requires considerable time and effort. The same accounts for the other data sources that were attempted in this study.

The methods of accident data collection and analysis, as described in this thesis, are laborious ones, as a consequence of the comprehensiveness of the data aimed at and the thoroughness of the analysis required for the purpose of the study. Reducing the time spent interviewing subjects by telephone or via mail questionnaires is discouraged, as this will be at the expense of the validity and comprehensiveness of the data obtained (see Weegels, 1991, 1992a).

The exclusion of factors may also seem time-saving, but since practically all factors included in the design of the study are found to be contributory to at least some of the accidents, there are no clear criteria for excluding some factors, and no conclusions can be drawn about factors that are not investigated. Time reduction might be accomplished by skipping the meticulous description of the accidents. Instead, a less time-consuming presentation of the data may be opted
for, such as providing designers with a video compilation of highlights. However, little investigation has been done into the value of different ways of presenting findings, such as a video presentation versus a verbal description.

A comment frequently heard is that often only a few accidents per product are available. How does one ascertain whether costly product changes, carried through on the basis of insights derived from only a small number of accidents, will prevent a majority of the accidents, and not only the few investigated? This question cannot be answered without having insight into the type and amount of exposure, e.g. who was using the product, how, where, for how long and how frequently. For example, changing the planing machine so that planing small pieces of wood does not result in an accident will be assessed differently if planing a small piece of wood leads to an accident every time, or only once in a thousand times. It is also necessary to know how often short pieces of wood are planed. Thus, for any assessment of the effectiveness of precautions taken, insight into the concept of exposure is indispensable. Only then can a sound appraisal of proposed changes in the product be made. A thorough analysis of the concept of exposure is not available in the area of consumer products. It would seem that a difference exists between exposure which reflects the researchers’ point of view, e.g frequency and duration of use, and the user’s perceptions of exposure, which may entail risk compensation mechanisms. Such an example would be the heavy person who may not use a fragile table as a step. It would be challenging to confront the researchers conceptions of exposure with those of the user.

Clearly, safety is only one of the many aspects industrial design engineers must take into account when designing a product. Obviously there are limitations to what designers can do. For example, there is little designers can reasonably do when the primary function of a product can cause injuries, such as the sharp parts of a knife. In addition, there are boundaries to the responsibilities of designers. The cat being dried in the microwave oven is a famous example in this respect! Self-evidently, the settlement of the designers’ responsibilities in the anticipation of accidents is an extremely complex matter.

Even if due attention has been paid to the prevention of accidents, there is always the likelihood of unforeseen new accidents. An example is the five gallon buckets which are widely used in the U.S. These buckets are very stable, but this also comprises a danger. When a toddler peers into the bucket and accidentally falls in, it is unable to get out because the bucket is so stable that it does not tip over. Several toddlers have, as a consequence, drowned in only a few centimetres of liquid left in the bucket (Jumbelic & Chambliss, 1990).
6.4 General insights

In their review of accident causation theories, Smillie & Ayoub (1976, p. 47) claim that

a theory of the accident causation process can be written, if most of the components of the accident can be discerned, and if the factors that contribute and lead to the accident can be discovered.

The present study has shown that even if comprehensive accident data are available, the occurrence of accidents with everyday products remains largely unpredictable. The most consistent finding is that there is no consistency. Of course, one can ask why one would expect any regularity, given the variety in possibly relevant factors. The observation that only a few regularities in sequences and combinations of factors can be detected may be a consequence of the limited number of accidents included in the study. This is not to say that the findings of this study can be considered irrelevant. It can be demonstrated that occurrences found in small samples have a low probability of being rare (see Kanis & Vermeeren, 1996). The crucial question is whether it would have been possible to identify regularities if more accidents had been included in the study. It is conceivable that the inclusion of more or different types of accidents would have revealed more regularities.

Obviously, regularities may be identified when accidents with the same type of product are investigated (see e.g. Jaartsveld & Mulder (1989) who formulated guidelines for chain saws). However, such findings are of no assistance to designers when the product being (re)designed differs from the product for which accident data are available.

A number of theoretical notions emerged from this study, some of which run counter to current ideas in the literature.

The findings indicate that people’s perceptions may be relevant to what is done with a product. Several subjects indicated that the product looked safe. In several accidents the product did not give feedback about its condition. If products had reflected their hazards adequately in these cases, the users might have acted differently. However, people may get used to the product’s unsafe appearance. In addition, the question is always whether people act differently if they are aware, or whether indeed they are able to act differently. The findings of this study show that, even if people are aware of the risk of injury, this does not mean that they will take precautions to avoid this risk. A more prudent approach would therefore be to make the product ‘fool proof’. In this approach, the product is designed in such a way that people’s use activities fall within safety margins, i.e. can do no harm. An example is the design of a hobby knife that contains a safety device that covers the blade immediately if the pressure on the blade disappears. A problem
here is that people may circumvent or inactivate safety devices, as in the case of the accident involving the planing machine. Also, the product may give people the impression of being safe. As a consequence, they may compensate for feeling safe by behaving more recklessly.

These findings indicate that industrial designers should examine how the various possible conditions of the product are perceived by future users, and, in particular, how users will react when they are deprived of perceptual information. The subjects in the present study do not seem to be involved more frequently in accidents than other people. This suggests that attuning products to the characteristics of people who are more frequently involved in accidents may not be very effective in the prevention of accidents. Nor does the adaptation of products to people’s physical characteristics seem to be of any help, since the physical characteristics of subjects do not appear to deviate from those of other people. However, only a limited number of static physical characteristics were included in this study. Here, people’s perceptual and motor skills may be more relevant in manipulating consumer products.

Practically all subjects can be considered to be familiar with the products used at the time of the accident. Only a few subjects might be typified as ‘inexperienced’ users. The longstanding habits that go hand in hand with the use of familiar products may be detrimental to the use of newly designed products (see Kanis & Wendel, 1990), which emphasises the relevance of giving due attention to the habitual use of consumer products.

The notion that people engage in risk-taking only after conscious decision-making could not be substantiated by our findings. The majority of the subjects reported that they had no perception of risks at all during the use of the product. Consequently, there seems little point in trying to raise the risk-awareness of people who are using everyday products by means of, for example, warnings (cf. Wagenaar, 1992).

An exploration of user’s self-reports on deviations showed that accidents may be partly related to deviations, but that in almost a quarter of the accidents the subjects could not identify any deviations at all. However, there may be a variability that we do not perceive, as Brehmer (1990) suggests. Consequently, it is possible that there were deviations from habitual use that these subjects did not perceive.
6.5 Directions for further study

The occurrence of accidents with everyday products appears to be unpredictable, which narrows the perspective of generally available guidelines which industrial designers can effectively apply in their efforts to anticipate accidents. The unpredictability of accidents constitutes a plea for the availability of a 'tool' to predict actual usage, including possible accidents. Successful application of such a tool presupposes that industrial design engineers recognise the usefulness of applied research.

Some directions for further study have already been mentioned, such as the concept of exposure, risk compensation mechanisms, and the presentation of findings from accident research to designers. In addition, the impact of product appearance on people's perceptions may be a relevant topic for further study. From our study it appears that people's perceptions and the feedback provided by the state of the product may have a significant impact on people's actions. In this chapter, two options were given for directing people's actions: making a product's condition visible, or making a product fool-proof, i.e. designing the product in such a way that use activities and situational characteristics fall within safety margins. It is far from clear how these strategies work out in practice and over time.

A further possibility for continuation of the present study may be the study of more serious accidents. In this study, only one subject had to stay in the hospital for some time. A study into accidents resulting in more severe injuries entails the assumption that the more severe accidents have precursors that differ from the less severe ones, an assumption which needs further exploration. In our study, only adults participated. The investigation of accidents involving children may constitute another follow-up, provided that these accidents include consumer products. The extent to which our findings can be generalised to accidents involving children may be restricted, since the 'use' of products by children is characterised by different aspects. Consider, for instance, playing with a toy versus cooking a meal. As far as can be seen, comprehensive data on accidents involving children are not available. Inevitably, the questioning of children may require special techniques, for example, because children are more easily influenced by leading questions.

Another option for further study is to look into the applicability of other types of research, such as user's trials and research into near-accidents. As to the latter, the present study shows that the reconstruction of accidents is far from uncomplicated. Even if the people involved in near-accidents can be traced, asking people to demonstrate what happened in a near-accident may be impossible. User's trials may be more promising as a basis for predicting possible accidents. Various user's
trials have been conducted by students in an optional course, with some of the products involved in the accidents investigated for this study. The subjects in the trials did repeat some of the use actions carried out with the product. However, the combination of factors which was necessary for the occurrence of an accident was, deliberately, not replicated, because then the subject would have been injured. Nevertheless, a comparison of product use observed during a user’s trial, and during the on-site reconstruction of accidents, may shed more light on the extent to which observations in a user’s trial can serve as a basis for the prediction of unobserved combinations of factors which may lead to an accident.

For the time being, industrial designers have to resort to hindsights. They must seize every opportunity to obtain information about accidents with their products, albeit post hoc. At the moment, companies increasingly open their doors to consumers’ complaints about their product as a means to cope with consumers’ dissatisfaction (see Ruyter, 1993; Lund, 1994). When consumers become aware of the possibility of bringing their complaints, e.g. on the lack of safety of a product, to the attention of manufacturers, this may provide designers with an easily accessible data source. In their efforts to cope with the safety of their product, the present study offers designers a way to look at accidents, investigate them and extract insights from accident data.
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Appendix 1. Procedure for the investigation of accidents

This appendix consists of the protocol for the investigation of accidents. The protocol contains instructions and procedures for the subsequent steps during the investigation on-site and for the inspection of the product.

On arrival

- Introduce yourself.
- Unpack and install equipment quickly.
- Meanwhile keep on chatting, for example about the weather and the news, thus preventing people from starting to talk about the accident before you are ready. If you did not previously inform the subject about the background of the project, tell the subject about the relevance and purpose of the research project. Also inform the subject on the application of the data.
- Go to the site of the accident.
- Ask whether the site has changed since the occurrence of the accident and, if so, if things can be rearranged as they were during the accident.
- Activate the sound- and video-recorders.

