Image schemas and intuition:

The sweet spot for interface design?

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Abstract

Recently, intuition has emerged as a key concept in interface design and studies have advanced towards developing methods of intuitive design. Yet, most of these methods elicited intuitive use by relying on a similarity-approach, mimicking previous technologies to produce familiar products. With the identification of abstract image schemas as representations for sensorimotor based knowledge, it appears that a solution is found to create user interfaces that are inclusive, innovative, and intuitive to use. Tapping into this knowledge that is gained through experience, opens up new possibilities to design truly novel interfaces, independent of technology familiarity. This thesis aims to highlight the significance of intuitive reasoning for human computer interaction with an extensive review of the process, relating it to the dual-processing continua and the skill, rules, and knowledge framework. Between flexibility and cognitive efficiency on one side and effortlessness, semi-automaticity and operation beneath conscious awareness on the other side, this modus is the sweet spot of processing. Secondly, this article makes a case for further investigation of the use of image schema representations in design, which in theory have the potential to mitigate several dark sides of intuition such as the assimilation bias and far-transfer problems. Furthermore, image schema methods could facilitate interfaces that are attuned to mitigate fallbacks to low level perceptive and intuitive mental behavior.

Keywords: Intuition; Intuitive Design; Experiential Knowledge; Intuitive Expertise; Metaphor; Image Schema; Active User Paradox; Far Transfer; Motivation

Contents

1 Introduction

Society is shifting towards more technologically integrated environments, with an increasing focus on merging technology with human functioning in many areas such as e-commerce, e-learning, e-government, e-health, and entertainment. With the increased complexity and steep growth of technological devices, the need for fluent interaction devices has become more evident. Additionally, the range of technology users has grown concurrently and has widened from a niche-population to a big portion of the general population. These developments place more stress on the ubiquitous accessibility of devices, thus understanding how users naturally interact with interfaces is necessary. In light of this, the term intuitive design has emerged more profoundly in design oriented contexts such as marketing, technology, patents, science, and political agendas. However, intuitive design is a vague concept (Mohs et al., 2006) and even intuition is not yet fully understood. In the last decade, there have been many attempts within the field of Human Computer Interaction to concretize and define intuition and its role in the use of digital products (Blackler, Popovic, & Mahar, 2006; Hurtienne & Israel, 2007; Macaranas, Antle, & Riecke, 2015; McEwan, Blackler, Johnson, & Wyeth, 2014; Mohs et al., 2006).

Intuition is a widely known phenomenon that is often described as a certain gut feeling or instinctive impulse which informs judgments or decisions (Blackler & Popovic, 2015; Blackler, 2008; Fischer, Itoh, & Inagaki, 2015; Hodgkinson, Langan-Fox, & Sadler-Smith, 2008; Ullrich & Diefenbach, 2010). When an individual encounters a situation, intuition can enable implicit understanding of how to behave in such a situation, and help to anticipate on consequences within this environment. When the interaction is successful, this is often perceived as a pleasant experience. It adds to the overall experience with feelings of accomplishment and competence, because the effortlessness of the interaction feels natural to the individual. With intuitive design, the discussion of intuition has been revived within the HCI field to inform innovative product designs. Intuitive design methods have been informative for design of interfaces and features that reinforce users of any type to recognize and understand them without the need of explicit instructions (Blackler & Hurtienne, 2007; Hurtienne & Israel, 2007; Hurtienne, Klockner, Diefenbach, Nass, & Maier, 2015). In addition to methods for interaction design, these results seem to have progressed our understanding of intuition.

In search for knowledge representations that facilitate intuitive processing, the concept of image schemas has re-emerged (Diefenbach & Ullrich, 2015; Hampe, 2005; Hurtienne & Israel, 2007; Hurtienne et al., 2015; Macaranas et al., 2015). This concept was first introduced by the philosopher Mark Johnson: 'An image schema is a recurring dynamic pattern of perceptual interactions and motor programs that gives coherence and structure to our experience' (Johnson, 1987, p. 14). This notion of abstracted schemas that may represent the 'building blocks' of knowledge comes from the assumption that the basis of our understanding consists of embodied, sensorimotor experiences (Johnson, 1989). Furthermore, image schemas reside at a lower cognitive level of knowledge, they are processed near-automatically and beneath conscious awareness. As such, image schemas seem to be the perfect knowledge representations to be processed by the intuitive systems of the mind, which are similarly characterized as consciously unaware and near-automatic. Thus, the idea on which intuitive design is built is to design interface elements that are based on these image schemas which can be ubiquitously understood, and easily processed by the intuitive system (Blackler, Popovic, & Mahar, 2010; Hurtienne & Israel, 2007; Hurtienne et al., 2015).

