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Triggers, Entry Points, and Affordances -
How to Improve Their Cognitive Congeniality

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I hereby certify that all material in this dissertation, which is not my own work, has been identified and that no work is included for which a degree has already been conferred on me.

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Abstract

At the core of this thesis lies the concept of triggers and how a trigger's general purpose is to raise attention to something. We discuss the similarities of triggers, entry points, and affordances in terms of medium dependency and information value, and how they can co-exist. As a basis of our trigger discussion we consider active and passive attention along with the use of tools as triggers. A number of problems are identified in trigger use, including continuous or discrete triggers and information value. Finally, suggestions are made regarding the handling of triggers, entry points, and affordances from a designer's point of view. We discuss and suggest that triggers and their contextual elements can be handled and designed on the basis of their type, information demand, cognitive congeniality, and characteristics.

Key words: Trigger, entry point, affordance, cognitive congeniality, attention, task transformations, information demand, medium dependency, information value.

Contents

1 Introduction

The efficiency and accuracy of work performance can be argued to be largely dependent on how the workspace is perceived and planned around the worker. In situations where we want to stimulate a change of behaviour in the worker, it might be rewarding to consider triggers and similar conceptions as a huge asset. Trigger conceptions are at the core of this thesis and are handled in several different ways. Today, within the assembly plant that is handled in this thesis, the consideration of trigger conceptions and their complexity can be argued to be significantly lacking. The features in the work environments that can be interpreted as attempts to design trigger conceptions are greatly misused and misdirected as is discussed in Chapter 3. Trigger conceptions can be viewed in several different ways. Firstly, there are concrete features of triggers such as visibility, intrusiveness, or freshness (Kirsh, 2001). Secondly, there is an approach to triggers which is more closely related to interaction and handles the question of what makes a trigger a trigger in the first place (Dix, Ramduny & Wilkinson 1998), and finally we will also discuss affordances, including what affordances are and how they can be used in workplace design. It might be rewarding to note that affordances, as Gibson (1986) described them, are not triggers but in many ways they incorporate many of the features and offer similar capabilities as other trigger conceptions do. This is discussed further in Section 2.3.2.

Much work on trigger conceptions, and probably also the applied use of them, seem to be based on conscious processing of the triggering object. In this thesis, a trigger is viewed as an external object or occurrence that catches the attention of a user and its main purpose is to alter human information perception from passive to active. However, there are also other concepts that will be discussed which contain more information about the task to be performed. These are entry points and affordances. The main differences between triggers, entry points, and affordances, which will be discussed later, are their information value and the relation they have to the referred environment.

When discussing entry points, affordances, and triggers as joint concepts in Chapters 3, 4, and 5, they will all be referred to as trigger conceptions, which is basically what they are. Entry points and affordances are in many ways closely related to basic triggers and in this thesis they will be treated as such and, at the same time, their unique features will also be considered.

In traditional Human-computer interaction (HCI) there is some implicit focus on triggers and trigger conceptions. An example is affordances which have been used since the early nineties in interface design to guide attention and to invite action with specific areas of interfaces (Norman, 1999). However, when viewing interfaces such as work stations, car interiors, and other physical interfaces, one finds that the research leaves a lot to be desired. It will be assumed in this thesis that the same mechanisms that are at work when we are sitting in front of an interactive interface, are active when we are interacting with physical interfaces. The key point is that perhaps we should be more interested in interfaces altogether instead of investigating them separately depending on their medium. An interface is an interface no matter how you interact with it or where you find yourself in relation to it. You can be looking at an interface or you could be standing in the middle of it, you can manipulate it directly or through input tools. This thesis will apply trigger conceptions on work stations in assembly plants.

Bäckstrand, De Vin, Högberg, and Case (2005) suggest a model where a worker in an engine assembly line uses passive information seeking in a high volume scenario. A high volume scenario might be when the worker assembles all engines in the same way while a low volume scenario might be when an engine is supposed to be assembled in a different way than most other engines. When a low volume scenario arises, the worker needs an appropriate trigger to break the passive attention mode and go into active attention and gather more information. The underlying idea is that as long as everything is as usual, we are in a passive attention mode, but as soon as something changes, we need a trigger to snap into an active attention mode in which we then continue to find information in order cope with the new situation.

When we want to analyze a work domain there are some concepts that, according to Kirsh (2001), are of great value. These are entry points, action landscapes and coordinating mechanisms. An entry point has huge similarities to a trigger and represents an invitation to an information space. The main difference between the two, as will be discussed thoroughly in Section 2.4, is the fact that an entry point has information value in itself, which a trigger does not. An entry point is often, but not always, closely related to whatever it is referring to, its referent. Later on in this thesis we also discuss affordances which take yet another step in the information value direction. An affordance is, as is discussed, always closely connected to its referent as that is what contains the affordance. An activity landscape is the space that is created by a user while trying to accomplish a task and a coordinating mechanism is an artefact or an environmental structure that helps a user to manage a complex task. Examples of coordinating mechanisms are a clock or a schedule. We will also discuss the concept of affordances (Gibson, 1986; Norman, 1999) in relation to triggers and entry points. In this thesis the focus is on both the similarities and the differences of triggers, entry points and affordances. Furthermore, coordinating mechanisms and activity landscapes are inevitably discussed in relation to these, but are not of sole interest. Also, as the title of this thesis reveals, we are handling the concept of cognitive congeniality. The concept was introduced by Kirsh (1996) to describe the hospitality of an environment and was later elaborated by de Léon (2003) to mainly describe how we, through task transformations, can reduce cognitive stress in a work sequence. The focus on cognitive congeniality as a concept is not only handled from their standpoints but is implicitly a part of all the discussions in this thesis. After all, when working with improving the work context we are also handling the cognitive congeniality of the same context. We will in Section 2.1.2 discuss a few examples of how to transform cognitive tasks to reduce stress and cognitive strain.

1.1 Aims

One of the main aims of this thesis is to discuss and clarify the dominant views on the subject of triggers or trigger-like concepts. In what ways are they similar and in what ways are they not? Discussing potential problems, properties, and types of triggers will be taking up a fair portion of this thesis. We will discuss what features a trigger would have to incorporate to be called a trigger. It is also fairly evident when reviewing the literature on the subject that the domain that is used to model these concepts is almost exclusively offices. It is of great interest in this thesis to discuss how other domains, especially industrial ones, can be used to model the concepts. One domain of particular interest is the industry and especially the assembly industry. This is a domain with a very high cognitive workload and very many triggers and is therefore in dire need of a trigger analysis closely bound to their context of work. This trigger analysis should not be mistaken for the framework presented by Dix, Ramduny-Ellis and Wilkinson (2004), but is simply a thorough analysis of triggers and the context that contains them. We will suggest new properties of triggers and important types of triggers that are of

great value in future works. Further, guidelines will be presented for how trigger conceptions should be handled by the designers in work contexts, what types of triggers that are suitable for certain contexts or tasks and what should be taken extra notice of. Finally, a simple checklist is presented towards the end of this thesis with the purpose to simplify the practical work in designing and evaluating work stations with trigger conceptions in mind. This thesis does not directly involve an empirical investigation but the data used here comes from Thorvald (2005) and also from personal experience as I have worked in these domains for several years. The study performed in Thorvald (2005), was performed at an assembly line at Volvo Powertrain, and focused on how contextual factors have a large effect on usability and work performance, including the strategies of work and the results of work. Both the social and physical context was argued to lead to problems in the form of cognitive overload. The study included an investigation of how these contexts effect work and the results showed that there are numerous factors in the physical and social contexts that can potentially lead to errors in work performance, usually in the form of missing articles on the engine block. The study involved active and passive observation at the assembly line with the explicit goal to find potential problems in the physical and social context.

1.2 Overview

In the background chapter we discuss the theoretical basis of the suggestions made in the following chapters. We discuss the distinction between active and passive attention (Section 2.1.1), how to alter tasks to reduce cognitive strain (Section 2.1.2), how tools and artefacts can be studied and how they can be considered to be triggers (Section 2.2). Finally, we introduce the concepts of triggers, entry points, and affordances (Section 2.3). The chapter ends with a discussion of the three, how the theories differ and how they concur. In the third chapter we address the potential problems that arise when triggers are not properly controlled. What implications a poorly designed trigger can have and what the information value and the medium dependency are of the three conceptions triggers, entry points, and affordances. Chapter 4 raises the discussion of how the conceptions can be constructed into complex chains of stimuli. By discussing information demand we are also able to make them more efficient. Finally, in Chapter 5 we discuss and suggest how triggers should be handled in a larger perspective. Among other things we suggest designing work stations with fewer to no triggers and while a new employee is in the learning phase, the information that is delivered can be controlled until an appropriate understanding of the information demand is achieved. We end the thesis in Chapter 6 by discussing the outlook of this particular field of science and what future work is needed.

2 Background

In this chapter we discuss the distinction between active and passive attention and how the two are affected by different types of stimuli (2.1.1). As mentioned, the issue of cognitive congeniality (Kirsh, 1996; de Léon, 2003), which is an environment's cognitive hospitality, is discussed and further elaborated in Section 2.1.2, concerning cognitive task transformations. Tools, artefacts, and cognitive aids all have a big part of the chapter and we discuss how an external aid can relieve cognitive workload with a great emphasis on Vygotsky's ideas surrounding peer and tool interaction (2.2). We also argue that many of the trade-offs made between a person and the environment can have the function of triggers. As mentioned above, trigger conceptions will be handled from different standpoints. We discuss properties of triggers and what makes them noticed, and we discuss different types of triggers (2.3). Finally we end the chapter in Section 2.4 by defining how triggers are to be viewed in this thesis and we will also have a form of classification for how triggers, entry points, and affordances are to be used.

2.1 The burden of cognitive processing

The strain that our cognitive functions are being exposed to, can be exemplified in a number of different ways. Naturally, there are limitations on how much information a person can process at the same time, be it memory processes, attention, or perceptual information. A classical, and probably the most popular, description for how we cannot handle all the information available comes from the work of Miller in the 1960s (Baddeley, 1999). He showed how our working memory can only handle 7±2 chunks at a time, chunks being things that matter to us, so called meaningful units. Consider this string of seemingly arbitrary letters:

NHLWWFBBCFIFAAOL

Our working memory capacity allows us only to remember 7±2 letters of the string, where each letter represents a chunk. But if we divide them into bigger chunks or units that have meaning to us, which can be related to information in our long term memory, we can remember more. Like this:

NHL WWF BBC FIFA AOL

Now, instead of remembering 7±2 letters, we can remember all five of the abbreviations, given that we know what they mean and thus can relate them to our long term memory. Perhaps we could even handle more information than this in our working memory if we had to. The process that takes place when we relate information to our long term memory to aid our working memory is commonly known as chunking and shows exactly what a chunk or a meaningful unit is (Baddeley, 1999). The example of chunking does not only involve the chunking of letters and there are many other ways in which the limitations of our cognitive functions can be observed. One of them involves attention.

2.1.1 Active and passive attention

Attention is a psychological concept that traditionally has been quite hard to define, even though most believe themselves to know what it is. Despite this, or perhaps because of it, many attempts to understand it have been made. One of the more popular descriptions of

attention, and also one that satisfies this thesis' aim very well, dates back to the late 19th century and was formulated by William James (1890, p. 402) who said:

> Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatterbrained state which… is called distraction.