Interview

Cursive text contains instructions for the interviewer. Straight text contains questions posed to the subject.

Can you show us what happened and tell us about it?

During the demonstration:
- encourage the subject, but do not probe;
- note any uncertainties, so you can come back to them later;

Can you show us again what happened?

When the subject is finished, pursue matters brought forward by the subject.

Can you tell us whether you did anything that is different from how you usually use the product?
If so, what?
Can you show us how you usually use the product?

Stop video-recording. Invite the subject to sit somewhere during the interview. Take the sound-recorder along.
Recapitulate what happened with the use of the checklist that follows.
Appendix 1

Use of the product
Check for every product involved.

- how often
- used product in this way before
- what for/with what
  - normally for this
  - why with that at the time of the accident
- workpiece
  - what kind
  - normally this kind
  - dimensions
  - what did you want to do with/make from it
  - bought where
  - always bought there
  - how long ago
  - storage
  - always store there
- where was product used
  - normal
  - why there at the time of the accident
- sight on work
- objects present
  - troublesome
  - normal
- lighting
  - what kind/where from
  - sufficient
  - normal
- sound/noise
  - what kind (e.g. radio, television)
  - troublesome
  - normal
- weather conditions/climate
  - humidity/rain
  - sun
  - wind
  - temperature
  - troublesome
- working height
  - normal
- posture
  - normal
- condition of hands
  - greasy/wet/damp → normally
  - gloves → normally
  - wounds, incisions
  - jewellery → normally
  - one of these things troublesome
- what time
  - normally
  - why at that time
- how long busy/progress
- did what before
  - was that unusual
- interruptions
  - e.g. by the bell, visitors, for drinking coffee, children...
  - does this happen often
- did what after
  - was that unusual
- someone present
  - normal
  - who
  - relation with this person
  - when did this person come in
  - what did this person do at the time of the accident
  - on which spot
  - physical nuisance from each other
  - talking to each other
  - about what
  - did the talking influence use actions
- state of mind and general condition at the time of the accident
  - e.g. not tired, nauseated, absent-minded, busy, hasty, no morning mood, no headache, ...
  - does this happen often
- how long ago did accident occur
- what day
- what happened after being injured (treatment)
- something else different from normal, any peculiarities
Product
*Check for every product involved.*

- former accidents with this product
  - how long ago
  - what happened
- at the time of the accident, did you have any idea this could happen
  - how/why, e.g. heard of/read about accidents
- use of similar products
  - how/for what
  - how often
  - where
  - accidents with these products
  - what type of accidents
- bought/received/borrowed/hired the product
  - where/from whom
  - how long ago/for how long
  - prime cost
  - did this before
- instructions for use
  - when read for the last time
  - what was in the instructions
- defects at the time of the accident
  - what
  - how long defective
  - repaired since accident
  - when
- defects in the past
  - what
  - how long ago
  - who repaired
- modifications
  - before accident
  - since accident
  - what
  - why
- maintenance/cleaning
  - how
  - how often
  - who does this
  - when was the last time
- reason for buying the product
  - for whom
  - what for

Social elements

- composition of household
- other users of the product
  - who
  - frequency
  - why: allocation of tasks?
- last user of product preceding the accident

Subject

- accidents in the previous half year
  - what happened
  - with what/at what/on what
  - how often
  - if no: cutting/bumping/burning/falling/stumbling...
- like/dislike of activity at the time of the accident
- clothing
- stature
- weight
- shoe size
- age
- profession
- hobbies
Appendix 1

After recapitulation
How often did you tell other people about what happened?
To whom?
When you told the story to others, what did you tell them?

Evaluation of accident
When you consider the product and think of the accident, would you say that there are features
of the product that played a role in the occurrence of the accident?
Would you say that there are other things that played a role in the occurrence of the accident?

Epilogue
We have found that we always want to learn more about the product once we are back at the
university. Would it be possible to borrow or to buy the product?
Can you show us again how the accident occurred?

If you are certain that there are no other subjects to be discussed, stop the sound-recorder.

Video-recordings
Instructions for the video operator.

During the interview:
• Start the video when the subject begins to tell about the accident.
• Record the use actions of the subject with the product. Make repeated close-ups as well as
  overall pictures.
• Make overall pictures of the posture as well as the site/working surface.

After the interview:
• Make video-recordings of the site and the working surface.
• When the product cannot be taken away, record the product, at right angles from above and
  from the side. Record dimensions also.
• When the workpiece cannot be taken away, record the workpiece in right angles from above
  and from the side. Record dimensions also.
• Record the position and dimensions of the wound, if possible.
• Record the top and the bottom of both hands of the subject, with the fingers joined, while the
  hand is positioned on graph paper.
• Record the instructions for use, if any are available.

Environment
Instructions for the interviewer.

Draw a floor plan of the layout of the site. Indicate the following on this floor-plan:
• dimensions
• working height
• sitting height
• dimensions of the working surface
• the surface of the working top
• the surface of the floor
• the direction from which sound came
• the direction from which light came

Measure the following features of the workpiece:
• the dimensions of the workpiece
• the weight of the workpiece

Describe/measure:
• the type of house
• the temperature
• the lighting with a lux meter

Measurement of forces

Cursive text contains instructions for the interviewer/assistant. Straight text contains questions posed to the subject.

Forces are measured only if the product involved in the accident is manipulated. The subject is instructed to build up the maximum force gradually and hold it for a few seconds. All measurements are conducted while the subject is seated at a table. The measurements are conducted in two postures:
• a standardised posture: forces are measured while the subject is sitting in an upright position, with the elbow in an angle of 90 degrees. The grip to be used is prescribed;
• a free posture: forces are measured in a free posture and a free grip.

Measurements of the forces are conducted both with the right and the left hand. If one of the hands is still injured, the measurements are still conducted for the other hand.

• Are you left- or right-handed in the following activities?
  - throwing a ball
  - writing
  - operating controls
  - lighting the gas: which hand operates the control and which hand holds the lighter
• Are you able to do everything you need to with your arms and hands?
  If no, what can you do with them?
• Pushing
  - push with forefinger
  - push with thumb
  - free grip
• Hand grip strength (adjust to size of hand)
• Pinching
  - lateral
  - pinch
  - free grip
Inspection of product(s)

Instructions for the inspector:

- note the brand, type and serial number;
- composition: the product is disassembled as far as possible. The various parts are video-recorded;
- adjustments: the various possible adjustments and positions of the product are registered and recorded on video;
- weight: the weight of the product and its parts are measured with a scale (accuracy 1 gram);
- centre of gravity: this is measured by balancing the product in vertical and horizontal direction on a fixed point;
- stability: check whether there is play between the product and the working surface;
- finishing: check the product visually for burrs and sharp edges;
- graphics: describe any text, signs, symbols or codes on the product, as well as the position of these graphics;
- materials: describe the types of material of which the product is made;
- texture: the texture of the product and its parts is established by feel and is described in terms of, for example: smooth, rough, ribbed and so on;
- flexibility/rigidity: describe the flexibility/rigidity of the product and its parts;
- the product is inspected visually with regard to the state of maintenance and the presence of defects and modifications. These are described and, if possible, recorded on video;
- if possible, the force required for operation of the product is measured;
- in case of electrical appliances the length of the cord is measured;
- any other relevant details of the product are described and if possible recorded on video.
Appendix 2. Type of accidents included in the study

Introduction

To provide insight into the type and severity of accidents, a description is given in terms of, for example, the product(s) involved, age of the subject, location, activity conducted and injury (cf. Mulder et al., 1995).

Synopses of the accidents

Appendix 3 provides a synopsis of each accident. The product(s) involved and what happened are described and illustrated. In several accidents two products were used simultaneously. For example, the user of the gas lighter simultaneously used the gas stove. The total number of products involved in the forty-two accidents amounted to forty-seven.

Acquisition and age of the products

Table A3.1 shows how the products used were acquired. Most products were newly bought. Several products were bought secondhand, were received as a present or were found. In three cases, the product was made by the subject or the owner themselves. In one case the product was borrowed.

Table A3.1

Way in which the products were acquired
(n=47).

<table>
<thead>
<tr>
<th>Acquisition</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newly bought</td>
<td>26</td>
</tr>
<tr>
<td>Received as a present</td>
<td>6</td>
</tr>
<tr>
<td>Bought/received secondhand</td>
<td>5</td>
</tr>
<tr>
<td>Home made</td>
<td>3</td>
</tr>
<tr>
<td>Unknown</td>
<td>2</td>
</tr>
<tr>
<td>Found</td>
<td>2</td>
</tr>
<tr>
<td>Received or bought</td>
<td>2</td>
</tr>
<tr>
<td>Borrowed</td>
<td>1</td>
</tr>
</tbody>
</table>

The age of the products is the total time that a product has been in use at the time of the accident. In nine cases the age of the product was unknown to the subject. Six of these products had been obtained secondhand and there were three non-durable products (a can, a needle and a bottle of wine). The age of the products varied from zero to approximately thirty years. The zero case concerned a product that was being used for the first time when the accident occurred. Seventeen products were less than two years old. Nine of these were not older than one year. The answers of subjects become less exact when the age of the products exceeds twenty years: subjects switch to naming decades.

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Appendix 2

Gender and age of the subjects
Nineteen women and twenty-three men participated in the project. The age of the participants varied from 20 to 69 years. The median age of the forty-two subjects was 43 years.

Location of the accidents
Table A3.2 shows the location of the accidents. Most accidents occurred in the kitchen (15) or in the living room (11). The remaining accidents occurred on various locations in or around the people's dwelling. Thirty-seven accidents occurred indoors; five accidents occurred outdoors.

Table A3.2
Location of the accidents (n=42).