This thesis is an attempt to further explore the cognitive properties of intuition and relate these to current theories of mental information processing, such as: dual processing, tripartite model of the mind, SRK, and expertise intuition. Above all, the goal is to argue why intuitive reasoning is the 'most fitting' mode of cognitive processing for interaction with computer devices. The reasoning behind this is that in terms of using devices, operations usually consist of goal-action structures that have to be conveyed to the user through the interface. The more efficient these are conveyed by the interface and processed by the user, the more successful the interface is in terms of design quality and usability. In a basic sense, the interaction between user and interface is a complex process of knowledge transfer. The purpose of design is best explained as 'bridging' the gap between current knowledge of the user and the target knowledge necessary to operate the system (see figure 1). Interface features can be best made conducive to intuitive processing when they represent and transfer information that is easily picked up by the intuitive systems. Preferably, this is knowledge that is universal and domain-independent, with the potential to reach wider ranges of users. This paper's purpose is to explain why intuitive processing is the 'sweet spot' for this knowledge transfer, or the 'holy grail' of interaction design (Diefenbach & Ullrich, 2015). This is explained in terms of the mechanism itself, with a balance between cognitive efficiency and flexibility to solve the knowledge gaps within designs. Using image schemas to tap into sensorimotor knowledge, the most recent studies show promising results of ubiquitously understood feature designs (Hurtienne et al., 2015). In terms of design, it seems that intuition and image schemas can be utilized to design fresh, novel interfaces without having to rely on mimicking established designs or devices.

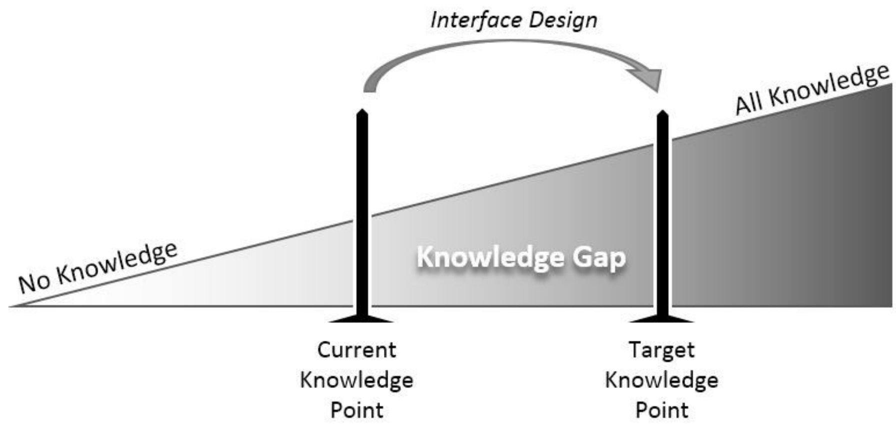

Figure 1. Illustration of knowledge gap between source knowledge and target knowledge of an interface (feature).

2 Intuition

There is a mutually beneficial interplay between the fields of human-computer interaction and cognitive psychology, as the advances in computer science enabled more elaborate observation techniques and complex task construction. Additionally, much of the research in the 21st century is conducted by virtue of industry financing, which in turn nudged the focus of many fields from an explorative to a more practical focused one. Yet, the matured HCI field has the strength to revive topics from cognitive psychology and advance them while keeping within this practical frame of mind. When technological innovations motivate us to explore the boundaries of our knowledge of human processing through computer interaction, this is only a good thing. A good example of such interplay is demonstrated with the main subjects of this article: intuition and intuitive design. For the field of HCI, it is of interest how we can design interfaces for fluent and intuitive operation. Yet, to be able to do this, we need to understand human information processing more profoundly from cognitive psychological perspective.

Interfaces cannot be intuitive (humans can), but they can be made more receptive to intuitive processing. In the following sections, intuition and intuitive interaction will be reviewed extensively. At first, the current state of research about intuition is explored, followed up by underlying characteristics of intuition and affiliated theories. Secondly, the intuitive processes are related to several models of human information-processing performance, with the aim to show how intuition emerges from everyday decision-making and investigating the balance between low-level perceptive, intuitive impressions and high-level reasoning.

2.1 The psychology behind intuition

Historically, intuition has been an elusive topic, for much of its processes were presumed to be subconscious, and this has long been regarded unsusceptible to scientific studies. However, in the late 20th and early 21st century, psychologists have started to recognize its importance in a variety of cognitive processes and new methods have been devised to enable the study of psychological mechanisms that are submerged beneath conscious awareness. There is still no empirical definition of intuition that is universally agreed upon, but there is agreement on several basic properties (Blackler, 2008). These properties and how they interact are illustrated below (figure 2).

The figure abstractly illustrates how intuitive processing informs human behavior by recognition of cues and key patterns in a given novel context. These cues or patterns are then compared to existing pattern structures, which are stored in experiential knowledge. If a match is successful, the individual can use this knowledge to correctly anticipate on the novel context and predict consequences before action is taken. The recognition of patterns, the matching and the resulting initiative are all executed without conscious awareness and with great speed and are perceived as 'automatic'. In other words; the individual performing intuitive processing has the perception of 'just knowing how to do it'. Yet, there needs to be stored knowledge for this mechanism to function. Note that this model is abstracted, these processes are involved in highly complex interactions within the cognitive system.