There are many interesting issues to discuss when it comes to attention. The debates of early vs. late selection or the issue of attention span are intriguing ones, and probably two of the more popular topics of science on attention during the first 50 years of cognitive science. However, they are of little interest here where our focus will be on the idea of active and passive attention. The short description of attention in this chapter serves not as an overview of the subject, but as a description of the perspective from which we move on into the distinction between passive and active attention which is our topic within the bounds of attention. James (1890) suggests a number of distinctions within the subject of attention and one of them regards passive and active attention. Firstly though, he suggests attention to be either immediate or derived. Attention is immediate when a stimulus is interesting in itself, without relation to anything else. When a stimulus is strong enough to catch the subject's attention by itself the attention becomes immediate. It is derived when its interest is owed to the association of some other stimulus which is immediately interesting. He further claims that attention may be either:

- Passive, reflex, non-voluntary, effortless
- Active and voluntary

In continuing to explain his distinction, James (1890) defines voluntary, active attention as always derived, whereas passive attention is sudden, instinctive, and immediate. Without much effort, this distinction can easily be applied to everyday situations in the context of work. It is clear that while in passive attention, which, according to James (1890), is where we spend most of our time, the stimulus has to be interesting enough in itself to attract attention of an immediate kind. However, while in active attention, we actively associate and find our way to the stimulus ourselves. The stimulus only has to be strong in relation to a previous immediate or derived one. However, in active attention, the derived stimulus always has to start with an immediate stimulus. This is to create an entry point from passive to active attention. Only one objection to James' ideas is to be put forth in this thesis and that is regarding the statement that active attention is always derived. It is plausible that a subject is exposed to a very strong stimulus while already in active attention. This stimulus would then lead to immediate attention though passive attention has not been involved. See also Figure 1 for an illustration.

The definition that will be used in this thesis to describe active and passive attention is very similar to that of William James (1890). It is as follows;

- Active attention is when we actively gather or process information.
- Passive attention is when we passively await a situation where our active attention is needed.

An example of passive attention is a process operator whose function is to observe an automated process. The operator is most likely in a passive attention mode until an immediate

stimulus triggers his or her active attention. Such a trigger could be anything from a warning light to a sound coming from the machine. In short, it is something that attracts the process operator's attention. On a side note, this also illustrates the difference between immediate and derived attention. The alarm would lead to immediate attention as it is what catches the process operator's eye and the attention mode in the troubleshooting phase that one can assume follows, is always derived from the first moment with the alarm.

Bäckstrand et al. (2005) conclude, in their engine assembly example, that the number of incorrectly assembled engines is largely influenced by the extent to which active information seeking behaviour is supported or triggered. This conclusion is very interesting since they, at first, suggested that a high number of incorrectly assembled engines were due to information overload and high production volumes. While a high production volume probably is a factor in this, they found that information overload is not since the assembly personnel did not use much of the information available to them. Instead, what Bäckstrand et al. (2005) suggest is that it does not matter how much information we cloud the subjects with if we do not support or trigger an active information seeking behaviour. This leads to an intriguing and not very far fetched idea. The idea, in short, is that as long as we are in a passive attention mode, we cannot suffer from information overload as we will not explicitly perceive any information.

The issue of why the assembly personnel do not use the available data is a complex one. However, one possible reason is the fact that humans continuously strive towards less effort in their everyday lives (Reason, 1990). This means that recurring tasks often become automated processes and they naturally coincide with a passive attention mode. Consider the task of driving a car. As you are learning to drive, it takes all the attention you can procure to keep the car on the road, switch gears, and to keep track of the road signs. Later on, when you have become an experienced driver, all these things seem to have become automatic. They are done without a thought at times, passively. In the case of assembly personnel it might be that the subject is so automated in the assembly behaviour that he or she passively, and maybe subconsciously, rejects the information. That is, the operator is in a passive attention mode and there are no sufficient triggers to support an active information seeking behaviour. As we shall discuss in Section 3.3 there are also situations where the operator finds it hard to trust that a trigger is important because of over use of them. This is probably not a very desirable situation for an organisation to find itself in. The assembly of an engine might indeed be fast and accurate most of the time but when a different engine is to be assembled, and the subject still does not reflect upon the information surrounding this particular engine, it will probably be assembled incorrectly. Since the subject is in an automated process we need an immediate trigger, interesting enough in itself, to break the behaviour and allow the subject to go into an active attention mode. In Figure 1 we can follow the path of an immediate stimulus (represented by arrows), affecting passive attention and forcing the individual to go into active attention. While in active attention the person can then gather more information, through derived or immediate stimuli. The derived stimulus is, as opposed to the immediate stimulus, gathered actively.

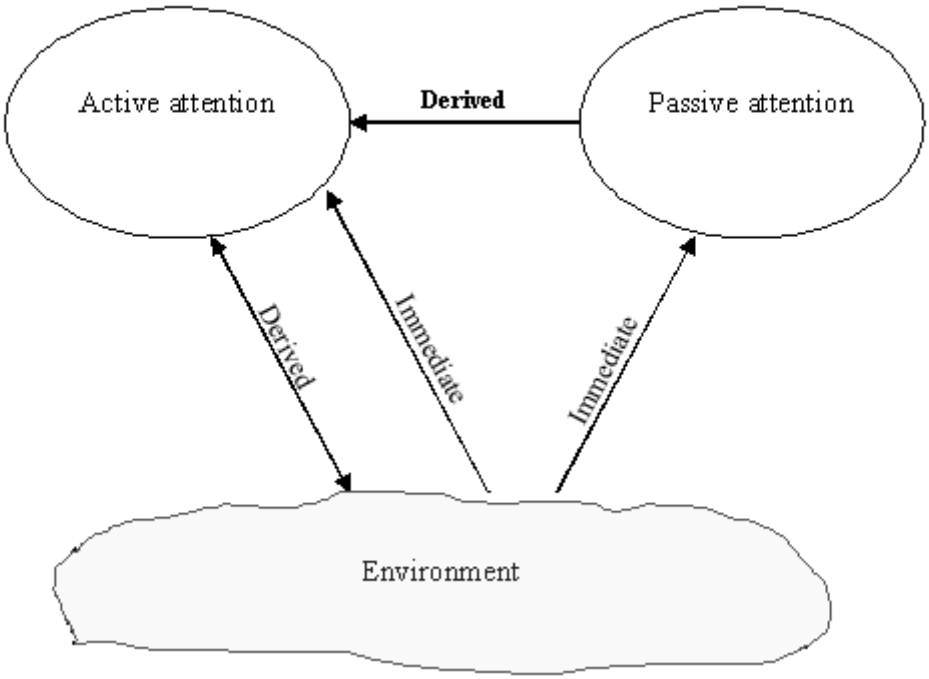

Figure 1. Illustration of the paths of attention. As shown, a derived stimulus can only affect an individual in active attention mode as opposed to an immediate stimulus which can affect both active and passive attention modes.

These immediate and derived stimuli naturally consist of something. They can be signals, objects or even other people. However, the common denominator is that they are all some kind of external aids, artefacts, or tools (further discussed in Section 2.2).

2.1.2 Cognitive congeniality

As discussed in previous sections, there are plenty of strains on human cognitive processing. Although the strains themselves, whether regarding memory, attention, or some other form of processing, shall not be of as much interest here as the use of artefacts and design solutions created to reduce them. Kirsh (1996) introduces the use of the term *cognitive congeniality* as a way of showing how cognitively hospitable a context is. He then further shows how an environment can be designed to handle different kinds of cognitive strain. The contextual features that surround a task, the tools available, the physical surroundings etc., all constrain and influence how the task is structured and performed (de Léon, 2003). Thus, when we design a workplace, we do not only affect what task is to be performed but also the sequence of steps that the workers must follow in order to finish the task. De Léon (2003) claims that different sets of tools can structure a task in very different ways. Some would be cognitively easier to manage and others harder. And in a similar way, he then claims, a difficult task with a high cognitive strain can be transformed to an easier task by good design of the resources. This is called *cognitive task transformations* by de Léon (2003), and the figures that follow will show a number of ways where we can, by simply altering some detail in the features of the task, completely change the chain of events or the sequence in which a task is carried out, while, at the same time, making it easier and less cognitively exhausting. It also allows us to avoid actions at which we are less adept or actions that lead to an unnecessary amount of stress on attention or short term memory (de Léon, 2003). We start by looking at an easy way of simplifying the sequence of events involved in a task; elimination (Figure 2).

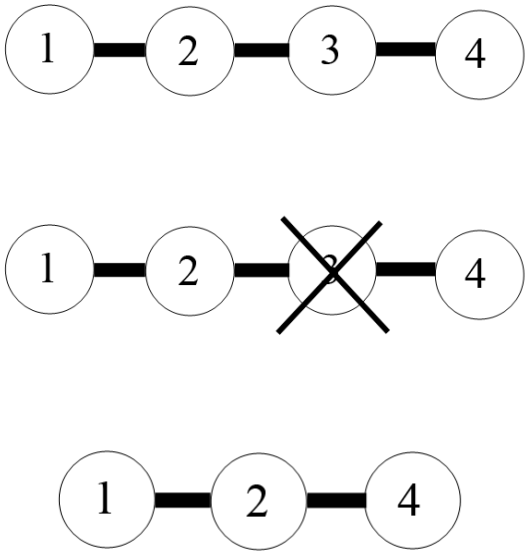

Figure 2. Elimination of a redundant action (Modified from de Léon, 2003).

De Léon (2003) exemplifies elimination of a redundant action with a Swiss army knife. The knife is an excellent companion when one does not want to carry around an entire tool box, but for more frequent use its design can be quite stressful. Perhaps the use of a regular screwdriver or scissors etc. would be more suitable. And with the use of *stand alone* tools we eliminate some of the actions that are forced by the Swiss army knife. We do not have to find the tool, unfold it, or refold it. Hence, we have eliminated several redundant actions. The key principle here is to eliminate actions that are not essential to the task. While trimming the actions of a task may be of great help when it comes to reducing the cognitive strain, it is not always an available option. There might be elements that are all crucial to the task and that cannot be eliminated without compromising the goal of the task. In Section 4.2.1 we further discuss the implications of using elimination as a principle when designing for trigger conceptions. According to de Léon (2003), when elimination is not an option, sequences of a task can sometimes be delegated to other agents or artefacts (Figure 3).

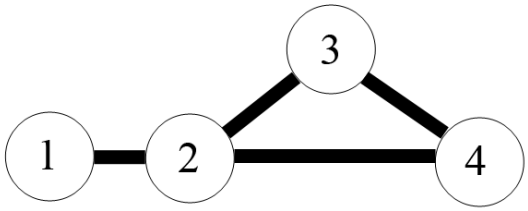

Figure 3. Delegation (Modified from de Léon, 2003).

An example of delegation, used by de Léon (2003), is the auto focus of a camera. The taking of a picture used to involve framing the shot, focusing it, and eventually taking the picture. With the employment of auto focus, this sequence has been altered and the action of focusing the picture has been delegated to an artefact. For an example that is closer to home in this thesis, set in an assembly domain, we can consider the use of simple gaskets. On certain

articles at the assembly domain of interest in this thesis, silicon occurs at several places to ensure a close-fitting. Instead of having the assembly personnel apply the silicon by hand, as was done in the past; a CNC-machine is now performing this task. Another delegation example is when the task is to report a serial number of a specific mounted part or something similar into the information system. Earlier, this action was done by hand and sometimes still is, but by delegating this task to a scanner which instead reads barcodes, we have significantly reduced the cognitive load of the task. By replacing manual input with scanners we are designing a delegation solution and at the same time we are substituting the keyboard, used for manual input, with a scanner.

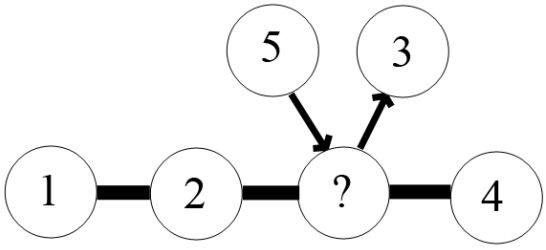

Figure 4. Substitution (Modified from de Léon, 2003).

When we replace an action for another we are applying a design solution called substitution (Figure 4), according to de Léon (2003). It could be when we replace passwords on computers for fingerprint scanners to reduce memory strain, or even when we replace one hard action for several simpler ones. This might be an action which has great demands and strains on attention and memory and that might be, if designed differently, possible to break down into several simpler actions performed in sequence instead of in parallel. Later on in Section 2.1.2 we discuss how several task transformation principles can overlap. We can, by replacing one tool with one or more other tools to eliminate a sequence, perform substitution and elimination at the same time. An example of this might be replacing a manual gearbox in a car with an automatic gearbox. The *substitution* of the gearboxes is done to *eliminate* the action of shifting gears. Finally the last of the cognitive task transformations that will be introduced here is tolerance.