<table>
<thead>
<tr>
<th>Location</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen</td>
<td>15</td>
</tr>
<tr>
<td>Living room</td>
<td>11</td>
</tr>
<tr>
<td>Workshop/shed/garage</td>
<td>5</td>
</tr>
<tr>
<td>Garden</td>
<td>4</td>
</tr>
<tr>
<td>Bedroom/study</td>
<td>3</td>
</tr>
<tr>
<td>Hall/passage</td>
<td>2</td>
</tr>
<tr>
<td>Stairs</td>
<td>1</td>
</tr>
<tr>
<td>Balcony</td>
<td>1</td>
</tr>
</tbody>
</table>

Activity
Table A3.3 concerns the activity that the subject conducted at the time of the accident. About half the accidents (20) occurred during housekeeping, generally in preparing a meal. Fourteen accidents occurred in do-it-yourself activities. The remaining accidents occurred during a variety of activities.

Table A3.3
Activities conducted at the time the accident (n=42).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housekeeping</td>
<td>20</td>
</tr>
<tr>
<td>- preparing food</td>
<td>12</td>
</tr>
<tr>
<td>- doing the laundry</td>
<td>3</td>
</tr>
<tr>
<td>- collecting garbage</td>
<td>2</td>
</tr>
<tr>
<td>- cleaning the product</td>
<td>2</td>
</tr>
<tr>
<td>- cleaning windows</td>
<td>1</td>
</tr>
<tr>
<td>Do-it-yourself</td>
<td>14</td>
</tr>
<tr>
<td>Personal care</td>
<td>2</td>
</tr>
<tr>
<td>Gardening</td>
<td>2</td>
</tr>
<tr>
<td>Moving around</td>
<td>2</td>
</tr>
<tr>
<td>Other (take post)</td>
<td>1</td>
</tr>
<tr>
<td>Demonstration fitness-stick</td>
<td>1</td>
</tr>
</tbody>
</table>
Phase of use
Table A3.4 depicts the phase of use during which the accident occurred. About three-quarters of the accidents (29) happened during the actual use of the product. The remaining accidents occurred during other phases of use, such as picking up the product, cleaning or repairing.

Table A3.4
Phase of use at the time of the accident (n=42).

<table>
<thead>
<tr>
<th>Phase of use</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pick up the product</td>
<td>1</td>
</tr>
<tr>
<td>Make ready for use</td>
<td>2</td>
</tr>
<tr>
<td>Actual use</td>
<td>29</td>
</tr>
<tr>
<td>Interrupt use</td>
<td>4</td>
</tr>
<tr>
<td>Cleaning</td>
<td>2</td>
</tr>
<tr>
<td>Repairing</td>
<td>1</td>
</tr>
<tr>
<td>Store/put away product</td>
<td>3</td>
</tr>
</tbody>
</table>

Injury and part of the body injured
Table A3.5 gives a review of the injury that the subjects sustained and the part of the body injured. In one case there was no injury; this concerned the housecoat that caught fire during cooking.

With respect to the hand, the thumb (9) is the most frequently injured finger. This is followed by the palm of the hand (6), the little finger (4), the ring finger (4), the forefinger (3) and the middle finger (2). The table shows that the most frequently occurring injury is an incision. In one case (amputation) the injury is permanent. In two cases, the injury is possibly permanent (dislocation of the arm and cut tendon); at the time of the interview this was not yet known.

Table A3.5
Injury and part of the body injured (n=41).

<table>
<thead>
<tr>
<th>Injury</th>
<th>Part of the body injured</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hand</td>
</tr>
<tr>
<td>Incision</td>
<td>16</td>
</tr>
<tr>
<td>Laceration</td>
<td>3</td>
</tr>
<tr>
<td>Burn/scald</td>
<td>2</td>
</tr>
<tr>
<td>Perforation</td>
<td>4</td>
</tr>
<tr>
<td>Fracture</td>
<td></td>
</tr>
<tr>
<td>Graze</td>
<td>1</td>
</tr>
<tr>
<td>Bruise</td>
<td>1</td>
</tr>
<tr>
<td>Dislocation</td>
<td></td>
</tr>
<tr>
<td>Amputation</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>28</td>
</tr>
</tbody>
</table>
Appendix 2

Treatment
In table A3.6 an outline is given of the medical treatment that the subjects had to undergo as a result of the accident.

Table A3.6
Medical treatment of the subjects (n=42).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment in outpatients</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>department, of which:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- suturing/gluing</td>
<td>21</td>
<td>follow-up treatment necessary</td>
</tr>
<tr>
<td>- surgery</td>
<td>3</td>
<td>follow-up treatment necessary</td>
</tr>
<tr>
<td>- replacement of bandages</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>- plaster</td>
<td>2</td>
<td>concerns burns/scalds</td>
</tr>
<tr>
<td>- no treatment</td>
<td>1</td>
<td>concerns torn jawbone, not treatable</td>
</tr>
<tr>
<td>Treated by the subjects self</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Hospitalisation</td>
<td>1</td>
<td>concerns amputation of index &amp; thumb</td>
</tr>
<tr>
<td>No treatment</td>
<td>1</td>
<td>concerns housecoat that caught fire</td>
</tr>
</tbody>
</table>

About three-quarters of the subjects (30) were treated in an outpatients department. As most injuries concerned incisions, the treatment of half of the subjects concerned suturing or gluing. About a quarter of the subjects (10) treated the injury themselves. In at least two of these cases, the subject probably should have undergone treatment by a doctor. In one case (amputation) the subject had to stay in the hospital for ten days.
Appendix 3. Synopses of the accidents

Introduction

This appendix contains a synopsis of each accident. The accidents are alphabetically ordered according to the principal product(s) involved in the accident. Each synopsis consists of a short description of what happened, accompanied by a video picture of the accident. Of course, the synopses contain only a fraction of the data and visual material that is actually available. In addition, the factor tree of each accident is given. The injury, depicted as a star, is always at the top. Italics indicate that it is not certain, generally according to the subject, that the factor occurred. Dotted lines indicate that it is not clear whether the factor was caused by the previous factor.
Axe
The subject was chopping kindlings of a slat, in the shed. When the slat was nearly finished he hit the forefinger of the hand that held the slat. The subject suspects that he chopped with the blade of the axe turned instead of chopping perpendicular to the wood. He also indicated that he had not changed the position of his finger as the slat got smaller.
Blender
The subject had been cleaning the blades and the liquidiser separately. The smooth blender provided little grip for his wet hands, while much force is needed for tightening the blade on the blender. To prevent his hands from slipping, he exerted more force to tighten the blades on the blender. One hand was positioned on the blades, the other on the control panel. In tightening the blades on the blender, the subject accidentally operated the pulse control, with the plug still in the socket. The palm of the hand was torn apart by the turning blades.
Bottle of soft drink
The subject was throwing away some trash in a plastic bag, hanging near the glass bottle of soft drink. Suddenly the bottle exploded. Fragments of glass hit his finger, arm and leg. According to the subject he did not touch the bottle. However, he said that the bottle may have been moved or hit the day before, during cleaning the kitchen. As is known, moving or hitting bottles of soft drink may instigate the built-up of enormous pressures.

Various incisions

- user stands near bottle
- bottle explodes
  - pressure is built up in bottle
  - moved/hit bottle the day before
Breadknife
The subject was cutting a baguette when his girlfriend came in and asked him a question. He turned around to answer the question, looking at his friend. The knife turned too, and while he went on cutting he cut off the tip of the (nail of the) forefinger of the hand that held the bread.
**Can**
The subject had opened the can with a can opener. She had left the lid attached to the can. In reaching towards the lid, to push it up, she cut her thumb on the sharp edge of the lid.
Appendix 3

Children’s table
The subject used a small table as a step to take something off the cupboard. The table is a piece of children’s furniture. While standing on the table, the tabletop broke at four of the six screws. The subject’s shin was torn open to the bone over 20 cm by a long screw. The table top consists of chipboard, which is fixed to the frame with six screws. According to the subject the table gives an impression of firmness because of the thick screws. There is nothing to indicate that the table is fragile.
Circular saw
The subject was sawing a plank in two with a stationary circular saw. In one way or another, the subject hit the revolving blade. The forefinger and the thumb were amputated. He does not know exactly how or why he hit the blade. The subject thinks that the wood got stuck in the revolving blade, so he had to push harder, thus hitting the blade. He also suggests that in bending forward the protective cover may have obstructed the view on his hands.
Corkscrew and winebottle
The subject was uncorking a bottle of wine with a T-shaped corkscrew. He had clasped the bottle between his knees, holding it with one hand. The subject indicated that he probably held the bottle in a sloping position, thus exerting force on the bottleneck. The bottle broke at the neck and cut the tip of the little finger. The subject said that he exerted much force in removing the cork, since the cork was firmly anchored in the bottle.
**Fitness-stick**

The subject noticed her son and a friend coming in with a fitness-stick. As she had heard of a serious accident with the stick, she wanted to warn the children by giving a demonstration of the use of the stick. While bending the strong spring, she kept the left handle closer to the body. Consequently, the spring back force is partly directed out of the hand. The left handle slipped out of the hand and smashed against the chin, thus injuring the lower jaw and the tongue. The handle is made of hard plastic with hardly any texture. The subject said she possibly had damp hands.
Food processor
The subject was removing the protective covers from the sickle-shaped knives of a food processor. The grip on the cylinder being insufficient in combination with wet hands, the knives slipped out of the hand. In trying to catch the knives, the tendon of the ring finger was severed by the uncovered knives. According to the subject, the covers stick when removing them. She indicated that the functioning of her arm has decreased due to an operation, and that, consequently, her force exertion may not have been well controlled.
Gas lighter and stove
The subject was lighting a gas ring on which a heat diffuser and a pan were positioned. The gas lighter has to be kept close to the gas ring before the gas lights, possibly because the flints of the lighter are worn down. In order to be able to reach the gas ring, the subject kept the gas lighter horizontal. In doing this, the subject burnt the finger of the hand enclosing the gas lighter on another, still hot, gas ring.
Gas stove
The subject was cooking during the morning, wearing her housecoat with wide sleeves. She stretched her arms above the tea kettle, which she had just put on the fire, to empty a dish into the pan behind the teakettle. The wide sleeves of the housecoat caught fire, possibly because the flames came from under the tea kettle.
Gas stove and pan
The subject used a tea-towel to take a pan off the stove. He used a tea-towel because the handles of the pan get too hot to touch with bare hands. The towel got caught on the grate of the stove. However, the subject did not notice this, and moved the pan further. The pan tilted and the boiling hot water gushed out of the pan, scalding both hands and arms.
Glass table
While looking at her friend, the subject walked into the corner of a glass table and cut her knee. The corner had broken off several days before the accident. The space for walking is small. The subject said that she may not have noticed the table because it is transparent.
Grater
The subject was grating a piece of Gouda cheese with a vertical grater. She had positioned the grater against her belly, holding the cheese vertically with the other hand. She could not see the position of her fingers at the bottom of the cheese. When the subject had finished about half the cheese, she cut her ring finger on the grater while moving the cheese.
**Handsaw 1**
The subject was making the surround of a television smaller, trying to make it fit into a cupboard. The television wobbled because it was lying on its screen. Therefore, the subject stabilised it with one hand. As he had removed the back cover, the subject tried to avoid touching the back, since this might cause an electrical shock. Also, he tried to avoid hitting the carpet, thus holding the saw horizontally. In doing this, the saw tore open the little finger of the hand that stabilised the television.