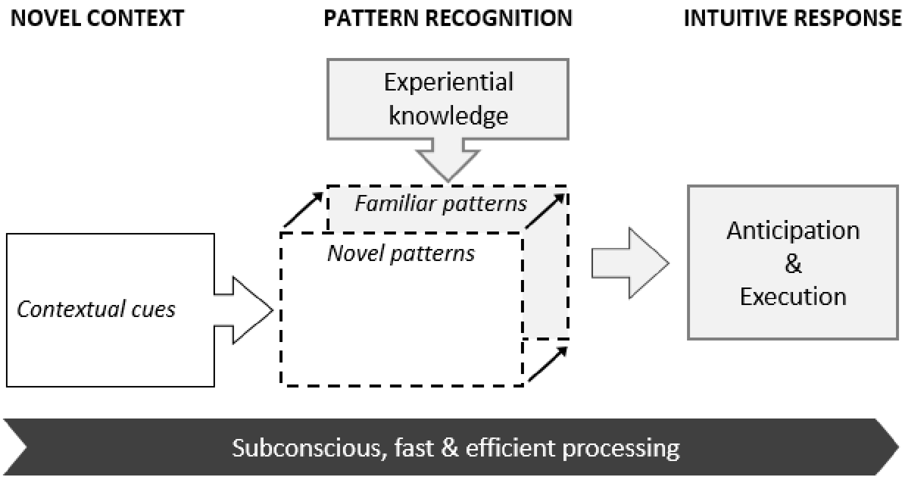

Figure 2. Intuition-based processing in a novel context.

2.1.1 Properties of intuition

The basic properties of intuition as shown in figure 2 are based on two extensive reviews of the topic (Blackler, 2008; Hodgkinson et al., 2008). In both these reviews, several proposed definitions of intuition from various studies have been selected and evaluated, with the aim to discover its characteristics. Hodgkinson and colleagues attempted to construct a definition of intuition by extracting properties from a range of definitions that were proposed in fifteen different studies (2008, pp. 5-6, table 2). They compiled the following definition: *"intuiting is a complex set of inter-related cognitive, affective and somatic processes, in which there is no apparent intrusion of deliberate, rational thought."* (2008, p. 4).

In Blackler's work, a similar approach is taken by selecting earlier definitions from various authors (2008). Based on this selection, she did not aim for a redefinition but instead focused on identifying the basic properties that were agreed upon. She demonstrated that much of the research contains definitions that ascribe key properties to intuition, especially 'past experience informing the processing'. Other key properties are the non-conscious manner of processing and the fact that intuition occurs faster and more efficient compared to other cognitive processes, and in a fairly automatic fashion (Blackler, 2008).

Earlier work on intuition was conducted by Gary Klein (1998), also known for the theory of naturalistic decision making (Klein, 2008). His definition of intuition still holds in light of the above work. *"Intuition depends on the use of experience to recognize key patterns that indicate the dynamics of the situation. It relies on implicit memory and grows out of experience"* (Klein, 1998, p. 34). However, the first description of intuition from an information-processing perspective was by Herbert Simon: *"The situation has provided a cue; this cue has given the expert access to information stored in memory, and the information provides an answer. Intuition is nothing more and nothing less than recognition."* (Kahneman, 2011, p. 11; Simon, 1981). In essence, not much has changed since Simon's definition, yet the understanding of how these processes exactly work and interact have become more elaborate and concrete, as will be shown in the next sections.

2.2 Experiential knowledge

The reliance on experiential knowledge is also the most tangible characteristic of intuitive reasoning, and is supported by a substantial amount of research (Bastick, 2003; Blackler et al., 2006; Bowers, Regehr, Balthazard, & Parker, 1990; Hodgkinson et al., 2008; Hurtienne & Israel, 2007; Klein, 1998; Salas, Rosen, & DiazGranados, 2010). There is early evidence for a strong relation between various modes of human processing and experience (Rasmussen, 1983; Shiffrin & Schneider, 1984). Experiential knowledge is gained through experience, as opposed to a priori knowledge, and in particular built up through time in similar situations. The term 'experiential' is used to indicate this iterative quality and is used in relation to processes of implicit learning resulting in an amalgamated implicit knowledge store which allows processes like intuition to operate (Reber, Walkenfeld, & Hernstadt, 1991).

According to Klein, people have stored sets of similar incidents that are implicitly used as a reference, intuition thus depends on the recognition of patterns and drawing from implicit memory to make inferences (Klein, 1998). Klein also states that people draw on memory for large sets of similar incidents, instead of specific instances, which may explain why people are not aware that intuition is in fact working on their own experience. Bastick follows up on this by proposing that the intuitive process integrates perceived information with the existing information that is stored in memory and these new associations produce insight, recognition or judgment while encountering novel situations (2003). In familiar situations, intuition 'reads' the cues in the environment and combines existing knowledge to rapidly generate answers on how to handle the situation.