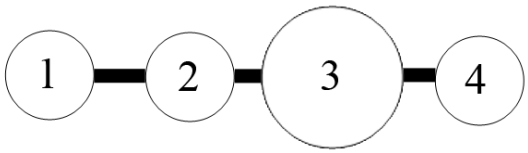

Figure 5. Tolerance (Modified from de Léon, 2003).

Tolerance, according to de Léon (2003), is when we are able to extend the acceptable input to a task (Figure 5). Two examples of this, used by de Léon (2003), are using a funnel to allow pouring liquids to be done more effectively or using a needle threader to more effectively thread a needle. An assembly domain specific example of tolerance is the use of elliptical holes on the articles. These are larger than the correlating screw-holes on the work piece, enabling the worker to first assembly bolts in these holes and then enter them a few threads in, still being able to steer the article on the assembly piece.

Before we leave the task transformations and cognitive congeniality we must clarify one thing. What de Léon (2003) and Kirsh (1996) handle when they discuss these issues are mainly physical tools. But in this thesis the cognitive task transformations will be extended to handle also concepts such as trigger conceptions which are mainly sensory stimuli. This will be discussed later on and an example of how task transformations can be applied on trigger conceptions will be handled in Section 4.2.1.

2.2 Artefacts and tools

The distinction between artefacts and tools is a disputed one with many suggestions to it. While the distinction between the two is of little importance in this thesis, the traits that they share are of greater importance. The common dictionary-view though, according to Susi (2006), seems to be that an artefact is produced by humans, or a product of workmanship. The term artefact would also be used for a prehistoric remnant. A tool on the other hand, seems to be mainly a hand-held device or something that is manually used by humans although there are few limitations on what could be considered a tool (Susi, 2006). But Susi does not assign very much weight to these definitions of tools and artefacts as they are in fact collected from dictionaries and not from literature concerning this specific field of science, and neither should we. Language has, for example, been considered the *tool of tools* (Susi, 2006; Cole & Wertsch, 1996) or the *ultimate artefact* (Susi, 2006; Clark, 1997) by many in the last century and language is certainly not a hand-held device, nor a product of workmanship. Even when considering the definitions of these concepts, used in the present field of science we find many different views on what an artefact or a tool is. A conclusion that would fit the purposes of this thesis is that tools and artefacts are *for something*, in the sense that it is the usage of a tool that defines it. What constitutes as being for something is also very hard to define. It can be argued that mainly aesthetic artefacts such as art have the purpose to raise attention to a subject or simply to make the viewer stop and think, and are therefore also for something. These definitions of tools and artefacts cover a lot of ground and even though we can include art and other abstract occurrences in the definition, the applied effects of this will be small since we will simply not concentrate on abstract objects. Instead, the types of tools and artefacts that could be covered include physical and psychological tools, external scaffolds and aids. However, in the upcoming chapters of this thesis, when tools and artefacts are discussed, we will solely be discussing *physical* tools and artefacts unless something else is indicated. We will exclude psychological and social tools from the notions of tools and artefacts to clarify what is referred to. Hopefully now it is clearer what potentially could be viewed as a tool or an artefact and the diverse meanings they might have. The terms tools and artefacts will also be used interchangeably in this thesis.

The effect artefacts have on human cognition has been known in the scientific community for a long time. Still, research has mainly been concentrated on unaided cognition, such as perception, memory, and attention, and very little work has been done on the complex interactions between humans and artefacts. However, the outline of what is known is covered very well by Norman (1991) in his work on artefacts. Norman (1991) argued for two views on the use of cognitive artefacts, *the system view* and *the personal view.* These two views occur when humans interact with artefacts and simply describe how the interaction is viewed from a distal and a proximal perspective. In the system view the entire process can be observed distally, and from this perspective the artefact enhances cognition. It becomes visible how a system can accomplish a great deal more with than without the artefact. However, in the personal view, which is the subject's view, working with the artefact, it does not enhance cognition; instead, the artefact is viewed by the subject as altering the task. The cognitive abilities are unchanged (Norman, 1991). This might lead to a consideration of the cognitive

task transformations, discussed in Section 2.1.2. Do the task transformations alter the task or do they enhance cognition? This question will not be answered in this thesis but it might be of importance in future research. Until then let us simply work from the system/personal view and assume that they can do both depending on your view of the matter. One of the major contributors in the field of artefact- and tool interaction, and whose work largely influences today's scientists in the field, including Norman, is the Russian psychologist Lev Vygotsky. Among other things he argued for the concept of a *zone of proximal development* (zoped). This zone is defined by Miller (1993) as the difference between someone's actual developmental level and the potential developmental level that can be achieved through interaction with a more experienced peer (Miller, 1993). The concept of zoped, in its original form, does not include artefacts and physical tools but even though Vygotsky does not suggest it, it might be appropriate to also include these human-physical tool interactions as a way of extending the zone since the same mechanisms can be argued to be used both regarding tool and peer interaction. We now have a view on zoped that includes interaction with physical objects. Even though this does not seem to be mentioned by Vygotsky (Miller, 1993), the idea is not very radical. If we can extend the zone with the help of a peer then why should we not be able to extend it with a physical tool? Of course, the nature of the interaction differs between human-physical tool interaction and human-peer interaction, but they offer similar services and provide us with the same kinds of results. Both peers and tools can function as memory reminders, scaffolds, offloading aids, etc.

Just as we use technological or physical tools to manipulate our environment, we also use psychological tools to aid our minds and our behaviour (Miller, 1993). We have already mentioned the concept of language as the tool of tools, and Vygotsky argued that the use of psychological tools is an important aspect in the development of our higher mental functions (Miller, 1993). When the concept of zoped is extended to include physical tool use, as suggested earlier, we also come into contact with another part of Vygotsky's theory, which, since his death, has come to be known as *scaffolding.* Scaffolding takes place when we extend our cognition into the environment and use it to aid our cognitive processes. That is, implications are very similar to our new view of the zone. In fact, it is through scaffolding that we can extend the zone (Miller, 1993). The peer or tool, used to extend the zone is a form of scaffold. It may seem unnecessary to extend the theory of zoped, but the point is to illustrate how both tool and peer interaction can extend and enhance cognition, much like in Norman's system view, and also how they are grounded in the same mechanisms. A good example to illustrate scaffolding is a knot on a handkerchief to aid memory. It is used as an external scaffold on which we offload our cognitive work. Also, the way we organize everyday objects into easily read structures is an example of scaffolding. A lot of Vygotsky's work concerned the bounds of human cognition and how humans use external and internal aids and tools to enhance our capabilities. The example with the knot on the handkerchief is one of Vygotsky's more known and recurring examples (Susi, Lindblom & Ziemke, 2003). Another popular example to illustrate Vygotsky's ideas is the blind man with his cane (Miller, 1993). The question of where this man's cognition begins and ends has been cause for reflection for a long time. One type of tools that can aid and relieve cognitive workload is external triggers. Triggers will be mainly handled as scaffolds in this thesis.

When looking at theories concerning tool and peer interaction (for a more elaborate picture on tool and peer interaction theories, see Susi, 2006), most of them based on Vygotsky's work, we can see the similarities of the interactions regardless of the aid, physical tool or peer. The two types of interactions both extend cognition beyond the individual and out into the environment. Whether it is a peer or a physical tool aiding the subject does not seem to make

much difference as the principle of the interactions are the same; both physical tools and peers aid and extend the subjects cognition.

This thesis is not a thesis of tools and artefacts. Its main issue is the use and design of trigger conceptions. Now that we have discussed the ideas of Vygotsky and Norman on how our cognitive workload can be relieved by external aids, it is time to consider a specific type of aids, namely trigger conceptions (Dix et al., 1998; Kirsh, 2001). We have already brushed upon the subject in our discussion on attention but there is more to triggers than simply their purpose, as discussed in more detail in Section 2.3. The purpose of a simple trigger in this thesis is to alter the attention mode but to clarify how this happens we must define what a trigger is and not just what it does. First of all, *a trigger is a tool* and it provides an external aid on which we can offload our cognition (but not all external aids and scaffolds are triggers). If we consider one of the very simplest types of triggers, an egg clock, it is obvious that the clock works as an external scaffold so that we do not have to remember the cooking time in our heads or have to keep checking our wrist watch. And when it is done it rings and triggers our behaviour to remove the pot from the stove. We know that, when the eggs are finished, the clock rings and we do not have to mind the eggs until then. Similarly, the knot on the handkerchief works as an external scaffold to aid cognitive processing and it is also a trigger for our memory. Not all the trade-offs made by humans in relation to their environment can be considered triggers, for instance, the use of a pen and paper is hardly one, but many can be. An example used by Clark (1997) is placing the waste bag by the front door to remember to take it out. When Clark discusses this example, he does it in the context of scaffolding and arguably the example shows how a scaffold very much can be a triggering object.

2.3 Entry points, affordances, and triggers

In this section we discuss different views on, what in this thesis is called trigger conceptions. Firstly, there is a simple view on triggers as objects. In this view, which is represented by affordances (Section 2.3.2) and Kirsh's entry points (Section 2.3.1), the interest lies in the properties of the two. Alan Dix and colleagues, on the other hand, view the concept of triggers a bit differently (Section 2.3.3). First of all they point out the potential dangers of triggers, secondly, they seem to be more interested in events as triggers instead of an object as a trigger. Instead of a trigger's intrusiveness they are interested in when and how the trigger exists. These two views and their three representatives are presented in this section.

2.3.1 Entry points

The interest we have in Kirsh's work in this thesis regards mainly the issue of entry points. Kirsh has taken an existing concept, called entry points, from the field of newspaper layouts and the like and adapted it to his research. When elaborating on the issue of entry points and making it his own, Kirsh (2001) claims that a reader can review or scan a newspaper and make a rational choice of where to begin. The reader can pick up *information scent* do develop a rough plan of how to get through this information landscape. He further argues that "Well-authored entry points make it easy to scan a paper and maximize the user's reading experience" (p. 311). This suggests that an entry point does not have to be the construct of a user as will be discussed in later chapters.

As mentioned earlier, Kirsh (2001) discusses activity landscapes and coordinating mechanisms in his work. However, what we are interested in here is, as mentioned earlier, entry points. Kirsh defines an entry point as "a structure or cue that represents an invitation to do something" (2001, p. 311). Given this definition of an entry point, it can be said to be very

similar to affordances (further discussed in Section 2.3.2), which Kirsh also acknowledges, as it invites a person to do something, which is very similar to the definition of affordances (Gibson, 1986; Norman, 1999). The major difference between the two, as will be discussed further in Section 3.1, regards their medium dependency. An affordance is highly bound by its medium as it is what it advertises. The domain that Kirsh uses to explain his theories is an office context. The entry points in the office are, e.g., folders, post-its, and calendars. Naturally, these entry points have different properties and he describes the dimensions that he considers central to how entry points attract someone's attention (Kirsh, 2001):

- Intrusiveness
- Richness in metadata
- Visibility
- Freshness
- Importance
- Relevance

These dimensions describe the amount of attention that the entry point attracts (*Intrusiveness*), to what extent the entry point says something about the underlying information (*Richness in metadata*), the visibility of the entry point (*Visibility*), whether or not the entry point has been handled or manipulated recently (*Freshness*), how urgent the activity is (*Importance*), and finally how useful or relevant the entry point is in current activity (*Relevance*).