---

**Diagram:**
- **blade tears little finger**
  - holds saw horizontal
  - blade has sharp points
  - holds still with hand on rim
  - TV is on carpet
  - TV wobbles during sawing
  - removed cover of TV (shock)
**Handsaw 2**

The subject was sawing up tree trunks on a field outside his garden, near a public path. He held the trunk with one hand in order stabilise the trunk, which wobbled during sawing. When a large dog pushed it's head between his legs, he made a movement of fright. The blade of the saw folded and tore open the thumb of the hand holding the trunk.
Hedge-trimmer
The subject was trimming a trunk from a bush with an electrical hedge-trimmer. As the trunk wobbled during trimming, he stabilised it with one hand. With the other hand he held the trimmer. The hedge-trimmer slipped and cut the thumb of the hand that held the trunk.
**Hobby knife**
The subject was cutting off a piece of mastic positioned in a drain pipe. As he could not reach the mastic in the small, deep pipe, he pulled out the blade for 8 centimetres. He held the mastic with one hand. In cutting the tough mastic, the blade folded and hit his forefinger. According to the subject, he could not see what he was doing, since the small drainpipe was covered by his hands.
Hot plate
When the subject came into the kitchen, she noticed bread crumbs on the hot plate. She did not know that one plate was still hot: because of her birthday, the children had made breakfast this time. After 15 minutes, the red glow of the plate disappears, leaving no visible sign that it still retains some heat. She wiped off the bread crumbs with her bare hand and burnt the palm of the hand. The subject said that she had overlooked the small lamp which indicates that one of the plates is hot.
Iron
The subject was ironing cloths while standing at a table. In order to work fast, she put down the iron in an upright position nearby while folding and burnt her arm on the hot tip of the iron.

```
burns arm

<table>
<thead>
<tr>
<th>arm contacts tip of iron</th>
<th>tip of iron is hot</th>
</tr>
</thead>
<tbody>
<tr>
<td>puts iron nearby</td>
<td>puts iron in upright position</td>
</tr>
<tr>
<td>no indications</td>
<td>that iron is hot</td>
</tr>
</tbody>
</table>
```
Knife (large)
The subject was cutting slices from a kohlrabi with a large knife. He said that he had to exert a lot of force, as the kohlrabi was very hard and the knife was blunt. To exert such force, he put one hand on the blade and one on the handle. The knife went slantwise and slipped out of the kohlrabi. In slipping, the blade cut the thumb.
**Knife (small)**
The subject was separating deep-frozen meat with a small knife. Since the slices were folded around each other, she had to exert a great deal of force. She positioned the blade in the direction of her hand. The knife slipped on the hard meat and gashed the ball of the hand that held the meat.
Metal saw
The subject was sawing a metal strip, which was clamped in a work-bench. As the strip wobbled during sawing he used his free hand to hold the strip still. The saw slipped out of the strip and hit the thumb. During the third reconstruction the subject discovered that, the week before the accident, he had put in the blade with the teeth in the wrong direction.
**Needle**
The evening before the accident the subject could not get the thread through the needle. She intended to go on with it the day after, and put the cloth on a chair. However, for various reasons she did not get round to it. When the subject sat on the chair the needle pierced her leg and broke in two. One piece had to be removed surgically.
Appendix 3

Plane
The subject was planing a plank, which was clamped to the working bench. In planing, the subject made circular movements, with the plane out of square, i.e. not perpendicular with the plank. Because he was hampered in his movements by a large machine, he had to lean over to reach the end of the plank. The plane slipped off the plank and the subject scraped his little finger on the rough plank.

Diagram:
- Scrapes finger
- Fingers jut out of plane
- Slips off plank
- Plank is rough
- Plane is out of square with pl.
- Leans over on plank
- Makes circular movements
- Large machine present
Planing machine
The subject was planing a short piece of plywood with a planing machine in a stationary position, i.e. turned upside down. Consequently, his fingers were close to the cutters. The cutters wedged themselves into the plywood, pulling the plywood down forcefully. The plywood canted and the subject slid into the revolving cutters with both middle fingers.
Appendix 3

Pump screwdriver
The subject was fixing a telephone rig with two screws, to the wooden wall of his garage. He had not pre-drilled the holes. Since he was working above his head, he did not exert force with the screwdriver in line with the screw, i.e. the screwdriver was at an angle with the screw. In pumping for the first time, the bit slipped upwards out of the cross-slotted screw. The turning bit pierced the middle finger of the hand that held the screw.
Razor

Because the 'lady-shave' had broken down, the subject took a hairdresser's razor to finish shaving her legs. In unfolding the razor, she dropped it. When she tried to catch the razor, the blade sliced along her knee.
Retractable clothesline
The subject was assembling a retractable clothesline. The cylinder inside the clothesline had been broken, and he had repaired it by gluing the two parts together. In winding the spring with the rotary control the cylinder broke again. He released the control when the spring released its energy. The control smashed against the thumb, which started to bleed and turned blue.
Scissors
The subject was pedicuring her feet. She had positioned her feet on sheets of a newspaper. During the pedicure, the scissors somehow became hidden in the sheets of paper. In pushing the paper sheets into a ball, the sharp points of the scissors pierced her thumb.
**Scraper**

The subject was placing the protective cover over the blade of a scraper, used for removing wallpaper. He did this by clicking the cover onto the scraper. The cover slipped and the point of the blade slashed the side of his hand. According to the subject the cover has to slide onto the blade. He said that he always avoided this by clicking the cover onto the scraper, as this is easier.

Both the cover and the scraper have a ridge. Possibly, the resistance of the ridges in clicking the cover on the scraper was so great this time that the scraper slipped.
**Screw auger**

The subject was fixing two small slats with a screw, using an electric drill with a special screw bit. To keep the slats together he held them with one hand. As he had not pre-drilled the wood, he pushed the screw into the plain wood. The screw and auger toppled. The still turning bit pierced the thumb of the hand that held the wood. There is a large distance between the haft, i.e. where the subject pushes on the auger, and the bit, probably contributing to the toppling of the screw.

![Diagram of screw auger process](image-url)
Screwdriver
The subject was dislodging a cap which covers the handlebar of her bicycle. She held the bar with one hand to stabilise the bicycle, and handled the screwdriver with the other hand. She said that she had to exert much force, as the cap was firmly stuck in the bar. The screwdriver slipped off the cap and pierced the palm of the hand holding the handlebar.
**Stair gate**
The subject always climbed over the stair gate, because the gate tilted and creaked, which woke his son. He slipped off the upper step while climbing over the gate. He fell backwards off the stairs, which dislocated his arm and resulted in extensive bruising.
Step and clothesline
The subject was hanging out the laundry, while standing on a step. In pulling down a wet sheet, the clothesline broke. She lost her balance and fell with the step, with her legs entangled in the frame of the step. She sustained a broken ankle, grazes and bruises.
Stepladder 1
The subject was standing on the upper step of a stepladder during wallpapering. To be able to reach the corner, near the ceiling, she leaned against the brace of the ladder. The ladder tilted, and the subject fell, face downwards. Her jaw was broken. The floor of the room appeared to be sloping towards the wall she was papering.
Stepladder 2
The subject had been working on the roof of his shed. In stepping off the roof, he heard his wife and daughter coming home. He turned around to look at them, but continued stepping off the ladder without turning back again. He stepped off the ‘wrong’ side (without steps) of the ladder and fell. The subject broke his wrist and sustained bruised ribs. The ladder did not have a brace.
Stool
The subject was cleaning windows, while standing on a stool. She had positioned the stool on the underfloor heating. One leg of the stool fell through the grid of the underfloor heating. She fell and broke her wrist. The underfloor heating appeared to have a ring missing, which gave room for the grid to part.
Thermos
The subject was making coffee, while the thermos was positioned on an uneven, sloping floor. With one hand the subject poured boiling water on the coffee filter and with the other hand he held a magazine that he had been reading. The top-heavy thermos tipped over in the direction of the subject’s feet. Both feet were scalded.
Vegetable slicer
The subject was slicing a large onion. As the onion was too large to fit in the safety holder, he sliced the onion without using the safety holder. Holding the slicer almost vertically, he could not see the position of his fingers at the bottom of the onion. In moving up the onion for the first time, the tip of the little finger was cut off. The subject said that he had positioned the blade in its thickest position, which is unusual.
Wastepaper basket
The subject emptied the wastepaper basket by grabbing the paper balls out of the basket. She did not want to pick up the basket, as this would leave fingerprints on the gleaming metal. In reaching into the basket, the subject gashed her hand at the rim. The subject indicated that she had never thought that she could sustain an incision, since the rim does not feel sharp.
Ongelukken met consumentenprodukten

Samenvatting

M.F. Weegels

1. Inleiding

Het probleem
Elk jaar worden in Nederland meer dan een half miljoen mensen medisch behandeld voor letsels opgelopen in een ongeluk met een consumentenprodukt. Ongelukken zijn ongewenste gebeurtenissen voor alle betrokkenen. Naast lichamelijk en geestelijk leed kan een ongeluk heel wat kosten met zich meebrengen voor zowel de consument als voor de samenleving. Het imago van een fabrikant kan ernstig worden geschad wanneer diens produkten als onveilig worden bestempeld. De financiële consequenties van een produkt recall, een negatief oordeel in een warentest of een toegekende produktaansprakelijkheidsclaim kunnen aanzienlijk zijn.