2.2.1 Connectionism

Support for the argument that intuition is based on experiential knowledge can also be found in the connectionist approach. Connectionists describe the mind as a huge interconnected network of processing units that work as an associative engine (Clark, 1997). Knowledge representation is based on associative networks, when one of the nodes in the network is activated, this can spread to other related items in memory through this network. According to Reason and Mycielska (1982) and Greenfield (2000), the activation levels of connections in such a network are affected by frequency and recency. So, connections that are commonly made are more likely to be triggered again. The connectionist theory thus supports the notion that intuition depends on knowledge from past experience.

There is no proof for a superficial 'instinct' that provides for intuitive thoughts and action. Instead it is approached as a fast recognition of cues and features from past experience. This experience could be coded by weighted connections between the units, and when we learn new things, these weights are adapted (Clark, 1997). Greenfield (2000) agrees, stating that common sense and intuition rely on endless configuring and reconfiguring of connections between neurons. The strength of the associations between events or things in memory could determine whether they are activated in similar circumstances, and as these events occur more frequently, the strong links become stronger and the weak links become weaker. This constant and dynamic build-up and retuning of associations could be a foundation for intuition (Simonton, 1980).

2.2.2 *Embodiment*

The notion of embodiment – albeit somewhat philosophical – may give additional insight in a more practical type of knowledge that is likely never to become conscious for most people. The central idea of embodiment is that the experience with using tools and signs in peoples' everyday lives is added to their implicit experiential storage and thus serves as a reference for use of similar objects. In light of this, Nardi (1996), posits that: "all human experience is shaped by the tools and sign systems that we use" (p.10). Blackler concludes similarly, that "tools and artefacts are part of the human experience and they contribute to the store of information on which intuition can draw" (Blackler, 2008, p. 26). The research into embodiment and experientialism in general suggests that experiential knowledge is (among others) gained through the experience of being in a human body and exploring possibilities and limitations of the physical manipulation of objects and tools. Practical knowledge such as the effects of gravity and the possibilities and constraints of limbs and fingers appears to be learned so early, and is utilized so easily that it is likely never to become conscious for most people. Still, this practical knowledge is very influential to people, as it guides all their interactions (Blackler, 2008).

2.2.3 *Mental models*

In the context of usability research, the term *mental model* is commonly used to indicate the user's mental representation of 'how something is expected to work'. When a novel situation is encountered, users are expected to mentally adhere to a script or protocol that guides their behavior, based on experience with similar situations (Johnson-Laird, 1980). Not surprisingly, these mental models appear without conscious awareness and are processed automatically, and the formed representations are dependent on former knowledge. Basically, mental models could be seen as protocols consisting of many instantiations that can be used intuitively.

In the discussion whether to use mental models to inform the design of products, one notable issue was encountered by Blackler. If a mental model approach is to be used, it is necessary to establish a reliable way to predict which mental model is used and how it can be triggered (2008). According to Blackler, the notion that each individual user may possess unique mental models (Marchionini, 1997) poses an additional problem. It would seem unlikely that with the enormous amount of different products, people would construct separate mental models for each one. She states that it is more likely that series of overlapping models exist, containing familiar features across many products (Blackler, 2008). The notion of a mental model still holds value, if only as the vehicle or framework that connects different fractured pieces of knowledge. In this article however, the focus is on exploring these pieces of knowledge and how they fit in the context of intuitive reasoning.

2.2.4 *Intuition & experiential knowledge*

Intuition is a cognitive process entangled with many aspects of human cognitive functioning (Hodgkinson et al., 2008). Our intuitive impressions continuously influence our daily reasoning, inference and physical interaction, and can guide our behavior within many contexts. We try to make sense of the world by constantly testing expectations against perceptions, in a continuous loop of recognition, anticipation and cognition, which happens largely intuitively and mostly without conscious awareness (Blackler, 2008). It is a mechanism that utilizes our enormous knowledge base in an extraordinary manner, as it can inform us discretely and automatically, in every thinkable situation. However, this mechanism is guided by contextual pattern recognition of cues in the environment. Thus, to truly understand intuition, not only the experiential knowledge on which intuition acts is important to consider, but the environment (i.e. situation, context) in which intuition performs is equally important. The influence of environment will be addressed further in this article, but not before some theoretical foundations of decision-making are explored. This is necessary because it helps placing the ideas about intuition and intuitive reasoning into perspective and increases our insight in how intuition emerges from everyday judgments and decision-making.