Most of the entry points in an office are created by the occupants themselves. Kirsh (2001) describes two categories of people and how they handle the entry points in their offices. These are *scruffies* and *neats.* Scruffies have very untidy desks with papers, folders, and notes everywhere. This naturally provides many entry points competing for attention. Neats, on the other hand, have very tidy desks with few entry points, leading to a high level of structure while the scruffies have a low level of structure. Whether a high or a low level of structure is preferred is not of interest here, but what we can see is that these external structures that are created serve as external scaffolds, for the office occupant, which can be used to handle the cognitive workload. We have already mentioned the similarity between affordances and entry points. However, there is a certain difference between the two concepts that is discussed by Susi (2006) that deserves some reflection. We will be discussing affordances in the next section but before leaving the issue of entry points we need to clarify that affordances, by definition, are invariant. An object's affordance can be found within the object at any given time (Gibson, 1986). However, if we look at the dimensions, mentioned above, that Kirsh described as central to attract attention, he also argues that some are subjective and some are objective. The dimension of freshness, for instance, is very much subjective since the entry point itself can hardly contain information about when it was last manipulated or handled[1]. But it can, of course, contain information about its own visibility, intrusiveness, and importance among other things. For a more elaborate discussion on this subject, see Susi (2006).

2.3.2 Affordances

The concept of affordances was introduced by James J. Gibson (1986) as a part of his ecological psychology or theory of direct perception. In his theory, Gibson suggested that perception is a direct process, that is, there is enough rich sensory information in the optic

[1] There probably are technological objects that can serve as entry points and that can handle this information but they are vastly outnumbered by those who cannot.

array for a human to accurately percept the environment without the use of higher cognitive processes. This is opposed to, for instance, constructivism which claims that the information in the optic array is incomplete and fragmental (Rookes & Willson, 2000). Constructivists therefore claim that to be able to make correct assumptions about what we perceive we have to mentally manipulate it. What is received through our senses is underspecified and we therefore need to "fill in the blanks" to create meaningful sensory inputs. What affordances are and the definition of affordances has been greatly mishandled during the years (Norman, 1999), but one original description of the concept that Gibson used was that "The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*" (1986, p. 127, emphasis in original). Gibson used affordances to describe how the potential use of an object can be perceived directly. We can see that a pencil can be used for writing, that it affords writing. According to McGrenere and Ho (2000) there are three fundamental principles of an affordance:

- An affordance exists *relative* to the action capabilities of a particular actor.
- The existence of an affordance is *independent* of the actor's ability to perceive it.
- An affordance does not change as the needs and goals of the actor change.

These statements may seem contradictory, but in fact they are not. To exemplify the first statement we can consider a flat surface that affords support for one actor but not for another (Gibson, 1986; McGrenere & Ho, 2000). Differences in height, for example, might afford sitting for one actor while it does not for another. The mentioned pencil might afford writing for someone but not for someone who does not know how to write. An affordance is a property of the action capabilities of any actor. This leads us to the second statement which means that just because you cannot see it does not mean it is not there. An affordance exists independent of your ability to perceive it, meaning that it may not be an affordance for you subjectively. But objectively it is an affordance to someone and that affordance does not stop existing because you cannot see it. An interesting result of this definition of affordances is that it cuts through the subjective/objective distinction. Affordances are objective as their existence does not depend on meaning or interpretation and they are subjective in that an actor is needed to establish a frame of reference (McGrenere & Ho, 2000). The pen still affords writing even if the person who cannot write cannot identify this particular affordance. Finally, the third statement shows that an affordance does not change even though the actor's needs or goals do. If you are sleepy, a bench may afford sleeping for you, but if you are well rested, it may not. This does not mean that the affordance changes or goes away but it means that what affordances you perceive depends on your internal states. The affordance to sleep on the bench still exists for someone else.

Over the years, affordance has become a very popular concept of use, especially in the field of graphical and industrial design (Norman, 1999). However, these are fields that have also very much misused and misunderstood the concept. Designers claiming to be placing affordances here and there show only too clearly how misused the concept has become. Norman (1999) accepts a lot of the responsibility for this since he used the term affordance to describe what was really merely *perceived affordances*. When we design we use both real and perceived affordances but it is important that we know the difference. Norman exemplifies with the clicking on a computer screen with a mouse button. He argues that it would be wrong to claim that a graphical object or an icon on a screen affords clicking, when in fact you can click anywhere on the screen. Yes, the icon or object can guide and help the subject to a proper action but these are cultural conventions, not real affordances. Real affordances are about what you *could do* not what you *should do*. Instead, if a designer really wanted to show a real

affordance in this context, then a constraint on clicking might be of use. If the user was unable to click anywhere but on the icon, then that would be a real affordance. But what then is a perceived affordance? The concept still does require some defining but here is the general idea of what Norman meant; perceived affordances are mainly subjective. One of the differences between Norman and Gibson is that Norman suggests a close coupling between affordances and knowledge and experience. This is where the cultural conventions fit into the picture. A cultural convention or constraint is very much part of a persons past experience and knowledge. It is what makes an affordance more or less visible. So when we place an icon on a computer desktop and claim that it affords clicking, what we are really saying is 'Given the cultural conventions regarding computer use that I can expect in this domain, the design and placement of this icon boosts visibility for this section of the screen and therefore provides a perceived affordance to click it.' Even though the entire screen affords clicking, by boosting the perceived affordance of an icon or graphical object, we can guide the subject to perform the desired action. Cultural conventions state that clicking an icon on a screen usually leads to some form of feedback. These cultural conventions can probably be traced further back than that since it is very likely that a novice on computers, if asked to click somewhere, would click on an icon. This would probably have something to do with what the icon represents but that is an entirely different subject[2]. According to McGrenere and Ho (2000) there are two very important but different aspects of affordances that also describe the distinction between real and perceived affordances. They are designing the utility of an object and designing the way this utility is to be perceived to the subject. The first one regards real affordances and the second one regards perceived ones. To sum up perceived affordances in a sentence, one might say that they are *information that advertises affordances*.

In design, both real and perceived affordances are important. An object naturally needs affordances to be usable and it also needs to be able to convey this to the user. When the perceived affordances of something match its intended use, design has been successful. When they do not match, that is when we need to work with the perceived affordances. In later chapters of this thesis we will try to apply the concept of affordances to different types of domains. Mainly, what we will be handling at that point is perceived affordances.

Before we leave the subject of affordances for now, it would be wise to also consider the concept of *sequential affordances.* Sequential affordances, identified by Gaver (McGrenere & Ho, 2000; Susi, 2006), are a result of the fact that passive observation cannot reveal all action-possibilities of an object. They are revealed over time. Susi (2006) describes this with an example of a door. A door handle might for instance afford grasping but the remaining affordances of a door (pulling down handle, pushing or pulling to open door) are not revealed until the first affordance of grasping the handle is acted upon. Many objects can be argued to inhibit the same types of sequential affordances as the door does. The specific computational affordances that a computer offers are not available until someone acts on the affordance to switch the computer on. So, even though sequential affordances were not defined until over a decade after Gibson coined the concept of affordances, we can clearly see that many of the affordances that are available to us in our everyday lives are, in fact, sequential. Sequential affordances are also very easily applied to industrial domains which are of interest in this thesis. In an assembly situation it might be that the affordance of an article to be mounted is not obvious until a bracket or something to fasten the article on is mounted first. One must then consider how and when the affordance should be presented (further discussed in Section 3.2).

[2] Gibson (1996) was very well aware of the implications that cultural conventions could have on affordances, but simply did not focus on it.

2.3.3 Events as triggers

As mentioned earlier, there are several different ways to approach the subject of triggers. When entry points and affordances are viewed as triggers (further discussed in Section 2.4) they are very concrete and absolute versions of triggers, focusing on their properties, but there are other views on how to study triggers and one of these views will be handled in this section.

The idea of what triggers are, according to Dix et al. (1998), does not differ much from the definition of triggers used in this thesis. Susi's (2005) description of how Dix and colleagues define triggers is very satisfactory; "A *trigger* is something that prompts an activity, something that tells you that you need to *do* something" (p. 2111, emphasis in original). It attracts one's attention to something important. However, the stance that Dix et al. (1998) take when examining triggers differ largely from Kirsh's approach to the similar concept of entry points. They do not handle the simple properties of triggers such as their visibility or their intrusiveness; they instead focus on different types of triggers and on potential problems in the use of triggers. When looking at long-term interaction, Dix et al. (1998) identify certain dangers to the desired activity.

Commonly used models for interaction in industrial settings include treating the worker in a very mechanistic manor, more or less as a robot (Dix et al., 1998). The worker is supposed to work in a stimulus-response manner, responding to alarms and commands and doing the work. The problem with this model is that the worker is treated as a robot and is therefore hindered from working on the basis of any long-term plans. There are ways to counter this problem, but as Dix et al. (1998) point out, the delay between the action and the result cannot be too great or the evaluation becomes too difficult. Dangers to long-term interaction, identified by Dix et al. (1998), are:

- *Action-effect gap:* This occurs when there is a long delay between an action and its effects.
- *Stimulus-response gap:* This occurs when the user is supposed to respond to a trigger but for some reason cannot do so at once.
- *Missing stimuli:* This occurs when an action is performed but the response is missing. In short-term interaction this is a minor problem as the response is relatively soon found missing. However, in long-term interaction this could be a great problem as the time scale is much larger and a missing response is harder to distinguish from a late response.

The stimulus-response gap is perhaps the most interesting one of these to us in this thesis, and possibly the easiest one to apply to an industrial domain. Consider the assembly line example of Bäckstrand et al. (2005). The worker might be working and waiting for a trigger/stimulus to perhaps mount a different valve than usual or something of the sort. Let us also assume that the valve is supposed to be fastened upon another article that the worker has to assemble first. When the trigger occurs, this second piece has to be fastened to the engine before the worker can actually act upon the trigger. This would be a case of a huge stimulus-response gap and from personal experience with assembly domains; this is not a very unusual scenario. A common view seems to be that as long as something is there to remind the worker of what to do, all is well. There seems to be very little understanding of properties and types of triggers.

Until now we have discussed triggers as very concrete and physical artefacts but there are other types of triggers identified by Dix et al. (1998). These types are fairly abstract concepts

and most of them seem to be *events as triggers* instead of *objects as triggers.* The types of triggers that Dix et al. (1998) suggest are:

- *Completion of previous activity* – When the commencing activity is triggered by the completion of the previous one. We must be cautious with this classification since if there is the slightest gap between the activities there must be other triggers.
- *Memory or sporadic actions* – This is probably a very common trigger and simply occurs when the individual remembers to do something without the aid of secondary triggers.
- *Periodic actions* – These are things that happen at regular intervals. They become part of a routine.
- *Temporal gaps* – This classification can easily be represented by deadlines and such that prompt the activity to take place before a certain time. However, we must question what it is that makes the individual notice that the deadline is coming up in the first place.
- *External events* – Probably the most common representative for this classification is some form of alarm or a clock. There are numerous external events that can trigger an activity. A green light can trigger driving or a timer can trigger taking a pot off the stove etc.
- *Receipt of a message* – This is a kind of external event and Dix et al. (1998) use it to classify receipts or telephone calls.
- *Environmental cues* – These are triggers in our environment that remind us to do things. A grocery list can trigger shopping and a diary can trigger making an entry.

It should be clarified that the environmental cues are of course not considered an event. As Dix et al. (1998) point out, we can ask follow up questions to these classifications forever if we want. If an individual is reminded of a deadline by looking in a diary, then what makes the individual look in the diary in the first place? And so on. However, there are some issues that might be useful to discuss in relation to these types of triggers. Firstly, there is a follow up issue to *memory or sporadic actions.* In this type of trigger one can question whether or not the memory itself needs a trigger of some kind. Secondly, the periodic actions, which Dix et al. (1998) themselves point out, are problematic. If a person goes to lunch every day at noon then how does the person know when it is time to eat? The third and final regards the *receipt of a message.* The objection is simply regarding why this category exists in the first place. Is it not covered by the *external events* and *environmental cues*? However, Dix and colleagues have discovered some of these problems with the classifications themselves and suggested an updated classification (Dix et al. 2004).