Tot dusver is op het gebied van veiligheid in de privé-sfeer aandacht besteed aan enerzijds het voorlichten van consumenten en anderzijds de technische veiligheid van produkten. Echter, de wet aangaande de produktaansprakelijkheid eist van fabrikanten dat ze rekening houden met het redelijkerwijs te verwachten gebruik van hun produkt. Bestaande inzichten bieden ontwerpers weinig houvast bij het anticiperen van toekomstig gebruik en mogelijke ongelukken daarbij. Dit proefschrift beoogt een bijdrage te leveren aan de ontwikkeling van middelen die ontwerpers kunnen ondersteunen bij het voorspellen van ongelukken.

Doel van de studie
In hun pogingen om ongelukken te anticiperen, kunnen industrieel ontwerpers worden geconfronteerd met tenminste twee situaties. In de ene situatie is bekend dat er ongelukken zijn gebeurd met voorlopers van het (her)ontworpen produkt. In dat geval kunnen methoden voor de observatie en analyse van ongevallen met het produkt ontwerpers van dienst zijn bij het opstellen van eisen voor het ontwerp. In de andere situatie bestaat het vermoeden dat er ongelukken met het te ontwerpen produkt kunnen gebeuren, maar is er geen empirische evidentie te achterhalen. Hier kunnen algemene inzichten in de toedracht van ongelukken mogelijk als basis dienen voor de eisen te stellen aan het produkt. Het doel van de studie in dit proefschrift is te voorzien in:

- methoden voor de observatie en analyse van ongelukken;
- algemene inzichten in het optreden van ongelukken met consumentenprodukten.

De bevindingen dienen te zijn toegespitst op toepasbaarheid in het ontwerpproces.
2. Status quo op het gebied van veiligheid

Theoretische inzichten
Gangbare ideeën over het ontstaan van ongelukken, zoals de systeembenadering, de sequentiële benadering en de epidemiologische benadering, vertonen een aantal tekortkomingen. De meeste benaderingen stammen uit verkeers- en beroepsomstandigheden. In deze benaderingen worden de aspecten die typerend zijn voor de omgang met consumentenprodukten vaak genegeerd, zoals een grote diversiteit in gebruikers en een relatief grote vrijheid hoe, waar, wanneer een produkt wordt gebruikt. De notie van een norm die in een aantal benaderingen terug te vinden is lijkt strijdig te zijn met deze relatief grote vrijheid. Andere beperkingen zijn de eenzijdigheid van technische en gedragsbenaderingen. In technische benaderingen blijft de gebruiker buiten beeld, terwijl in gedragsbenaderingen het produkt slechts een marginale positie toebedeeld wordt.

In de literatuur wordt een veelheid van uiteenlopende factoren genoemd als mogelijk bijdragend in het optreden van ongelukken, variërend van de maancyclus tot persoonlijkheidskenmerken van de gebruiker. Het merendeel van de literatuur gaat over de gebruiker als boosdoener, zoals diens tijdelijke conditie (inclusief haast en moeheid), cognities (kennis en ervaring), risico-perceptie en niet te vergeten de gebruiker als brokkenmaker. Het daadwerkelijke gebruik van produkten en de rol van het uiterlijk van het produkt blijven onderbelicht in de literatuur.

De genoemde beperkingen maken het niet aantrekkelijk één van de bestaande benaderingen als uitgangspunt te nemen voor de observatie en analyse van ongelukken met consumenten produkten.

Observatie van ongelukken
Onderzoek naar ongelukken valt in te delen naar retrospectief onderzoek versus onderzoek ten tijde van het ongeluk, en de studie van ongelukken versus bijna ongelukken. Om diverse redenen is retrospectief onderzoek is de meest gerede methode voor ons doel. Echter, in retrospectief onderzoek is de validiteit van bevindingen in het geding, omdat bijvoorbeeld geheugenprocessen het beeld dat de betrokkenen heeft van het gebeurde kunnen vertekenen. Daarom is nagegaan welke maatregelen de literatuur op het terrein van de ondervraging van ooggetuigen adviseert om dergelijke vertekening te beperken. Voorbeelden van maatregelen zijn de betrokkenen zo snel mogelijk na het ongeval te bezoeken, het slachtoffer te laten voordoen hoe deze het produkt ten tijde van het ongeluk hanteerde, en de combinatie van een open interview met een checklist.

Analyse van ongevalsgegevens
Voor de analyse van ongevalsgegevens zijn diverse technieken beschikbaar, waaronder scenario analyse, deviatie analyse, multidisciplinaire reviews en systeem analyse. In de meeste technieken blijft de wijze waarop oorzaken worden of dienen
te worden herleid uit ongevalsgesgevens impliciet. Dit is opmerkelijk gezien het feit dat beoordelaars of experts worden ingeroepen voor het identificeren van de oorzaken van ongevallen. Diverse auteurs benadrukken dat verschillen kunnen optreden in de oorzaken geïdentificeerd door verschillende beoordelaars. Er wordt echter zelden dieper ingegaan op de herkomst van die verschillen. Empirisch onderzoek op dit terrein is nauwelijks aangetroffen. Zolang niet expliciet gemaakt wordt op basis van welke overwegingen oorzaken zijn herleid, is de plausibiliteit en falsifieerbaarheid van bevindingen in het geding. Daarom bevat dit proefschrift een aparte studie naar de manier waarop beoordelaars oorzaken uit ongevalsgesgevens herleiden.

3. Observatie van ongelukken

**Benadering**

Gezien de beperkingen van bestaande benaderingen, wordt in dit proefschrift een benadering geïntroduceerd die is toegespitst op ongelukken met consumenten produkten. In deze benadering wordt een ongeluk gezien als een consequentie van het functioneren van produkten. In technisch/fysische zin is dit functioneren het resultaat van het samentreffen van een produkt, gebruiksacties en de omgeving. Hoe en tot op zekere hoogte ook waar een produkt wordt gebruikt kunnen samenhangen met sensorische, mentale en fysieke kenmerken van de gebruiker. Een belangrijk verschil met bestaande benaderingen is het gezichtspunt dat invloeden van kenmerken van de gebruiker alleen via gebruiksacties, i.e. wat mensen doen, kunnen bijdragen in het optreden van ongelukken. Door uit te gaan van het samentreffen van produkt, gebruiksacties en omgeving wordt een eenzijdige benadering uitgesloten.

**Methode**

Samenvatting

Aanwijzingen voor vertekening
De bevindingen uit de reconstructies kunnen om een aantal redenen afwijken van de - onbekende - daadwerkelijke gebeurtenissen ten tijde van het ongeval. Sommige respondenten droegen nog steeds verband of gips tijdens het onderzoek ter plaatse. Andere ongelukken konden niet helemaal nagespeeld worden, bijvoorbeeld het vallen met een huishoudtrap. Een aantal produkten was om veiligheidsredenen niet ingeschakeld tijdens het onderzoek. In enkele gevallen waren de omstandigheden onherstelbaar veranderd na het ongeluk. Het gebruik van opname-apparatuur kan ervoor zorgen dat mensen zich anders gaan gedragen. Een enkele participant maakte een opmerking over de opname-apparatuur, maar de meeste respondenten leken zich er niets van aan te trekken. Andere, mogelijke bronnen van vertekening zijn verschillen tussen mensen in de zelfverzekerheid waarmee ze zich uitdrukken, en de neiging om een ‘sociaal wenselijk’ verslag van het gebeurde te doen om niet ‘dom’ te lijken. Respondenten zijn gevraagd om drie keer te laten zien wat er gebeurde - twee keer voor het interview en één keer na het interview - om na te gaan of en wanneer intra-individuele verschillen tussen de demonstraties optreden. Meer dan de helft van de respondenten vertoont intra-individuele verschillen in demonstraties. Deze verschillen hebben mogelijk te maken met het ophalen van nieuwe details uit het geheugen gedurende de demonstraties en het interview. In hoeverre het bij deze verschillen gaat om random variatie dan wel systematische verschillen (vertekening) kan op basis van de gegevens niet worden nagegaan.

4. Beoordelen van de oorzaken van ongelukken

Studie met beoordelaars: inleiding
Om inzicht te krijgen in de vraag hoe, op basis van wat voor redeneringen, uit ongevallen gegevens oorzaken kunnen worden herleid door beoordelaars is een aparte studie gedaan. De verkregen inzichten dienen toepasbaar te zijn in de analyse van ongelukken, zodat de herkomst van oorzaken geëxpliceerd kan worden. De gegevens over vier van de onderzochte ongelukken werden voorgelegd aan twaalf beoordelaars, waaronder zes industrieel ontwerpers en zes academici uit verschillende andere disciplines. De beoordelaars werden gevraagd om schriftelijk aan te geven wat in hun ogen oorzaken van de ongevallen waren. In een nagesprek werden beoordelaars gevraagd de door hen aangegeven oorzaken toe te lichten. Verder werden ze gevraagd de oorzaken te ordenen naar belangrijkheid en aanbevelingen te doen voor verbetering van de betrokken produkten.

Resultaten
De overeenstemming over de oorzaken van de ongevallen bleek beperkt te zijn. Drie tot zes oorzaken per ongeval (mediaan 4) werden door meer dan zes beoordelaars genoemd. Andere oorzaken werden genoemd door hooguit de helft,
maar meestal slechts een of twee beoordelaars. Er bleken wel overeenkomsten te zijn in de wijze waarop beoordelaars redeneren bij het bepalen van oorzaken. Een drietal criteria c.q. redeneerwijzen kan worden onderscheiden. In het criterium van deviaties, oftewel afwijkingen, vergelijken beoordelaars het gebeurde met bepaalde normen en waarden, zoals de eigen ervaring met soortgelijke produkten, de gebruiksaaanwijzing, of wat zij als normaal, logisch of juist beschouwen. Oorzaken zijn die condities die afwijken van een norm. Eén van de redeneerwijzen die beoordelaars gebruiken is nagaan in hoeverre het ongeval ook was gebeurd bij afwezigheid van een factor (counterfactual reasoning). Ze redeneren als volgt: als deze conditie afwezig zou zijn geweest, was het ongeval dan ook gebeurd? Als het ongeluk niet zou zijn gebeurd in afwezigheid van de conditie, dan wordt deze conditie beschouwd als een oorzaak. Een ander criterium is de veranderbaarheid van condities (mutability). Condities die als onveranderbaar of gegeven worden gezien, zoals bijvoorbeeld de zwaartekracht, worden niet als oorzaak aangemerkt.