2.3 Human information-processing performance

Essentially, human information-processing is suggested to operate on a continuum between automatic and controlled processing. The skill-rule knowledge model by Rasmussen (1983) suggests that there are various 'points' along this continuum at which different cognitive mechanisms operate. For example, controlled attentive processing is consistently observed as slow, generally serial, effortful, limited by WM capacity and regulated. On the other end, automatic processing is executed rapidly, parallel, effortless and not limited by working memory capacity (Shiffrin & Schneider, 1984). Additionally, there is a negative relation between the amount of control and the speed of processing. On the basis of its identified characteristics, intuitive processes can be placed roughly on the right of the center between controlled and automatic processing. The continua are illustrated below (figure 3), though these are highly abstracted, especially in the vertical alignment.

The processes shown in the continua are increasingly (left to right) dependent on available knowledge; if one encounters a novel situation there is no available knowledge of the situation. To deal with novel or inconsistent information, consciously controlled processing is used for more analytic and explorative knowledge gathering (Shiffrin & Schneider, 1977). According to Shiffrin and Schneider, processes that are now automatic were initially learned in a conscious mode (1984). They suggest that repeated exposure to novel information results in more responses that become learned. The processing style slowly shifts towards the right side of the continua. Thus, the more experienced we become at a task, the more automatic our processing is executed and the less aware we become of it.

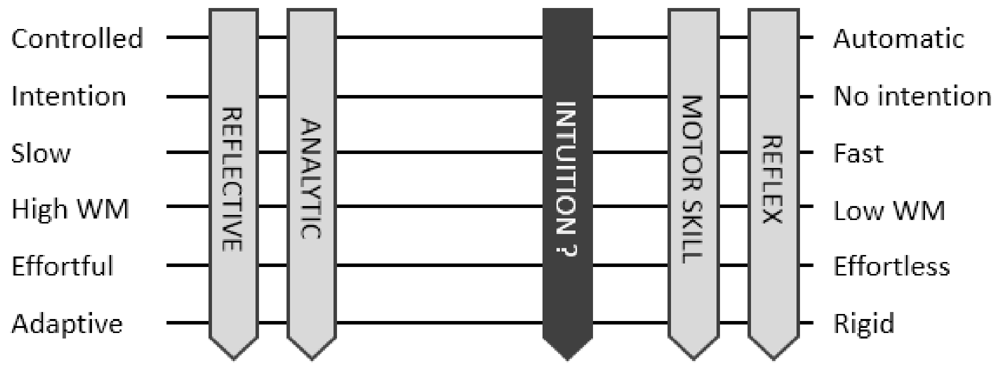

Figure 3. Abstracted illustration of continua of human processing properties, with estimations at which reflective and analytic reasoning, intuition, and motor skills and reflexes are supposed to operate.

The placement of intuition between these two extremes is a theoretical estimation. It is quite clear that intuition is different from analytic and reflective reasoning, because these processes require cognitive effort and deliberate intention. On the other side, intuition seems to be much closer to mechanisms such as acquired skill and reflexes, yet there appears to be a distinction in terms of automaticity. In an expansion of the SRK model (Rasmussen, 1983), Wickens et al. have equated rule-based with intuitive processing, separating intuitive from automatic processing (Wickens, Gordon, & Liu, 1998). They claim that intuitive processing is based on rules and procedures which are learnt through experience, but it is not completely automatic.

2.3.1 Dual processing theory

Describing human information processing in terms of a duality is part of a wider, much older scientific discussion. Theories of dual processing have been proposed across many disciplines that aim to understand human processing. Over time, many labels for both systems have emerged (table 1). Although these models indicate important distinctions between the systems, they are essentially related (Salas et al., 2010). In their review of dual processing, Salas et al. clustered one distinct system that is fast, holistic and does not require conscious cognitive effort. And a second system that is slow, analytic and does require conscious cognitive effort.

The study of dual process theories has progressed in different directions over the last two decades, and some tendencies can be distinguished. Earlier work has focused to a large extent on detailing the properties of each system. (Epstein, 1994; Evans, 2008; Shiffrin & Schneider, 1984; Sloman, 1996; Stanovich, 2000). More recently, the focus has shifted towards studying how the two systems interact, which is challenging because both systems operate in parallel and have complex interactions (Haidt, 2001; Salas et al., 2010). Another tendency is the inclusion of expertise in intuitive decision making (Kahneman & Klein, 2009; Kahneman, 2003; Klein, Calderwood, & Clinton-cirocco, 1986; Tversky & Kahneman, 1971).

Table 1. *Early dual process models*

System 1	System 2	References
Automatic	Controlled	Schneider & Schiffrin (1977)
Experiential	Rational	Epstein (1994)
Heuristic	Systematic	Chen & Chaiken (1999)
Heuristic	Analytic	Evans (1989, 2006)
Associative	Rule-based	Sloman (1996)
System 1	System 2	Stanovich (1999, 2004)
Holistic	Analytic	Nisbett et al. (2001)
Reflexive	Reflective	Lieberman (2003)
Unconscious	Conscious	Dijksterhuis & Nordgren (2006)

In an analysis of dual processing theories, Evans identified four clusters of distinctive attributes for the two systems (2008). These clusters describe differences between the two systems in terms of consciousness, age of evolution, functional characteristics, and individual differences. Summarized, cognitive processing in system 1 operates largely without conscious awareness, is a much older system, is domain-specific and contextualized (associative parallel processing), and there appears to be little between-person variation due to its independence of WM and general intelligence. Cognitive processing in system 2 is deliberative and consciously accessible, is a more recent system, it functions more abstractly and is rule-based, and there is a wide variation between individuals' capacity and ability (Evans, 2008). In later work, Evans and Stanovich (2013) conclude that the terms system 1 and 2 are misnomers because they imply a singular system, which is not the case. The most recently updated table is shown below (table 2).