- *Immediate* – Right after previous task.
- *Temporal* – at a particular time after a particular delay.
- *Sporadic* – When someone thinks about it.
- *External event* – Some event occurs such as a phone call or the receipt of a message.
- *Environmental cue* – Something in the environment prompts action.

This new classification covers what the old one did but really does not add anything new to it. However, it is easier to use since the categories are fewer and the triggers are easily put in their respective category.

Similar to Kirsh's entry points, Dix et al. (2004) suggest the use of placeholders as a concept. Susi (2005) describes placeholders as something that tells you what you need to do. Placeholders help remind us of what to do next. This is obviously very similar to entry points if we look at the information that is potentially incorporated in the two. However, there are differences also. Entry points, for instance, are invitations to do things while placeholders show the user what to do. Dix et al. (2004) do not view triggers and placeholders as one and the same thing. Instead, triggers and placeholders can be incorporated in the same artefact but the difference is that the trigger prompts behaviour while the placeholder shows the individual where to exert the activity and what activity is to be performed. As an example we can consider a sound alarm triggering assembly behaviour. The sound is the trigger and the engine to be assembled is the placeholder. This agrees very well with the definition of triggers that is used in this thesis, that a trigger has little or no information value in itself. The user has to actively search for the placeholder once the trigger is noticed.

Dix et al. (2004) suggest a framework called *trigger analysis* which should not be mistaken for how the term is used in this thesis. When Dix and colleagues discuss the concept they present it as a specific method for how to understand and analyze triggers. When the concept of trigger analysis is used in this thesis, it has a broader and more general range of use. It is simply any analysis of trigger conceptions, whether it is by some framework or not.

2.4 Discussion on trigger conceptions

To summarize the discussion of triggers in this chapter we can say that we have three descriptions or views on them. Two of them, entry points and affordances, are very similar and concentrate on the objective and subjective properties of objects. Our third view, events as triggers, has a different approach to the subject. It mostly considers events as triggers and classifies different types of triggers. Even though there are differences in how the subject is approached in these descriptions of triggers, they still can correlate. Most of the time they complement each other, e.g., when we have a temporal trigger, which cannot be described in terms of the classical notion of entry points or affordances, we use the events as triggers view to describe it. And there are also cases where Kirsh's properties of entry points can be used to describe, e.g., an external event, environmental cues, etcetera. In the remainder of this thesis these views will be combined. We may describe a temporal cue or a periodic action in terms of affordances or entry points and we may consider simple properties such as visibility and freshness of the receipt of a message. Ways to combine and apply these views will be discussed in the following chapters.

In order to proceed to the subject of interest, this is a good time to elaborate on the definition of triggers used in this thesis. Basically a trigger is a very simple object or event. Its sole purpose is to cause a shift in attention to an active mode, or simply direct attention if the subject is already in active attention mode. This differs a bit from the other views on similar concepts that we have discussed. Entry points, for instance, often contain information about the task to be performed(cf. Section 2.3.1), which a trigger does not. To illustrate this we can use Kirsh's (2001) example. Consider a "sign here" sticker placed on a sheet of paper. This would be an entry point that invites a signature. However, using our new definition of triggers, it could be argued that *the sticker itself is the trigger that causes a change in attention*. While the subject is then in an active attention mode, he or she gathers more information about the situation. Here, the information to gather is the 'sign here' scribbling on the sticker and possibly information about the piece of paper that is to be signed. When viewing triggers and entry points this way it is arguable that entry points are triggers combined with the information to be gathered. As Kirsh (2001, p. 311) puts it: "An entry

point is a structure or cue that represents an invitation to do something". In this thesis, a trigger has little or no information value in itself. A trigger does not represent an *invitation to do something*.

The three conceptions, discussed in this section, seem hard to combine and indeed they might be. Instead they may complement each other. When we discuss simple medium independent triggers, we will use the term triggers. When we discuss conceptions with some information value, most often regarding the 'what' in the task, we will use the term entry points. And finally when we discuss topics that are closely bound by their medium and very constrained, we will use the term affordances. Also, what is worth taking notice of before we move on is the fact that an affordance cannot be treated as a trigger in all situations. A trigger's main purpose, as we have already discussed, is to catch an actor's attention to suggest further information search. This is also fairly applicable on entry points, they just also contain information value about their referents. But an affordance does not have the purpose to catch anyone's attention. Affordances are often, not always, not even perceived until an active attention mode has been reached. However, it is plausible that perceived affordances may have more in common with triggers. A boost in perceived affordance would increase, e.g., visibility or intrusiveness and then function as a trigger. When we discuss applied affordances in the rest of this thesis, we will mainly be talking of perceived affordances and with their coupling to attention and the higher conceptual level, as considered here, this will hopefully not pose a problem.

3 Properties and problems

Before we move on to discussing how triggers, entry points, and affordances can be applied in different types of domains we should stop and consider what dimensions are useful to study when it comes to the design of them and their contexts. We discuss what problems we want to solve using these conceptions, what dimensions we are interested in, and what shortcomings they might have. In this chapter we therefore investigate and discuss actual problems that arise in an assembly environment, to illustrate what factors or dimensions are of interest to focus on. Of great weight in this chapter is the description of information value and medium dependency, which separates our trigger conceptions from each other on the basis of how much information they contain and how bound they are by their referent. But before we move on we must assign some attention to the methodology of this study.

As stated earlier, this thesis does not include an empirical study. Instead we draw our empirical data from Thorvald (2005) and also from personal experience as I have been working at the assembly plant of interest for over six years, and therefore have a high degree of expertise. Both *participatory* and *non-participatory* observations have taken place, outside of this thesis, at several assembly lines at the plant that manufactures heavy diesel engines for use in trucks, boats, haulers, etc. In Thorvald (2005), the main questions to be answered were:

- What factors in the social context influence how the worker performs his job?
- What factors in the physical context influence how the worker performs his job?
- What assistance does the context provide the worker in order to handle cognitive strain?

The results consequently consisted of three categories: Social factors, physical factors, and the ability to cope with cognitive strain. The emphasis in this study lies on the ability to cope with cognitive strain although the other two categories are not absent in the data. In the study, the data was collected on the basis of 15 questions that were considered for each work scenario. These included questions regarding auditive and visual distractions in the environment, the possibility for workers to guide their own work and tool use, pressure and stress, documentation, social interaction, and information use, etc. The questions were largely inspired by Hackos and Redish (1998) and their compilation of factors that need to be considered in both physical and social environments. Two work stations were selected and focused on during this observation, based on informal information that implied that these were stations that easily could become slightly stressful. Both stations were then observed at two occasions, three hours for each occasion. Each station was observed for three hours for two shifts, leading to a total of six hours per station.

3.1 Information value and medium dependency

Given what we now know about affordances we can relate back to what Kirsh (2001) argued about entry points, that they represent an invitation to do something. This is, as Kirsh acknowledges in his work, very similar to affordances even though affordances are defined in a way as to invite an action *in relation to an environment*[3]. However, according to Kirsh's entry point definition, the 'invitation to do something' is not necessarily bound by its referent or its medium, as in the case of affordances. So according to these concepts, a bed can afford lying down, sitting, or jumping. A phone can afford a telephone call and a handkerchief can

[3] Gibson (1986) also identifies and briefly discusses social affordances but as they are of little interest here, we will discuss affordances solely in the context of physical objects.

afford blowing your nose. However, the main issue here is that, for instance, a handkerchief can never ever afford making a call, but, properly placed and prepared, a handkerchief can provide an entry point for making a telephone call. The handkerchief can do this, simply by being tied around the phone or placed somewhere that reminds the subject to make a phone call. This is one major difference between affordances and entry points that is of interest in this thesis. In the beginning of this chapter we also discussed information value and closeness to the referent. Using our new definition of triggers to also cover Dix and colleagues' view on the subject, there are a few conclusions to be drawn on information value. Firstly, a trigger does not have any information value. We have discussed this before in the example of the 'sign here' sticker and if it seems that a trigger has information value, then it is either combined with a placeholder, or it is some form of entry point or affordance.

Entry points, on the other hand, often do hold information value and are often closely related to their referents. They can give hints about what is to be done and by the factor 'richness in metadata', that Kirsh (2001) describes, we can see how this represents information value. Now, one might wonder what information value the handkerchief tied to a telephone might have to make it eligible to be called an entry point. In that example, it is not the handkerchief itself that possesses the information but the nature of its presentation. The fact that it is tied to a knot around a telephone tells us that we need to do something with the telephone. Granted, this might be considered a simple trigger as the handkerchief attracts the attention and by information search we find the telephone. This shows that there is a very thin line between triggers and entry points. The information is there but whether it can be considered to be part of the trigger conception or not is simply a judgment call. Practically, it probably does not make much difference as long as the conception designer is familiar with the underlying principles. Probably, the designer does not even think in terms of triggers and entry points after a certain point, but merely considers the medium dependency and information value. Finally, affordances are always closely connected to their referents and consequently do hold information value. An affordance is connected to its referent simply because it is strictly referring to itself. So to conclude, a trigger is medium independent. A trigger can be anything from a sound to a piece of paper and the rule of thumb is that any form of trigger can work as a trigger for any type of action[4]. An entry point can be related to a medium but it does not have to be dependent upon it and finally an affordance is always dependent of its medium. An affordance in a stone can only be about that stone. However, a stone as a trigger or entry point can refer to almost anything. See Table 1 below for a summary of the relations between trigger conceptions and their information value and medium dependency.

Table 1. Triggers, entry points, and affordances, and their relation to information value and medium.

	Information value	**Medium dependency**
Triggers	None	None
Entry points	Yes	Low
Affordances	Yes	High

The medium dependency of entry points deserves some clarification here. As stated earlier, *an entry point is often closely related to its referent, but it is not bound by it*. Therefore its medium dependency has to be low as it is not dependent on its medium but is often related to it. And to describe this relation to the medium we need information value.

[4] There are probably exceptions to this and that is why it is a rule of thumb and not a rule or a principle.

The similarities in the conceptions could lead to considering them in terms of a hierarchy. However, it is very hard to clarify a hierarchy between our conceptions as they vary over two dimensions. If we, for example, only had the dimension of information value to consider, triggers would be at the bottom of the hierarchy and entry points and affordances would be at the top. It is not the intention of this thesis to present a hierarchy between them but if one would want to anyway, one would need to consider the dimensions separately. In the dimension of information value, as mentioned, triggers would be at the bottom while affordances and entry points would be equal at the top of the hierarchy. In the dimension of medium dependency, triggers would still be at the bottom, this time accompanied by entry points while affordances reside solo at the top.

3.2 Continuous vs. discrete triggers

If we consider the properties of entry points as Kirsh (2001) suggested them we can quickly state that it is very much 'one dimensional'. The properties Kirsh has identified are very reasonable and sensible ones but one might ask if they are enough to accurately model the properties and effects of entry points. Arguably, what Kirsh has neglected is the factor of time. Consider what Dix et al. (1998) suggested about the stimulus-response gap, and apply this to Kirsh's properties of entry points. The stimulus-response gap and its effects on work will be discussed further later in this thesis and it will be suggested that it plays a very important part when it comes to the design and evaluation of work stations. While Dix et al. (1998) did identify the problems with stimulus-response gap, it is evident that the problem and its implications deserve more attention.

At this plant, a specific scenario has been found to be most interesting. When a work piece arrives at a station, the worker consults the assembly documentation which is incorporated on a computer screen. Triggers in the documentation, which is what they are as they do not hold information value, are in the form of an image of a blue button. Whether this constitutes a trigger according to our definition is unclear as it basically presupposes that the user is searching the screen for it. But for arguments sake we will consider it a trigger for now. The blue button on the screen represents a blue button that the worker has to press to confirm that the trigger has been noticed and acted upon. The fact that the worker has to confirm this is not a working security measure as the button often has to be pressed many times at each station and the number of presses usually accumulates and is done all at once, usually when all the assembly on the station is done. So, when the worker consults the documentation on the screen he/she easily notices what is to be assembled, largely due to the trigger. But, in this scenario, this is where the problem starts. Often, the station is designed so that it, or the workers assembly strategy, conflicts with the use of these triggers. These conflicts arise in connection to the stimulus-response gap. If the worker is unable to perform the action that the trigger pointed to at once, then the chances of that action not being performed at all greatly increases. And finally, when all assembly is done, the worker simply presses the blue button a couple of times so that the work piece can be allowed to move forward to the next work station.