Implicaties voor de analyse van ongelukken
Vergelijkbare criteria te vinden zijn op het gebied van de sociale psychologie en de filosofie. Terwijl sociaal psychologen zich bezig houden met de manier waarop counterfactual reasoning de perceptie van oorzaken van dramatische gebeurtenissen door leken beïnvloedt, hebben filosofen zich vooral gebogen over de waarheid en de onderbouwing van uitspraken gedaan op basis van counterfactual reasoning. Dit laatste komt overeen met ons probleem: de plausibiliteit van uitspraken over de oorzaken van ongevallen.

Anders dan het criterium van deviaties, dat voornamelijk lijkt te berusten op interne normen en waarden van beoordelaars, kan counterfactual reasoning gestaafd worden met evidentie. Zodoende wordt deze redeneerwijze gebruikt in de analyse van de 42 onderzochte ongelukken. De evidentie gebruikt ter ondersteuning van counterfactual reasoning kan bestaan uit beschikbare kennis, zoals fysische of psychologische wetmatigheden, uitkomsten van metingen en uitspraken van de gebruiker over diens interne toestanden. Mutability, dat in de literatuur wordt gezien als een voorwaarde voor counterfactual reasoning, wordt in onze analyse beschouwd vanuit een ontwerpersperspectief: dat, wat op één of andere manier te beïnvloedens is met of via het ontwerp van een produkt, wordt gezien als mutable. Dit perspectief dient als afbakening van de factoren die worden onderworpen aan counterfactual reasoning. Opgemerkt zij dat counterfactual reasoning geenszins garandeert dat verschillende mensen tot dezelfde conclusies komen. De merites van deze redeneerwijze liggen daarin, dat het herleiden van oorzaken navolgbaar gemaakt kan worden.

De analyse van de onderzochte ongelukken verloopt in de volgende stappen. De beschikbare gegevens van elk ongeluk worden doorzocht op oorzaken, oftewel bijdragende factoren, gebruik makend van counterfactual reasoning. Vervolgens wordt de evidentie gebruikt ter ondersteuning van de counterfactuals (als niet ...
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dan ...?) geëxpecteerd. De aldus verkregen oorzaken, of liever gezegd, bijdragende factoren worden geordend naar volgorde en samentreffen met andere factoren. Voor ieder ongeval worden de bijdragende factoren grafisch weergegeven in een zogenaamde factorboom.

5. Op zoek naar wetmatigheden

Inleiding
De factorbomen vormen de basis voor de analyse van regelmatigheden in de toedracht van ongelukken. Zulke regelmatigheden kunnen bestaan uit een dominante bijdragende factor, patronen in de sequenties en combinaties van factoren of bepaalde samenhangen tussen gebruikerskenmerken en hoe en waar produkten worden gebruikt. Tevens wordt ingegaan op de vraag in hoeverre deviaties, ofwel afwijkingen, te relateren zijn aan het optreden van ongelukken.

Patronen in het optreden van ongelukken
De resultaten laten zien dat een aantal factoren relevant is in een kwart tot de helft van de ongelukken, maar dat het merendeel van de factoren bijdragend is in een klein aantal ongevallen. Er is niet één dominante factor. Regelmachtes in de sequenties en combinaties van factoren zijn zeldzaam. De gevonden sequenties van factoren variëren enorm. Combinaties van factoren die herhaaldelijk zijn aangetroffen zijn:

• de gebruiker raakte hete of scherpe delen van het produkt (aan);
• de gebruiker schoot met het produkt uit of op het bewerkte materiaal in de richting van een lichaamsdeel;
• de gebruiker viel van of met het produkt.
Deze combinaties van factoren gaan alle vooraf aan het optreden van letsels. Wanneer we verder terug in de tijd gaan, lijken de gebeurtenissen uit te waaieren, waarbij nauwelijks regelmatigheid te ontdekken valt.

Kenmerken van gebruikers
Vijftien respondenten zeiden dat ze bijvoorbeeld niet opletten of onvoorzichtig, gehaast, moe, geërrieide waren ten tijde van het ongeluk. Dit relatief grote aantal gaat hand in hand met de zelf-beschuldigende houding die respondenten hebben: bijna de helft weet het ongeluk aan zichzelf. Als de frequentie van produktgebruik als indicatie voor de bekendheid met het produkt wordt genomen, dan kunnen de participanten niet worden betiteld als zijnde onervaren of onbekend met het produkt. Driekwart van de respondenten gaf aan dat ze geen idee hadden dat ze het risico liepen zichzelf te verwonden. Het ziet er naar uit dat het in de literatuur wijdverbreide idee dat mensen risico's nemen na bewuste besluitvorming niet opgaat voor het gebruik van alledaagse produkten.
Diverse respondenten zeiden dat het produkt een veilige indruk op hen maakte, met als gevolg dat zij dachten dat bepaalde handelingen geen kwaad konden. In een aantal ongevallen gaven de produkten geen terugkoppeling over de conditie waarin het produkt zich bevond. Ook wanneer respondenten zeiden dat ze bewust waren van het risico een ongeluk te krijgen, namen ze niet altijd maatregelen nemen om dat risico te vermijden.

Respondenten lijken geen brokkenmakers te zijn. Met andere woorden, zij lijken niet vaker dan andere mensen betrokken te zijn in een ongeluk. Wat hun fysieke kenmerken aangaat wijken de respondenten enigszins af van andere mensen. Echter, fysieke kenmerken bleken slechts in een beperkt aantal ongevallen relevant te zijn voor hoe en waar het produkt werd gebruikt.

Deviaties
Nagegaan is in hoeverre deviaties, oftewel afwijkingen, van een of andere norm te relateren zijn aan het optreden van ongelukken met consumenten produkten. Deviaties zijn gebaseerd op wat de respondenten normaal dan wel afwikkend vinden. Een kwart van de respondenten kon geen afwijkingen noemen; in hun ogen was alles ten tijde van het ongeluk normaal. Niet alle afwijkingen kunnen als bijdragende factor - geïdentificeerd met counterfactual reasoning - worden aangemerkt. Het merendeel van de bijdragende factoren kan niet worden beschouwd als een afwijking. Hoewel afwijkingen dus soms een bijdragende factor zijn, zijn niet alle afwijkingen als bijdragend aan te merken. Deze bevindingen impliceren dat het ontstaan van ongelukken met produkten slechts voor een klein deel te verklaren is uit het optreden van afwijkingen.

6. Algemene discussie

Beperkingen van de studie
Allereerst een aantal beperkingen van de studie in dit proefschrift. Om te beginnen is deze studie beperkt tot bestaande produkten. Dat zou kunnen betekenen dat ontwerpers bij het ontwerpen van hun produkt al rekening hebben gehouden met die factoren die in slechts een aantal ongevallen als relevant aan te wijzen zijn. Bijvoorbeeld, het feit dat lichaamsafmetingen van gebruikers slechts in een beperkt aantal ongelukken als relevant zijn aangewezen, zou kunnen betekenen dat ontwerpers al met deze afmetingen rekening hebben gehouden bij het ontwerpen van de produkten.

In het onderzoek is alleen naar ongelukken gekeken. Inzicht in het gebruik van produkten dat niet in ongelukken resulteert, en in de mate waarin participanten verschillen van anderen is beperkt. Verder is geen inzicht verkregen in de mate waarin mensen compenseren voor hun sensorische, mentale en fysieke
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beperkingen. Bijvoorbeeld, zware mensen stappen mogelijk niet op een fragiel uitzend tafeltje in de wetenschap dat dat tafeltje hen niet zal houden. Het is mogelijk dat een deel van de mensen aan wie werd gevraagd mee te doen aan het onderzoek heeft geweigerd omdat ze dan opnieuw zouden moeten vertellen hoe ze ‘stom’ zijn geweest. Deze zelf-selectie heeft mogelijk geleid tot vertekening in het soort ongelukken dat is onderzocht.

De observatie en analyse van ongelukken
De methoden voor de observatie en analyse van ongelukken, zoals beschreven in dit proefschrift, zijn nog niet getoetst in de ontwerppraktijk. De toepasbaarheid in de praktijk is afhankelijk van enerzijds de kosten in tijd en geld, en anderzijds de opbrengsten ervan.

De geïntroduceerde methoden vragen veel tijd als gevolg van de nagestreefde uitgebreidheid van de data en de benodigde grondigheid van de analyse. Reductie van de benodigde tijd door mensen per telefoon te interviewen of door hen schriftelijk te ondervragen valt af te raden, omdat dit ten koste gaat van de validiteit en uitgebreidheid van ongevalsgesprekken. Een andere optie voor reductie van de benodigde tijd is het schrappen van factoren uit het protocol voor het onderzoek ter plaatse. Aangezien vrijwel alle factoren tenminste nu en dan relevant blijken te zijn, zijn er nauwelijks aanknopingspunten voor het uitsluiten van factoren. Een mogelijk obstakel voor de toepassing van de geïntroduceerde benadering is de recruterings van respondenten.

Een veelgehoord kritiekpunt is dat vaak maar over een paar ongelukken per produkt gegevens beschikbaar zijn. Hoe kun je er dan zeker van zijn dat dure produktveranderingen het grootste deel van de ongelukken voorkomen en niet slechts een paar? Voor het inschatten van de effectiviteit van produktveranderingen is inzicht in expositie, oftewel blootstelling, zoals wie, hoe, waar, hoe vaak, hoe lang een produkt gebruikt, onmisbaar. Op het gebied van consumentenprodukten is echter geen grondige analyse van het begrip ‘expositie’ te vinden.