Table 2. *Clusters of Attributes Frequently Associated With Dual-Process and Dual-System Theories of Higher Cognition (Evans & Stanovich, 2013)*

Type 1 process (intuitive)	Type 2 process (reflective)
Defining features	
Does not require working memory	*Requires working memory*
Autonomous	*Cognitive decoupling: mental simulations*
Typical correlates	
Fast	Slow
High capacity	Limited capacity
Parallel	Serial
Nonconscious	Conscious
Biased responses	Normative responses
Contextualized	Abstract
Automatic	Controlled
Associative	Rule-based
Experience-based decision making	Consequential decision making
Independent of cognitive ability	Correlated with cognitive ability
System 1 (old mind)	System 2 (new mind)
Evolved early	Evolved late
Similar to animal cognition	Distinctively human
Implicit knowledge	Explicit knowledge
Basic emotions	Complex emotions

Salas et al. (2010) state that deliberate thinking can serve two purposes: (1) reasoning is used to evaluate the product of an initial intuition, and (2) new information is uncovered on which the intuitive system responds. Intuitions from Type 1 thus only operate as input to the deliberate Type 2 system, which in turn is responsible for the executive action selection. According to Salas et al., intuitions act only to guide deliberate decision making, and judgments cannot be made without deliberate thinking. Feelings, emotions, and intuitions are just informational, they rarely influence the actual decision or action (thinking before acting). Interestingly, a contrasting view instead proposes that judgments are primarily made through System 1 processing (Haidt, 2001). Haidt posits that Type 2's role is to generate post hoc analysis primarily to rationalize why a specific judgment was made, but this rarely alters the initial judgment. From this perspective, people are thought to judge or act directly on their feelings, emotion or intuitions. Deliberate analysis is only used in hindsight, to make sense of it.

These contrasting perspectives illustrate the complexity of the interaction between these two systems. In terms of intuitive reasoning, both views acknowledge the fast, rapid and automatic responses made with Type 1. However, it is possible that another factor is at play, as some people may act on their intuitions more than others. This is illustrated by a paraphrase from Albert Einstein: "The intuitive mind is a sacred gift and the rational mind is a faithful servant. We have created a society that honors the servant and has forgotten the gift." (Samples, 1976). This paraphrase implies that being able to rationalize on intuitions is an acquired skill. If it truly is, this means there is variation between individuals in terms of 'ability to rationalize' intuitions. which is in line with the variability of type 2 performance concluded by Evans and Stanovich (Evans & Stanovich, 2013; Evans, 2008). Yet, the interaction between type 1 and type 2 systems is not as black and white as the two contrasting positions in the previous paragraph may suggest.

2.3.2 Type 1 – Type 2 interaction

In work by Kahneman (2003), the distinction between intuition (type 1) and reasoning (type 2) and their interaction is explained more thoroughly. At first he states that the most useful indication of whether a mental processes belongs to Type 1 or Type 2, is shown through the effect of concurrent cognitive tasks. Because the capacity for mental effort is limited, effortful processes tend to disrupt each other, while effortless processes do not, even when combined with other tasks (Kahneman, 1973, 2003). In figure 4, the characteristics of both processes are summarized with an additional distinction between content and processing. Kahneman states that the operating characteristics of System 1 are similar to the features of perception, yet with one important distinction: The operations of System 1 are not restricted to current stimulation like perception (2003).

Kahneman also explains more thoroughly what he thinks is 'intuitive' about the generation of judgments. Intuitive judgments produced by System 1 deal with concepts and percepts and can be evoked by language. The product of perception and the intuitive operations of System 1 are 'impressions' of the attributes of objects of perception and thought (Kahneman, 2003). These impressions (intuitions, percepts) appear involuntary and are not verbally explicit. Judgments are always intentional and explicit, even though these are not always expressed. Whether judgements originate in impressions or deliberate reasoning, System 2 is involved in all these judgments. As such, Kahneman states that the label 'intuitive' is applied to judgments that directly reflect impressions without being modified by System 2.