This problem has been the number one reason for the suggestion of continuous and discrete triggers. *A discrete trigger is a trigger that is only attended or presented once. A continuous trigger is presented and attended continuously.* Consider a scenario where you receive a text message on your phone. This text message incorporates a very strong discrete trigger to reply to it. It is discrete because if you do not reply at once, then the trigger to do so will never

appear again[5] unless you actively navigate into your inbox and find the text message there. But still, the same trigger as when you first received the message will not appear again. You would have to rely on other factors to remind you to reply to the message. In another scenario you get a phone call. The signal of a standard telephone is continuous. If you do not answer after the first signal it does not stop but continues ringing until you answer, or until the caller hangs up. A continuous trigger does not mean that it goes on forever. This brings us up to the scenario we discussed in the beginning of this section. There may be a small problem to classify the trigger of the blue button as it does not disappear when it is viewed but it also requires the active attention from the user. To clarify this, we can consider the definition of continuous and discrete triggers. A discrete trigger is a trigger that is only attended or presented once and a continuous trigger is presented and attended continuously. According to this definition the blue button trigger is discrete as it is only attended once or at least not continuously. The fact that we have attending as a factor in this classification also leads to another important matter. We bring the user into the picture as a frame of reference. So it does not matter if someone has put a lot of time and effort into designing a good work station with well thought through triggers if the user does not interact with them as intended. It is of utmost importance to allow the end user to be a part of the design process whether we are developing computer systems, games, work stations, etc. Whether a trigger is continuous or discrete, good or bad, cannot be determined for sure without user involvement.

The distinction between continuous and discrete is meant to apply to all kinds of triggers, events, entry points, and even affordances of the perceptual kind. This distinction neither bound by the concept of triggers and what a trigger is meant to do. The implication of this is that it is not limited to perceived affordance but can also, in principle, be applied to real affordances. A continuous or discrete conception simply states its own nature of presentation. However, the suggestion of a discrete real affordance is not possible as an affordance by definition is always present in an object (Gibson, 1986). Consequently, the claim that a continuous-discrete distinction can be applied to all kinds of triggers, excludes real affordances. The extent to which real affordances can be covered by the claim stretches only to the external manipulations that can be made to the affordance, for example if we were to boost an affordances visibility, that visibility can be discrete or continuous. An object either has or lacks the affordance for a specific action in relation to the organism. It cannot have it at times and not have it at another time.

3.2 Sequential affordances

The basic idea behind sequential affordances is not very complicated and therefore sequential affordances will not take up much space here. They are simply affordances that are not revealed until a different affordance is acted upon. However, the occurrence of sequential affordances and the inability to handle them in different complex contexts could potentially pose for unexpected problems. In a way, sequential affordances are related to the continuous and discrete distinction of triggers in that they both handle the temporal aspects of trigger analysis. Also the idea of something sequential should perhaps not only be limited to affordances but be applied to all trigger conceptions. We must also be aware of both the upside and downside to the concept of sequential triggers. They might be of use at times when the user does not need all the information at once and they might simply be making it harder at other times when the user wants to change his work strategy. It is often sought after that a worker should have the opportunity to guide and plan his own work within certain boundaries.

[5] Depending on your telephone of course but most of the phones on the market does not have this function.

But with sequential triggers we are guiding and constraining the worker to a preset work strategy.

3.3 Decreasing effects

An intriguing question posed by assembly workers and surrounding personnel at the assembly line is whether a trigger or a similar conception can be forever functional as it is implemented. The hypothesis, suggested by them, is that all triggers loose their effect over time and eventually are not noticed very well. However, it would be highly unlikely that this would be correct for all triggers. A well designed trigger, which is active only when there actually is a purpose in it, is very probable to sustain its effect. However, the issue does pose another challenge in designing by our three key conceptions and their surroundings. The fact that this idea is put forth at all tells us that the conceptions can loose their effect, and in this domain they often do. To exemplify we can consider the blue button again. This is the dominating trigger and probably the only trigger with the purpose of being a trigger that exists along the assembly line. One of the major problems with its use is that in many ways it is being overused. There have been situations over the years where the blue button trigger has become the norm at a work station. It is more often there than not, even in situations where it is not needed. Suppose that we have two different kinds of valves that can be mounted but only one is to be used on each engine. If both of these valves are accompanied by the trigger then the trigger looses its function. One can easily relate this to the story of “the boy who cried wolf”, in that the trigger appears when there is no use for it. The worker then starts to ignore it and does not notice when there actually is something important in the assembly list, like the other type of valve, marked with a blue button trigger that needs to be noticed. Another example that was recently stumbled upon comes from an assembly station where pre-fuel filters are mounted. The mounting task consists here of two subtasks. Mounting a heater or a bowl to the filter and mounting the whole batch to the engine. In the case of the large volume motor, the heater is mounted in over 90% of the cases as opposed to the bowl being mounted on less than 10% of the motors. Yet the heater is marked on the screen with a blue button trigger. So when a bowl is to be mounted instead, it too is marked with the same trigger and the only way this can be noticed is by reading the instructions on the screen carefully. It cannot be decided at a quick glance which is often what the worker can afford in the information gathering phase.

4 A new perspective

In this section we base our discussion on our new view of trigger conceptions and consider what factors should be considered when they are applied in different domains. This chapter also introduces a new perspective on the information associated with triggers in the section about information delivery vs. information demand.

4.1 Constructs

In a situation of developing work stations, user interfaces, vehicular driving interfaces, and many other types of domains, it is not unlikely to stumble upon different kinds of affordances and the process of triggering even though they might not always be known even to the developer. As we have illustrated the differences and similarities between affordances, entry points, and triggers, we can use this knowledge to develop more usable interfaces in whatever domain we might apply it. As mentioned in Section 2.3.1, the concept of entry points can be used, according to Kirsh (2001), to tailor information scent and maximize a users reading experience. This shows, firstly how an entry point does not have to be the construct of the user, and secondly how we can apply these thoughts on other domains than offices, which seems to be the most popular domain in this field of science. If, by manipulating the entry points in a newspaper, we can direct the reader to certain news, then we should be able to manipulate or construct entry points in other domains that will help users to make correct decisions with very little effort. We can also relate this to the aforementioned example Bäckstrand et al. (2005) use in their engine assembly domain. Perhaps properly constructed entry points would attract the workers attention and bring him to active attention. Naturally, if this is true for entry points, then we should be able to do the same with perceived affordances and triggers. So, in an assembly domain, through the design of triggers, entry points, and perceived affordances, we can guide the workers towards the information that we want them to attend to.

4.2 Combining concepts

During my time as both an active and a passive observer in several industrial assembly domains, a problem has been identified that relates to how we teach others to perform a task. As mentioned earlier, the existence of triggers in an industrial domain is virtually inevitable. When a particular article needs to be mounted, the workers are usually affected by some sort of trigger or something similar. Even though these triggers are seldom very thought through or appropriate, usually they only appear once, they are only part of the problem. With proper trigger analysis, a lot could probably be improved but what also needs to be improved is the attitude regarding how we handle triggers. Usually when a trigger is used, its purpose is to raise attention to something. But because of the poor trigger design, workers seldom notice it. Instead what is taught in many situations is that ‘this is usually what is mounted’. We learn the consequence and not the underlying principle; we learn what to do instead of how to do it. Consider for a moment standing by an assembly line. Perhaps the task to mount a valve on an engine is controlled by a trigger. The trigger might be a flashing light, a loud sound, or simply a written instruction. The light, sound, or instruction triggers the behaviour to search for more information about the article to be mounted. When the information has been gathered, the correct valve is mounted. In this situation, it could be argued that the use of affordances instead of triggers, or affordances as triggers, might be more effective. The main idea here is to use elimination from the cognitive task transformations (cf. Section 2.1.2) to eliminate the step where we gather more information and make it run automatically. If we for example had something that drew the attention to the valve that is to be mounted, this might be considered

a perceived affordance or possibly an entry point. We could have lights that are pointed to the loading pallet where the valves are kept. Arguably, the light itself is a trigger and not an affordance but when the lights hit the valve, its perceived affordance is boosted. The valve always has the affordance to be mounted, as does the valves in the next slot, but when the light hits one particular type of valve, the assembly worker discovers its affordance. We boost its perceived affordance. So the problem is not about the real affordance, which is always there, but to make the assembly worker discover it. If we also consider what we discussed earlier about active and passive attention in Section 2.1.1, we might conclude that the use of perceived affordances instead of triggers can in some cases make the switch to an active attention mode unnecessary. If we are constantly guided by external aids that are accessible to our passive reception then the need to actively gather information is gone. Just as in the case of the lights on the valves in the loading pallet. So when the behaviour is learned, the subject does not learn that 'this valve usually is mounted', but learns that 'the valve that is lit up is mounted'. This way we allow the work process to become automated and handled by passive attention without it having any negative repercussions on the finished product. In passive attention we are not completely isolated. We can still absorb information and act on it as long as it is low in complexity. A popular example of passive attention is car driving (Endsley, 1999). Most consider this to be an automated behaviour for an experienced driver and thus handled in passive attention but this does not stop the driver from processing small amounts of information. He/she would have to do so to avoid crashing the car. However, as Endsley (1999) also concludes, we are not very good at interpreting data in passive attention. Her studies show that users can perceive data but become less effective at comprehending it while in passive attention. This seems like a fairly easy principle to comply and it probably is, to the constructors and designers of the assembly station. If it is to be followed by the workers, we will need a great deal of better trigger analysis.

4.2.1 Information demand and delivery

The issue of how behaviour is learned also sheds light on another topic, addressed briefly by Bäckstrand et al. (2005) as 'information delivery vs. information demand'. The core of this issue is that it is not always clear what information demand exists before an information delivery is pursued and that information is often delivered when there should be a demand for it first. Granted, an information delivery is required when there is a need for information. But just because there is a need does not mean that the worker knows this and has a demand. It is the pushing out of information instead of creating a demand for it.

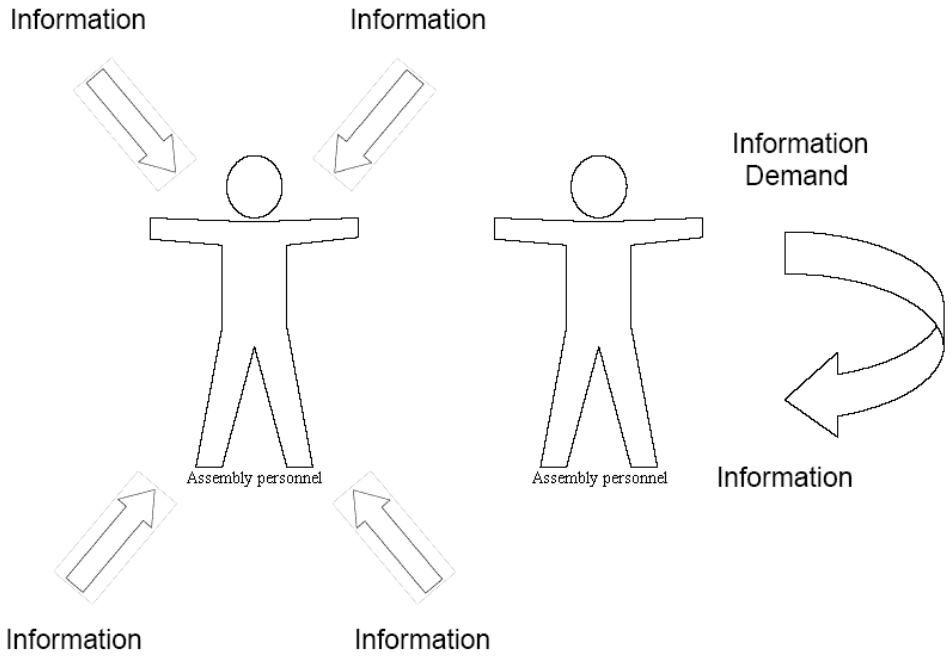

Figure 7. Illustration of information delivery and information demand (Modified from Bäckstrand et al., 2005).