Natuurlijk is veiligheid slechts één van de vele zaken waarmee industriële ontwerpers rekening moeten houden bij het ontwerpen van een produkt. Er zijn nou eenmaal beperkingen aan wat ontwerpers kunnen doen. Bovendien zijn er grenzen aan de verantwoordelijkheden van ontwerpers. Zelfs wanneer ruime aandacht is geschonken aan de veiligheid van een produkt bestaat er altijd de mogelijkheid dat nieuwe, onvoorziene ongelukken worden geïntroduceerd.

Algemene inzichten in het optreden van ongelukken
Het optreden van ongelukken met alledaagse produkten blijkt in hoge mate onvoorspelbaar. Eén van de weinige regelmatigheden die is gevonden is dat nauwelijks regelmatigheden te ontdekken zijn. Daarbij dringt de vraag zich op waarom er regelmatigheden zouden zijn, gezien de grote variatie in mogelijk relevante factoren. Dat er maar enkele regelmatigheden in sequenties en combinaties gevonden zijn, kan een gevolg zijn van het beperkte aantal ongelukken.
dat is onderzocht. Een cruciaal punt is of wél regelmatigheden waren gevonden als er meer ongelukken zouden zijn onderzocht. Vanzelfsprekend is het mogelijk om wetmatigheden te ontdekken als ongelukken met eenzelfde produkt worden onderzocht. Zulke inzichten bieden doorgaans weinig soelaas als het produkt dat wordt ontworpen verschilt van het produkt waar ongevalsgegevens over zijn.

Een aantal theoretische noties is uit dit onderzoek naar voren gekomen. Sommige van deze zijn in strijd met vigerende ideeën in de literatuur. Wat mensen doen met een produkt lijkt in belangrijke mate te worden gestuurd door enerzijds de percepties van de gebruiker, bijvoorbeeld hun blikveld, en anderzijds de terugkoppeling die het produkt geeft, of juist niet geeft over de toestand waarin het zich bevindt. Ontwerpers zouden daarom na moeten gaan hoe hun produkt wordt waargenomen door toekomstige gebruikers, en, meer in het bijzonder, hoe gebruikers reageren wanneer ze gede priveerd zijn van informatie over de toestand waarin het produkt verkeert.

De respondenten lijken niet vaker dan andere mensen betrokken te zijn in een ongeluk. Fysieke kenmerken van deelnemers blijken slechts in een beperkt aantal ongevallen relevant te zijn voor hoe en waar een produkt wordt gebruikt. Dit duidt erop dat het aanpassen van produkten aan bepaalde groepen of bepaalde kenmerken van mensen niet veel zal helpen in de preventie van ongelukken. Het idee dat mensen risico’s nemen na bewuste besluitvorming valt niet terug te vinden in onze resultaten. De meeste respondenten zeiden geen enkele perceptie van risico’s te hebben tijdens het gebruik van het produkt. Deze afwezigheid van enige risico-percectie heeft mogelijk te maken met het feit dat de meeste respondenten de produkten geregeld gebruikten. De resultaten impliceren dat het weinig zin heeft om mensen bijvoorbeeld te waarschuwen als ze alledaagse produkten gebruiken.

De toekomst
Mogelijkheden voor verdere studie zijn een verkenning van het begrip expositie, onderzoek naar de invloed van het uiterlijk van het produkt op de perceptie van gebruikers, inclusief compensatie-mechanismen, en de toepasbaarheid van andere typen onderzoek, zoals gebruiksonderzoek, voor het verkrijgen van inzicht in ongelukken.

Vooral nog zullen industriële ontwerpers elke gelegenheid moeten aangrijpen om meer te weten te komen over ongelukken met hun produkt, zij het dan post hoc. In hun pogingen om ongelukken te anticiperen, biedt het onderzoek in dit proefschrift een manier om naar ongelukken te kijken, hoe deze onderzocht kunnen worden en hoe inzichten aan ongevalsgegevens kunnen worden ontleend.
Accidents involving consumer products

Summary

M.F. Weegels

1. Introduction

The problem
In the Netherlands, the number of people medically treated for injuries sustained in an accident involving a consumer product - in the broadest sense of the word - amounts to over half a million per year. It need hardly be said that accidents are undesirable. An accident may cost the person(s) injured not only pain and inconvenience, but also considerable amounts of time and money. The interests of manufacturers may be seriously harmed if they become discredited when their products are labelled as not being safe. The financial consequences of a product recall or an awarded product liability claim may be considerable.
So far, efforts in the area of consumer product safety have been mainly directed at, on the one hand, educating consumers and, on the other hand, the technical safety of particular products, such as electrical appliances. However, the product liability legislation urges manufacturers to face the reasonable use of their product. Current insights are of little assistance in the anticipation of future use that may result in accidents. Thus, adequate means to predict how people will use products are not available. The study presented in this thesis is meant as a contribution to the provision of these means.

Objective of the study
In their efforts to anticipate accidents, designers may be confronted with at least two situations. In the first situation, accidents are known to occur with forerunners of the product to be (re)designed. In that case, methods for the observation and analysis of accidents may assist industrial designers in their efforts to set criteria for safer products. In the second situation, the product to be designed is suspected of being prone to involvement in accidents, but no empirical evidence is accessible. Here, general insights into the occurrence of accidents may provide starting points for criteria that should be met by the design. The aims of the study in this thesis are:
• to generate methods for the observation and analysis of accidents;
• to gain general insights into the occurrence of accidents involving consumer products.
The findings should be directed towards application in the design process.
2. Status quo in the area of safety

Theoretical insights
Several shortcomings can be observed in existing perspectives on the emergence of accidents, such as systems approach and the epidemiological perspective. For example, in most approaches, which generally originated in traffic and occupational conditions, aspects which typify the use of consumer goods are neglected. These include the considerable diversity in user populations and the great amount of freedom as to how, where and when to use a product. In several perspectives, such as systems approach, the deviation concept and human error models, the notion of a norm does not match with the above-mentioned aspects. In addition, some approaches can be characterised as one-sided. In the technical approaches, the human elements remain out of the picture. In the behavioural approaches, the product is allotted only a marginal position. Many factors have been associated with accidents. In general, the evidence for the relevance of factors is not very convincing and often contradictory. Little exploration has been done into the relevance of product appearance in accidents, while human characteristics have received excessive attention, seemingly at the expense of actual behaviour. However, it is the actual product use that can be influenced by designers, while the significance of human characteristics is limited to how closely they can be linked up with how and where products are being used. The shortcomings indicated above make a single approach to the observation of accidents involving consumer products an unattractive choice.

Accident research
Various types of accident research can be distinguished, such as retrospective versus concurrent research, and the study of accidents versus near-accidents. The evaluation of prevailing methods of accident research shows that, for various reasons, retrospective research into accidents is most appropriate for the aim of the present study. Since validity is always at issue in retrospective research, the literature on the influence of, for instance, memory processes has been explored. Various precautions can be taken to minimise bias, such as visiting subjects as soon as possible after the accident, the reconstruction of the accident on-site and the combination of an open interview with a checklist.

Techniques of accident analysis
Several different techniques for the analysis of accidents can be found in the literature, including scenario analysis, deviation analysis and multidisciplinary reviews. Most techniques involve human judges or experts, who are called in to identify the causes of accidents. A common flaw in current techniques of accident analysis seems to be that they are not explicit on how the causes of accidents are identified. So far, hardly any empirical research has been conducted into the identification of causes, although it has repeatedly been remarked that differences
may arise in conclusions reached by judges and experts. As long as little is known about how causes are inferred from accident data, the outcomes of accident analysis can never be justified. Therefore, this thesis includes a separate study into this topic.

3. The observation of accidents

Approach
Given the shortcomings of existing approaches, this thesis introduces an approach which is attuned to the observation of accidents involving consumer products. An accident is seen as a consequence of the functioning of the product. The technical/physical functioning is a result of the consecutive co-occurrences of the product, use activities and the situation. How and, to some extent, where products are being used reflect human interference and thus may be linked with the sensory, mental and physical characteristics of the user.
A basic difference from many existing approaches is the view that influences of human characteristics assume importance only by way of actions taken by the user. A one-sided approach is precluded by taking the co-occurrence of the product, use activities and the situation as a starting point for the observation of accidents.

Method
Accidents have been reconstructed in an investigation on-site. Subjects were asked to demonstrate what happened. This was video-recorded, and followed by an open interview using a checklist as a backup. The interview was sound-recorded. As is recommended in the literature, subjects were first given ample opportunity to tell their own story. The checklist was used as a guarantee for the inclusion of possible relevant factors. After the interview, video-recordings and/or measurements were taken of the situation, the product, the hands and the exertable forces. If possible, the product was taken along for an inspection in the laboratory, otherwise it was inspected on-site.
Subjects (n=42) were recruited via the emergency department of a hospital (30), public calls (11) and general practitioners (1).

Indications for lack of validity
The accident data have been examined with respect to indications for lack of validity. In some cases, evidence is available that the demonstrations may differ from the unknown actual occurrences, for example, because the bandages that subjects were still wearing hampered in a demonstration of what happened, or because it was too dangerous or even impossible to demonstrate what happened. Observing subjects and making video- and sound-recordings sometimes seems to have interfered with how the subjects behaved. However, the majority of the subjects did not seem to pay any attention to the recorders.
Summary

Bias may also have emerged from differences between people in regard to the certainty with which they express themselves, and from the tendency to provide a ‘socially desirable’ account of what happened in order to avoid appearing foolish. Subjects were asked to demonstrate three times what happened: twice before and once after the interview. The analysis of the within-subject differences in demonstrations shows that more than half of the subjects display differences in the three demonstrations. These differences may have arisen from the retrieval of new details during subsequent demonstrations. However, to what extent the within-subject differences in demonstrations concern random variation or systematic variation (i.e. bias) is not known.

4. Judging the causes of accidents

Introduction to the study with judges
In order to gain insight into the identification of the causes of accidents, an additional study into the possibilities of establishing causes by means of human judges was conducted. These insights should be applicable in the analysis of accidents, so that the inference of causes can be clearly shown.