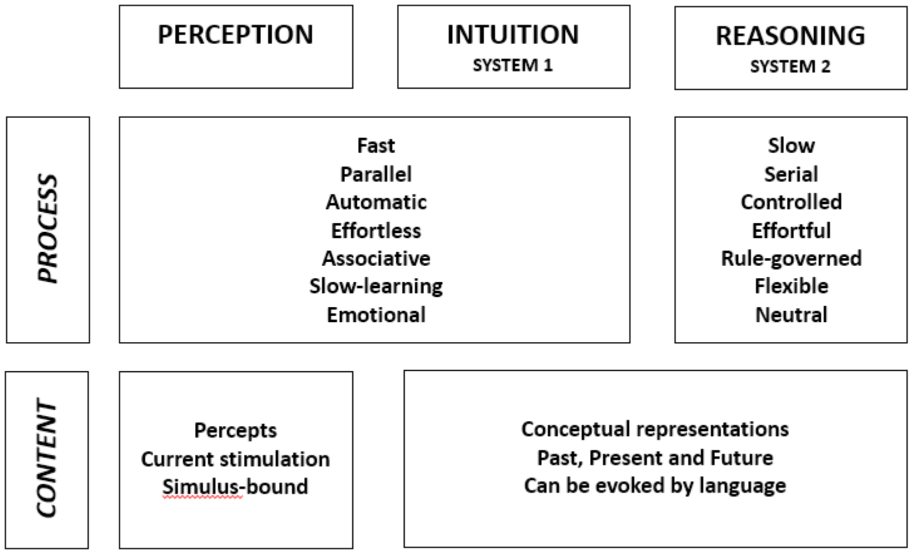

Figure 4. Process and content in two cognitive systems (Kahneman, 2003)

However, on the basis of this explanation, it is still unclear if decision makers deliberately choose whether or not to 'use' System 2 modification. According to Kahneman, this is explained by the effects of disruption of the self-monitoring quality of System 2. When decision makers are occupied by a cognitively demanding activity, they tend to respond to another task without much thought (no monitoring). Overall, the monitoring is suggested to be quite lax, allowing many intuitive judgments to be expressed and not without errors (Kahneman & Frederick, 2002). From this we can conclude that decision makers can deliberately choose to activate System 2 thinking, but most times they do not because of cognitive limitations or just not being used to thinking hard about their judgments. So, in terms of Kahneman, complex judgments and preferences are called intuitive in everyday language when these come to mind effortlessly and rapidly, similar to percepts (Type 1). These kind of judgments and intentions are intuitive in the sense that these can be overridden or modified by a more deliberate mode of operation (Type 2).

2.3.3 Tripartite model of the mind

The tripartite model of the mind (Stanovich, West, & Toplak, 2011) further explains the interactions between the processing clusters of systems (figure 5). But, in service of unravelling intuitive reasoning and due to the complexity of this subject matter, only a fraction is discussed here. This section zooms in on the theory that explains the individual differences and the types of knowledge structures associated with dual processing. The model discerns between three clustered systems of the mind (Evans & Stanovich, 2013; Stanovich et al., 2011). *The autonomous mind*, characterized as a set of autonomous systems which are the source of Type 1 processing. *The algorithmic mind* is seen as the algorithmic level of Type 2 processes, and *the reflective mind* is the reflective part of Type 2 processing. Stanovich describes two levels of control associated with Type 2 processing, and one with Type 1 processing. The autonomous systems implement goals unless overridden by an inhibitory mechanism in the algorithmic systems. However, the override itself is initiated by a higher level of control, which resides in the reflective systems. The reflective mind contains control states which serve to regulate behavior, these consist of higher level goal states and thinking dispositions that act at a high level of generality (Evans & Stanovich, 2013).