Arguably, the consideration of information demand can lead to a better and simpler information usage from the subjects. The workers themselves are allowed to determine what information they want to use when occupied with a task. And the organization simply provides the information. What and how much information should be made available would naturally have to be determined from case to case. There are cases where all relevant information should be accessible to the worker. This would still not necessarily be information delivery as long as the information is supplied in the same way. The problem with information delivery is not that subjects are supplied with too much information. It is the clouding them with information while, at the same time, failing to make the user recognize *where* information is needed and also *what* information is needed. As long as information is not 'shoved in their faces', but merely made accessible to those who need and want it, we can never have the information delivery problem. Bäckstrand, De Vin, Högberg, and Case (in press) also describe four possible situations that can occur from the information demand/delivery view. Bäckstrand et al. (in press) also use the term information need similar to the use of information delivery but also concludes that a need is an actual need and should not be confused with whether the subject has recognised it or not (demand). Although this might not always be proper as the information need is an objective need and has nothing to do with whether or not the information is delivered by someone or demanded by the worker. The user might need information to perform a task and the information might even be delivered, but if the user does not know that he needs the information, there is no demand. Similarly, the user might demand information that he/she thinks is needed and it might be delivered as well, but this does not mean that there is an actual need.

- There is a need or a delivery but no demand. The subject does not recognise the information needed to perform the task. In this situation, an error will sooner or later occur. This situation can be remedied by introducing appropriate triggers that can create the required demand.

- There is a delivery and a demand. This situation is the preferred one. In this situation, the error risk due to a lack of information is lowest. However, this situation still requires that the information available matches the need and demand.

- There is a demand but no delivery. This situation can be frustrating for the personnel. They have identified a need and have a demand, but the context of, e.g., the assembly station does not provide them with the needed information,

- There is no need and no demand. This situation is more or less trivial. Even if we had a delivery here it would not bother the user as he is not looking for any information. It is a waste of resources.

The issue of what parameters of information should be presented also leads to a similar problem, which is when an activity can be performed with less information than is supplied. Arguably the information not used is causing more problems than it helps due to some form of information overload. Let us start by considering exactly what it is we do when we teach a worker to mount the lit up valve as in the example in Section 4.2. If we assume that in the original setting we use triggers to change the user's behaviour, this is what the chain of reaction would look like.

Trigger activation → Active attention → Information search → Exert activity

However, when we use affordances instead, what we do when we eliminate several steps in the chain is a cognitive task transformation as discussed in Section 2.1.2. Since affordances do contain information value and are medium dependent, our chain of behaviour would change and would instead look like this.

Affordance perceived → Exert activity

This may seem overly optimistic but let us view it in more detail. Firstly, if we use an affordance instead of a trigger in this case, we do not need to switch to an active attention mode as the perceived affordance can be acted upon within passive attention. With that we have eliminated step two in the trigger chain. Secondly, as the affordance contains all the necessary information about itself, we do not need to perform an information search. And when the part is to be mounted on the engine block, it is very plausible that a real affordance in the form of threaded holes afford the mounting of it using screws. This also shows us that we are really handling a form of sequential affordances. A question that may arise here is what makes a subject discover the affordance in the first place. As we have clarified many times, a triggers main purpose is to draw attention, so no problem there. We have also argued that a perceived affordance is very similar to a trigger in that it is often designed to attract attention. However, a real affordance has very little to do with attention. Whether an affordance is attended to or not depends more on the internal and external states of the subject and the surroundings. This obviously makes the suggestion of altering the chain of events using affordances slightly limited but in principle a real affordance can be used just as well as a trigger or a perceived affordance. The difference is that the designer of the work station needs to be aware of the properties of an affordance. He needs to create a *demand* for this affordance within the workers to make sure it is acted on properly. Actually, one of the keys to working with real affordances is to be able to create a demand for it. It is still unclear to what extent a real affordance can be manipulated or even created (see, e.g., McGrenere & Ho, 2000; Norman, 1999). To avoid this trapdoor let us simply not claim that we can do either.

Instead what we can do is handle the affordance. It is evident that a threaded valve affords being screwed onto something and with the proper combination of affordances, the valve combined with a threaded hole of the same size, leads to mounting. What we are doing here is creating a demand for an affordance. When the user picks up the valve and recognizes its affordance to be mounted onto something, his internal states become more likely to discover the affordance of the threaded hole. What makes a real affordance noticed are the internal and external states of the subject and the surroundings.

In the assembly domain of interest in this thesis, another very clear example of elimination in combination with substitution is the use of electrical and pneumatic drivers with several different sockets. When using only one driver and several sockets for it, the worker is forced to swap sockets after a specific action or sequence of actions and fasten bolts with the next one. If using two or three drivers with one socket on each, the swapping is unnecessary and eliminated. Naturally, this is only applicable when the amount of sockets is not too great. We cannot have too many drivers hanging from the ceiling at each station. But still, this is a factor worth taking extra notice of. One action which is often not contributing to the finished product is looking for tools, usually the sockets are all gathered at one place on a bench, shelve, or something similar, but the work is seldom carried out there. Instead, the work is carried out where the drivers are and it might therefore be interesting to consider if all the tools used can be moved as far as possible towards where the work is actually performed. A stand or some other holding device for sockets, fastened on the driver might be possible in some cases but of course not all.

With the clarification of task transformations, we can return to the question of information demand and delivery. The example we just discussed shows us that there is a discrepancy between the information demand and the information delivery. This also leads to a very important question; how much information does the worker actually need? Are we possibly, by pushing out all the information we have, simply making it even harder to find the information that one really needs? Let us consider the example of the valve. Do the workers have to know what the article number on that part is or is it enough that they know that there are two different kinds of valves, and are sufficiently trained to discriminate between them? Traditionally, in the industry, all parts have long article numbers or appellations and it is very questionable if this is of any use to the assembly worker. Perhaps using basic terms like ‘the blue valve’ or ‘the big valve’ would suit many purposes better. Using numbers and ungrounded appellations also leads to what can be called *spatial confusion*[6]. This occurs because humans usually relate information to its spatial properties. Therefore, an expression like ‘the red key’ is better than ‘key #4’ and also ‘the blue valve’ is a better term than ‘valve #325489’.

By performing the changes suggested in this section we are also using cognitive task transformations as described by de Léon (2003). We are using elimination when we remove unnecessary steps in the trigger process, we are using delegation when we start using an affordance instead of a trigger as suggested in 4.2, and finally we are using substitution when we rename the keys or valves as in suggested in 4.2.1. Actually we are using a combination of elimination and substitution when we replace triggers with affordances to reduce cognitive strain as in 4.2.1.

[6] Translated from Swedish (spatial virrighet) and part of ‘cognitive work environment problems’ (Kognitiva arbetsmiljöproblem, KAMP) as described in Schneider (1993).

5 Discussion on applying triggers

In this chapter we discuss the possible implications of applying trigger conceptions, keeping in mind the issues we have discussed in this thesis. A number of key concepts to keep in mind as one performs either trigger analysis or designing by our trigger conceptions, will be suggested and argued for. It is suggested how to handle problems in the design by our trigger conceptions from the viewpoint of trigger type, information demand, task transformations, and the characteristics of triggers.

Humans are a tool-using species. A lot of what we do on a day to day basis is largely dependent on tools. As discussed in Section 2.2, tools help humans extend their capabilities and cope with harder tasks than would be possible without them, this is a process called scaffolding (Clark, 1997). It can be argued that triggers should be placed into the category of tools. A trigger fits very well into the everyday use of the words tools and artefacts in the scientific community[7]. A trigger is an external aid; it serves as a scaffold in the environment that allows us to offload our cognitive processes. It can aid us to extend our zone of proximal development in that it allows us to make trade-offs with the environment regarding what information is important at each time step. This allows us to focus on the things that are important at a specific time.

As triggers are perhaps not optimally designed at the assembly plant, we must give a lot of credit to the workers there for still getting it right most of the time. But why is this? Why do they not make more mistakes? One plausible explanation would be that the experienced workers learn what triggers to trust at different work stations. The example of the pre-fuel filter, mentioned in Section 3.3, is potentially a big problem but since the problem is known among the workers, the implications can be limited. Errors are still made because of these types of problems but they are not as common as could be expected. However, one of the issues when working with these problems is the issue of new employees and the use of lent personnel from employment agencies. These people cannot be expected to be familiar with what triggers to trust and so the problem sustains. Through personal communication with both blue and white-collar workers, a few ideas for how to handle this problem have arisen. From the beginning, before the study in Thorvald (2005), when the sources and reasons for the problems in the assembly line were largely unknown, a lot of discussions lead to the suggestions of giving the workers more responsibility and to ensure that the workers take this responsibility, a rise in quality control of each worker was suggested. This was thought to force the workers to actively seek out information before commencing assembly on each engine. However, this suggestion is rejected, at least in this thesis as well as in Thorvald (2005), as this is not where the key problem lies. Today, the personal quality control is fairly informal. This is a good thing because it does not make the individual worker feel singled out, but when a mistake is made, he/she is told about it and that is it. As we have discussed all throughout this thesis though, the problem lies not as much with the worker as many might think at first glance. All the information is out there, so why are we making mistakes? As we have discussed, the triggers are a large part of the problem. With better triggers we can guide the information flow better and make sure that the workers really do absorb the key information. At the same time, information that is less important is still available for the worker to seek out if desired. After all, the amount of information is not what is important, it is the quality and relevance of the information that makes a difference.

[7] Were you to ask someone not familiar with the field about tools and artefacts, you might get a different view. Just as the dictionary review in Susi (2006) shows (Section 2.2).

As discussed above in this chapter, and in Section 3.3, the triggers as they are designed today, can still largely be handled by experienced workers. And even if we do design better triggers, there is always going to be problems as we can never fully anticipate how each individual is going to react to various triggers. We mentioned in Section 2.3.2 how affordances exist relative to the action capabilities of a particular actor and at the same time their existence is independent of the actor's ability to perceive them. This means that while affordances are objective in the sense that they are there whether you see them or not, they are also subjective in the sense that they exist relative to someone's action potential. The same thing can be argued to be true for triggers and entry points. Just because we think that we have designed a brilliant trigger, entry point, or perceived affordance, does not certify that it will be noticed by whoever it is designed for. It is noticed if his/her action capabilities allow it to. If we have designed a trigger based on sound and a hearing impaired person is subjected to it, then the trigger still exists to someone, but not to him or her. So, no matter how good we are at designing triggers, there is always going to be cases where things go wrong. So if a trigger is not perceived as it was meant to be, the largest risks probably lie with the new employees and the lent personnel. To meet with this problem, discussions at the factory have led to the suggestion of trigger-stations. This would mean that when designing an assembly line, special consideration might be taken to design certain stations to be very simple when it comes to triggers. These might be stations where there are very few variations in the assembly work, stations where the same articles are assembled on every engine. At other places of the assembly line one might try to gather all the tricky assembly work and all the variations and triggers at one station. The reason for doing this is actually twofold. Firstly, as expected, one can place inexperienced personnel at the "easy" stations and experienced personnel at the more difficult ones. This argument is based on the observation that experienced workers learn what triggers to trust and when to throw an extra glance at the information system. Secondly, when working at such a cognitively challenging work station, the worker would be kept on his/her toes at all times. This does not mean that the worker would be in active attention at all times. Instead, it would lead to a situation where the worker knows what triggers to pay extra attention to and what they mean. They become more likely to respond to certain immediate stimuli and can ignore others. As we have discussed in Section 2.1.1, many of the problems can be traced back to the switching of attention modes from passive to active. In this case, where the work is very diverse, the hypothesis is that a passive attention mode is very rare. Naturally it would occur at times but not as often as at the easy stations, or as the assembly line is designed today where the triggers are spread out over the assembly line. Bäckstrand et al. (in press) discuss the importance of triggers in their article about the cognitive challenges in an assembly domain and statess some notes to consider about triggers. Among other things they discuss where to present triggers and if the sources available to the workers are reliable. Also this regards when to present triggers. The trigger and the information should be synchronized so that the need and the demand coexist.