The data of four accidents were presented to twelve judges. Six judges were industrial design engineers, six judges were academics who came from various other disciplines. The judges were asked to write down the causes of each accident. During a debriefing, they were asked to explain their considerations in identifying causes. In addition, they were requested to rank the causes according to importance and to give recommendations for a redesign of the product.

Findings
The findings showed that agreement on the causes of the accidents was limited: from three to eight causes per accident (median 4) are indicated by at least seven judges. The remaining causes of the four accidents are indicated by at most six judges, but usually by only one or two. Similarities were found, however, in the criteria and type of reasoning that the judges used in the inference of causes. Three different criteria could be distinguished. In the criterion of deviations judges compare what has happened to their norms and standards, such as experiences with similar products, the intended function of the product, the operation manual or what they consider as normal, proper or logical. Conditions that are seen as deviating from a norm are considered to be causes. In counterfactual reasoning judges reason as follows: if this condition had been absent, would the accident still have happened? If the accident would not have happened in the absence of the condition, this condition is considered a cause. In the criterion of mutability, judges consider the extent to which conditions can be influenced or changed. Conditions that are seen as immutable or fixed are not indicated as causes.
Implications for the analysis of accidents
Similar criteria were found in the fields of social psychology and philosophy. While social psychologists have been concerned with the role of counterfactual thinking in people's evaluation of events with negative outcomes, philosophers have mainly been concerned with the truth, or the sustenance of counterfactual reasoning. The issue of supporting counterfactuals, as dealt with in the philosophical literature, corresponds to the aim of the present study, i.e. to make the identification of causes explicit.

Counterfactual reasoning is used in the analysis of the 42 accidents, as this type of reasoning can be supported by external evidence, whereas the criterion of deviations seems to depend predominantly on the internal norms and standards of judges. The evidence supporting counterfactuals includes existing knowledge, outcomes from measurements and user's statements. Mutability, seen in the literature as a prerequisite for counterfactual reasoning, is considered from a designer's perspective, i.e. what can be influenced - in one way or another - by the design of the product is seen as mutable. This perspective serves in the analysis as a limitation on which factors can be influenced and, thus, which factors are subjected to counterfactual reasoning.

Note that counterfactual reasoning does not guarantee that different people reach the same conclusions. However, the conclusions drawn are made explicit. Thus, counterfactual reasoning is incorporated in the analysis of the accidents, which proceeds in the following steps. The data of each accident are searched for contributory factors, while using counterfactual reasoning. Then the evidence used in sustaining the counterfactuals is explicated, followed by the ordering of contributory factors according to their sequences and co-occurrences. The factors are graphically presented in so-called factor trees, which constitute the basis for the analysis of patterns in the occurrence of accidents.

5. On patterns in accidents

Introduction
The accident data are examined to find out whether regularities in the occurrence of accidents can be detected. These regularities may consist of a dominant contributory factor, patterns in the sequences and combinations of contributory factors, or particular relations between user characteristics and how and where products are being used. Also, the question to what degree deviations can be related to the emergence of accidents is answered.

Regularities in the occurrence of accidents
The findings show that a few factors are relevant in a quarter to half of the accidents, but that the majority of the factors are relevant in only a small number of accidents. There is not one factor that can be considered as dominant.
Summary

Regularities in the sequences and combinations of factors are sparse. The sequences of factors greatly diverge. Combinations of factors that were found repeatedly are:

- the body hit or contacted cutting or hot parts of the product;
- the product slipped off or onto the material processed in the direction of a part of the body;
- the user fell off or with the product.

These combinations all preceded the injury. Looking further back, the occurrences seem to fan out, leaving hardly any regularities to be detected.

Characteristics of the user

Fifteen subjects reported being drowsy, rushed, irritated or such. This relatively large number goes along with the attitude of self-accusation found in this study: almost half of the subjects thought the accident was their own fault.

Taking the frequency of use as an indicator of people’s familiarity with the product, subjects cannot be classed as being unfamiliar with the products involved. The absence of the awareness of running the risk of being injured in three quarters of the accidents may be related to the subjects’ familiarity with the products. When people use products regularly, it is doubtful whether they use these everyday products after conscious decision making, as is widely assumed in the literature.

In the present study, several subjects indicated that the product looked safe. As a result, they thought particular use activities could do no harm. In several accidents the product did not give feedback about its condition. Also, the findings show that, even if people are aware of the risk of injury, this does not mean that they will take precautions to avoid this risk.

The findings further indicate that subjects do not seem ‘accident prone’, in the sense that they were more frequently involved in accidents than other people. Our subjects seemed to deviate slightly from other people with respect to their physical characteristics. However, in only a few accidents could the physical characteristics of user be identified as relevant for how and where products were used.

Deviations

In an attempt to explore the significance of the concept of deviations in describing and explaining the occurrence of accidents involving consumer products, it was argued that the identification of deviations should be based on the subjects’ self-reports. A quarter of the subjects could not identify any deviations at all. The findings further show that not all deviations, established on the basis of the subject’s self-report, can be considered as contributory factors, which were established by means of counterfactual reasoning. In addition, the vast majority of contributory factors cannot be identified as deviations. Thus, although deviations may sometimes be seen as contributory to the occurrence of accidents, not all deviations can be considered as contributory factors.
Apart from the difficulties with the concept of a norm, these findings imply that the concept of deviations does not convincingly explain the occurrence of accidents involving consumer products.

6. General discussion

Some disclaimers
Several limitations of the study should be mentioned. The study concerned existing consumer products. Factors that turned out to be contributory in only a small number of accidents may already have been considered in the design of the products. For instance, the limited number of accidents in which the users’ physical dimensions were found to be relevant may imply that the designers had already taken these dimensions into account. Furthermore, only accidents were studied. Some comparisons between our findings and external data could be made, such as the subjects’ accident involvement versus that of other people. However, for many factors such comparisons could not be made due to lack of data. In addition, no insight is gained into the extent to which people compensate for sensory, mental and physical abilities. For example, heavy people may not use a fragile table as a step, knowing that it may not support them. Some of the people who received our letter requesting their cooperation may not have considered participation, because it would mean recounting yet again how ‘foolish’ they had been. This self-selection may have led to bias in the type of accidents included in the study.

The observation and analysis of accidents
The methods proposed in this thesis have not yet been applied in design practice. Inevitably, the feasibility of any tool is to a large extent determined by, on the one hand, the costs and time required and, on the other hand, the benefits. The methods of accident data collection and analysis, as described in this thesis, are laborious ones as a consequence of the comprehensiveness of the data aimed at and the thoroughness of the analysis required for the purpose of the study. Finding subjects and getting them to cooperate entail possible obstacles in the application of the approach introduced. Reducing the time spent by interviewing subjects via telephone or mail questionnaires is discouraged, as this will be at the expense of the validity and comprehensiveness of the data obtained. There does not seem to be a valid reason for excluding factors in order to save time, since practically all factors included in the protocol for the on-site investigation are found to be contributory to some of the accidents.
A comment frequently heard is that often only a few accidents per product are available. How does one ascertain whether costly product changes, carried through on the basis of insights derived from only a small number of accidents, will prevent a majority of the accidents, and not only the few investigated? Insight into
the concept of exposure, such as how, where, how long and who is using the product, seems indispensable for the assessment of the effectiveness of precautions taken. Only then can a sound appraisal of proposed changes in the product be made. However, a thorough analysis of the concept of exposure is not available in the area of consumer products.

Clearly, safety is only one of the many aspects industrial designers must take into account in the design of a product. There are obviously limitations to what designers can do. In addition, there are boundaries to the responsibilities of designers. Even if due attention has been paid to the prevention of accidents, there is always the likelihood of introducing new hazards.

**General insights into the occurrence of accidents**

The occurrence of accidents with everyday products appears to be largely unpredictable. The most consistent finding is that there is no consistency. Of course, one can ask why there would be regularities at all, given the variety in possibly relevant factors. The observation that only a few regularities in sequences and combinations of factors can be detected may be a consequence of the limited number of accidents included in the study. The crucial question is whether it would have been possible to identify regularities if more accidents had been studied. Obviously, patterns may be identified when accidents with one and the same type of product are investigated. Such knowledge generally provides little help for designers when the product being (re)designed differs from the product for which accident data are available.

A number of theoretical ideas emerged from this study. Some of these ideas run counter to current ideas in the literature.

People's perceptions appear to be relevant in what is done with a product. For example, the feedback provided or not provided by the product appears to govern people's use actions. These findings indicate that industrial designers should examine how the various possible conditions of the product are perceived by future users, and, in particular, how users will react when they are deprived of information.

The subjects in the present study do not seem to be involved more frequently in accidents than other people. In only a few accidents the physical characteristics of users could be identified as relevant to how and where products were used. This suggests that attuning products to particular groups or characteristics of people may not contribute to the prevention of accidents.

The idea that people involve in risk-taking only after conscious decision-making could not be retrieved in our findings. The majority of the subjects reported that they had no perception of risks at all during the use of the product, which may be related to the fact that most subjects are very familiar with the products. These findings would suggest that there is little point in trying to raise the risk-awareness of people who are using everyday products.
The future
Possible directions for further study include an exploration of the concept of exposure, a study into the impact of product appearance on people’s perceptions including risk compensations mechanisms, and the applicability of other types of research, such as user’s trials, in obtaining insight into accidents. For the present, industrial designers must seize every opportunity to obtain information about accidents with their products, albeit post hoc. In their efforts to cope with the safety of their product, the present study offers designers a way to look at accidents, investigate them and extract insights from accident data.
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Curriculum Vitae

Mieke Weegels was born in Weert on 17 July 1965. After Gymnasium B at the Bisschoppelijk College Weert, she studied at the Wageningen Agricultural University, from 1983 till 1989, with the safety and usability of consumer products and assistive devices as major topics. From September 1987 till January 1989 she combined her study with a part-time job at the design studio of the Rehabilitation Centre Amsterdam, where she conducted user's trials and product tests involving assistive devices. Her graduation project at the Department of Product and Systems Ergonomics of the Faculty of Industrial Design Engineering concerned accidents involving consumer products. After receiving the Masters Degree in June 1989, the graduation project was continued as a PhD research project, which resulted in this thesis.