5.1 Key issues

Now that we have come this far it is time to start summarising this thesis. What have we found and how should we deal with it? The following sections will discuss four key areas where triggers and similar conceptions are key concepts and suggest how they should be handled in future design work. The areas to be discussed are:

- Types of triggers. Object or event?
- Demanding affordances. Do we employ trigger conceptions that are demanded by the user?

- Cognitive task transformations. Why and how do we make task transformations?
- The characteristics of triggers. How are the triggers designed and when are they presented to the user?

When designing with these four key areas in mind, it might be useful to consider four important questions throughout the design process. What actually does this trigger indicate? How is it perceived? When is it perceived? Why is it perceived? These questions, asked in each section presented below (5.1 – 5.4), constitute a form of guidelines that can be used for trigger and information design and evaluation.

5.1.1 Trigger type

One of the key issues that have been discussed in this thesis is information value and medium dependency. Whether we design stations using affordances, triggers, or entry points very much depends on the contextual factors that rule at the work station. What is arguably always of importance though, is that it is clear to the designer which ones are used. If we use an entry point and treat it as a trigger we will miss out very much of what an entry point offers that a trigger does not. Especially when it comes to the information value, but also to some extent when it comes to medium dependency, as an entry point does show high information value and some medium dependency, while a trigger shows neither. So, when deciding what type of trigger conception we want to use we should ask ourselves the following questions:

- Do we have or need medium dependency or could medium dependency add to or reduce the cognitive strain when it comes to the design of this particular task?
- What information should the trigger conception retain, if any?

By following these questions we should be able to design simple, medium independent conceptions as triggers. The conceptions with slight information value, usually regarding the ‘what’ in the task, should be considered entry points. An entry point in the form of a folder might indicate what work project needs attending. Finally, the medium dependent conceptions that hold a lot of information should be considered affordances (real or perceived). Similar to the way that ‘what’ is central to entry points, affordances can handle even more questions like ‘what’, ‘where’, ‘when’, and ‘how’. Also the properties that come with triggers, entry points, and affordances should be considered. For example an entry points freshness or the temporal nature of an event.

5.1.2 Demanding affordances

As stated on several occasions, what makes a real affordance noticed is based on the internal and external states of the subject and the surroundings. Of course, a real affordance which involves bright lights or something similar probably would attract some attention but the point is that an affordance has little to do with attention even though affordances, in some situations, can act as strong attractors of attention. So how do you make real affordances noticed then? One suggested way is to create demands for them. As stated earlier, the issue of whether a real affordance can be created or manipulated is still up for discussion in the scientific community (see, e.g., McGrenere & Ho, 2000; Norman, 1999). However, what we can do with affordances is to consider the information demand vs. information delivery debate and create demands for affordances. If we do choose to work with real affordances, one option is to do it as a result of a cognitive task transformation process. The key is that a designer of trigger conceptions must be aware of how to create the demand of an affordance and also, at times, create demands for triggers as triggers are very much incorporated in the information demand idea.

5.1.3 Cognitive task transformations

The possible reasons a task might be cognitively stressful are many. It might be because of its structure or because the separate actions are demanding in memory and attentional resources. Humans are better at certain tasks and de Léon (2003) points out how we are particularly good at recognising patterns and manipulating physical objects for example, and notably poor at solving logical problems. However there are artefacts and tools that can help transform the cognitively challenging tasks into actions that better suit human limitations and constraints. This simple background to why we sometimes need to transform certain cognitively demanding tasks into simpler ones is of greater importance than one might think at first. When replacing a trigger with an affordance, for example, as showed in Section 4.2.1, we are also performing a number of task transformations. But these task transformations would be totally useless if the designer would not know why they were made. Only with the understanding of why, can we understand how to transform a task. Even though it is a fact that humans are relatively good at physical operations, our capabilities are not perfect. We still have problems when we need to handle several physical objects at once and there are cases when a cognitive task transformation should be focused on physical tools and objects as it in fact is in the works of Kirsh (1996) and de Léon (2003). Ultimately, what we need to ask ourselves in the light of cognitive task transformations is; does this action lead to a better result or can we achieve similar results without it? Also, sequential affordances or triggers are of interest here. If sequential triggers are used, they must be specifically monitored as they can easily constrain the worker in his work sequence. This applies to any case where we work with sequences of behaviour. There are times when we need to constrain the worker, perhaps for quality reasons, and times when it is not preferred as an unconstrained worker is arguably happier with his work situation.

5.1.4 Characteristics of triggers

Finally, and perhaps most importantly, what should particularly be noticed is the characteristics of the conceptions. How are they situated and designed? Are they continuous or discrete? Is it possible for them to loose their effect? If we use an entry point or an affordance of some kind, an important question that needs to be addressed regards the information value that the conception holds. What information is incorporated and how can it be translated by a user. Also the temporal factors are very important to consider here. The action-effect gap and the question of continuous or discrete triggers can have great consequences for a task if they are not properly handled. Perhaps more important is to keep track of the stimulus-response gap as it potentially can cause great problems for the worker if a trigger is presented long before the actual task is to be executed. Another question, which we have not spent much time with but that relates to the stimulus-response gap, is when a trigger conception is presented. Should it be presented late or early in the task process? Perhaps it is dependent on the task but we must still consider the action-effect gap and not fall into the trap of presenting the task too early. Here, we can also take into account the notes that Bäckstrand et al. (in press) present regarding when and where to present triggers.

5.1.5 Summary of key issues

It is now time to sum up the key issues that we have just discussed:

- Trigger type
- Information demand
- Cognitive congeniality
- Characteristics

With the clarification of a trigger's medium dependency and information value, we can easily discriminate between types of triggers (entry point, affordance, or trigger). We need to unravel the demand for the trigger and the information that goes with it, from the standpoint of the end user. If there is no demand we might ask ourselves if we need the trigger. If we find that we do, we must consider our options on how to make the user see the need and create a demand for information. Also, we must ask ourselves if each action leads to a better result or if we can reach the same results without it. Perhaps some revising and elimination of actions could lead to a more effective work sequence. Finally, a trigger conception's characteristics are of utmost importance. The *how*, *where*, and *when* questions, however simple they might be, can give a lot more information than one might think. If for some reason you only have the opportunity to do very little analysis of triggers in your domain, how, where, and when, is where to start. These key issues are very important in designing triggers and contexts as is discussed and described in the next chapter where we also present a checklist, based on the key issues.

6 Contributions

In this chapter we discuss the contributions to the field of trigger analysis and design and present a checklist application of these thoughts in assembly domains.

6.1 Checklist

One of the aims described in the introduction regards a checklist for use in work station design and evaluation. This checklist is based on the discussions presented in Chapter 5. The overall aim of this thesis is to discuss and clarify the dominant views on trigger conceptions. However, we have also been discussing information design in more general terms because it is an important and interesting issue in much work and especially when discussing triggers from an information value standpoint. The checklist should therefore incorporate both trigger conceptions specifically, and information design generally. Based on our discussions in this thesis, the following checklist has been developed:

- Learning
  - Do we tell our new employees what to do or do we show them how to find out what to do? There could be a huge difference.

- Types of triggers
  - Physical trigger
  - Event-driven trigger
  - Could medium dependency increase or decrease cognitive strain?
  - What information should the trigger conception incorporate, if any?

- Information demand
  - Is there a demand from the worker for information?
  - If not, is there a need? (i.e. should there be a demand?)
  - If there is a need, how do we create a demand?

- Cognitive task transformations
  - Can the chain of events be audited so that we can achieve similar or better results within fewer events?

- Characteristics of triggers
  - Continuous or discrete?
  - Are they necessary? A redundant trigger could loose its effect.
  - What information value does our trigger conception incorporate? Is this information correct and sufficient?
  - Where and when to present a trigger.
  - Action-effect gap, is the effect evident within a reasonable timeframe?
  - Stimulus-response gap, is the worker able to directly act upon a stimuli?
  - Missing stimuli, is there a response to perform at all?
  - Sequential triggers, is all the relevant information presented at once or are actions necessary to reveal new information? Both alternatives are acceptable for different situations as long as we understand why one is preferred in a given situation.

The points in this checklist are nothing but extensions of the questions and sections presented throughout Chapter 5 and may not be directly applicable to different domains.

7 Conclusions and outlook

One aim of this thesis has been to discuss and clarify dominant view on triggers and similar conceptions. We have been discussing what properties that a trigger can incorporate that are potentially of interest when analyzing them. Also we have presented suggestions for how to categorize triggers on basis of their information value and medium dependency. A lot of the time has also been spent on information design which might seem to diverge from the path laid out by our aims but the information design and the informational context in a work situation is of utmost importance when it comes to incorporating triggers in a satisfactory way. The presented checklist still needs validation but is still somewhere to start when applying trigger analysis and design in different types of domains. A general goal has been to present the results in this thesis with domain application in mind. Therefore the checklist was developed so that it easily can be followed by a layman. Hopefully, we can also validate much of what has been discussed here in future studies.

7.1 Future work

There are still several loose ends in this field of science but in this thesis some have hopefully been tied up. Elaboration and validation of the checklist in Section 6.1 is something that would be of great use to future application of the ideas in this thesis. We have suggested tentative solutions and we would need further practical investigations to validate and provide support to some of the suggestions made here. As this thesis has not involved an empirical study, further investigations of the suggestions made in this thesis would be appropriate. The questions of decreasing effects and continuous vs. discrete triggers deserve particular attention (cf. Chapter 3). A clarification of whether or not triggers loose effect and in that case why they do so, and a proper study on the consequences of using discrete triggers instead of continuous ones would be of great importance and interest. Also, a substantial amount of work on the subject of information demand and delivery would be very helpful in modelling the true information behaviour that a user acts by. If we were able to create a satisfactory model of this information behaviour, it could be of great help in our effort to increase the usability and design of trigger conceptions.

When it comes to the pre-existing categorizations of trigger conceptions (cf. Section 2.3), triggers and entry points according to Dix et al. (1998, 2004) and Kirsh (2001), studies on other types of domains would be of interest. Until now the studies that have been pursued have almost exclusively been regarding office domains where the pressures on the accuracy of triggers are argued to be small. Instead, studies in industry domains, where the proper design of triggers arguably is more important to the work, would be of great value and would probably also produce more usable data to the researchers as a result of the greater complexity of the context.

Perhaps the most interesting future work would be a complete model of the field of trigger conceptions, be it doable or not. In this thesis the field has merely been reviewed and summarized together with the suggestion of a few new issues that should be incorporated. Therefore, a model of the field and how the different parts relate to each other would be of great interest and could also validate the conclusions in this thesis. As a result of this, one could issue heuristics to follow when it comes to design by trigger conceptions. These would presumably be easy to follow, even for laymen.

What has been found in this thesis, but perhaps not mentioned as it is not of core interest, is the relationship between our trigger conceptions and information. One goes with the other. We have discussed information value but the relation seems to go further than that. A trigger conception is useless without accompanying information. This also applies to simple triggers which have been argued in this thesis to hold no information value. However, the information does not have to be physically tied to the trigger as it is in the case of affordances, which is the condition for having information value. The information, when working with simple triggers, can be positioned anywhere, the trigger is merely a pointer, and a pointer that does not point to anything is fairly useless.

As a finishing note it may be wise to also consider that the elimination of all cognitive strain might not be something to strive for. This thesis concerns reducing cognitive stress but we must still remember that a world without cognitive challenges would hardly be worth living in.

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