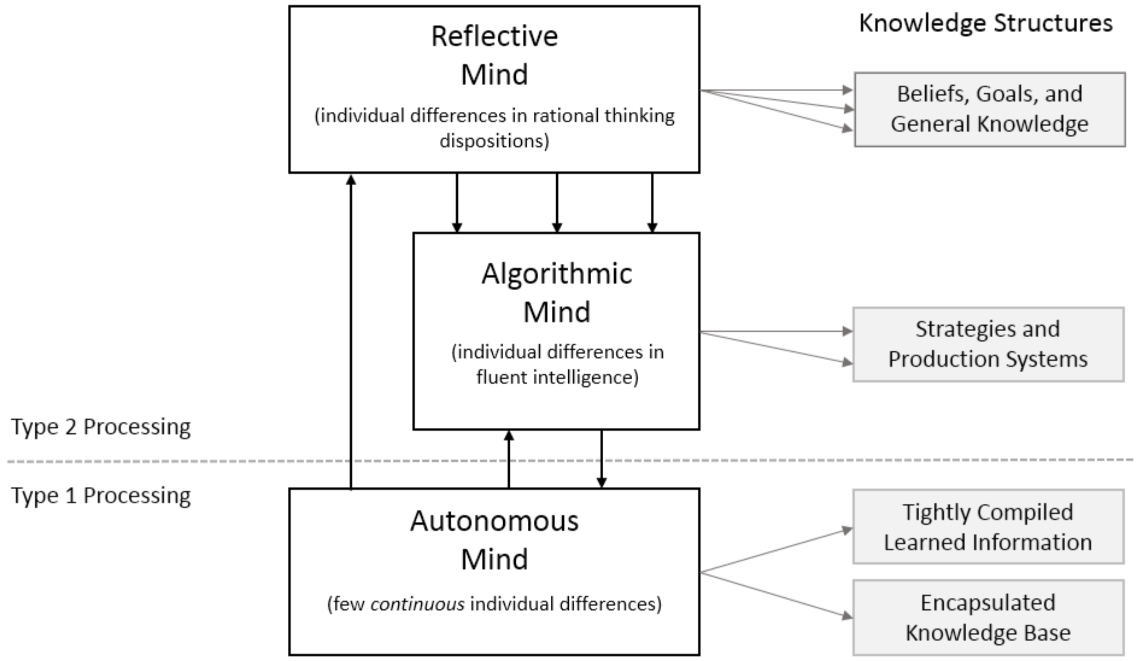

Figure 5. Tripartite model of the mind, with added locus of continuous individual differences and associated knowledge structures (Evans & Stanovich, 2013; Stanovich et al., 2011).

The distinction between the algorithmic and reflective mind is an important one, as it offers some explanation for the contrasting positions of Haidt (2001) and Salas et al. (2010). Stanovich describes it in terms of how individual differences between cognitive ability and thinking dispositions are measured (figure 5). Cognitive ability is explained as a measure of the algorithmic mind's ability to sustain 'decoupled representations', which are used for mental simulation and inhibition. Thinking dispositions are explained as measures of the reflective mind's ability to control the processing of information in accordance with higher level goal states. Which is reflected in the tendency to collect information from various points of view before coming to a conclusion, or the tendency to think about potential consequences before taking action (Evans & Stanovich, 2013).

Concerning the discussion whether Type 1 or Type 2 are responsible for actions or conclusions, the tripartite model actually indicates that both are possible. Variations in cognitive ability (algorithmic) and thinking dispositions (reflective) could result in Type 1 responses being expressed without being overridden by Type 2 processes. The post-hoc analysis could be the result of the reflective mind making sense of the consequences of the Type 1 expression. It may even be the case that these consequences are stored, which may lead Type 2 systems to attempt to inhibit or regulate the response in a subsequent iteration.

Stanovich also discussed the role of knowledge structures associated with the three systems of the mind (2011). He states that each level has to access knowledge to be able to carry out its operations, and these structures are unique for each level of the mind (figure 5). For the reflective mind, the persons' opinions and beliefs, and reflectively acquired goal structure are used for its regulatory functions, additional to the general knowledge bases. The algorithmic mind predominantly uses strategies for cognitive operations and production system rules that are responsible for thoughts and sequencing behavior. The autonomous mind retrieves information from two separate knowledge structures. One that consists of tightly compiled knowledge bases which are stored traces from practice and overlearning, and a second which consists of encapsulated 'evolutionarily-compiled' knowledge bases, also known as Darwinian modules (Stanovich et al., 2011).

In terms of knowledge structures associated with the autonomous Type 1 system, these tightly compiled knowledge bases can be compared with the experiential knowledge that is associated with intuitive reasoning. Stanovich emphasizes the importance of recognizing that the autonomous mind *"can come to contain high-level analytic knowledge learned over extended periods of time, including many normative rules of rational thinking (…) as well as important cue-validities that are picked up inductively"* (Stanovich et al., 2011, p. 108). These types of high-level analytic knowledge formations are most evident in individuals that have extensive knowledge in their domain (Kahneman & Klein, 2009; Klein et al., 1986; Klein, 1998).

2.3.4 Expertise intuition

High levels of skill or knowledge within a certain domain is what is commonly known as expertise. Closely related to dual process theories, two major contrasting approaches exist concerning intuitive decision making by experts: The Naturalistic Decision Making (NDM) approach, spearheaded by Gary Klein, and the Heuristics and Biases (HB) approach, spearheaded by Daniel Kahneman.

NDM is concerned with demystifying intuition by identifying the cues that experts use to make judgements (Kahneman & Klein, 2009). The approach grew out of early research on master chess players (Chase & Simon, 1973), in which the performance of chess experts was described as a form of perceptual skill in pattern recognition. Other critical work that would further crystallize the NDM approach, was based on the decision-making of fireground commanders (Klein et al., 1986). In their decision making process, they could draw on a single plausible option, even while under time pressured conditions of uncertainty with life threatening consequences. This option was evaluated by mental simulation, modified if needed, or replaced by the next plausible option until an acceptable course of action was identified. This strategy is also known as recognition-primed decision making (RPD). According to Klein et al., this was possible because the fire commanders had the ability to draw upon a huge repertoire of knowledge, accumulated over more than a decade of experience (Klein et al., 1986).

While NDM is more focused on studying the wonder of intuitive judgment of field experts, the heuristics and bias approach instead focuses on fallibilities associated with expert judgment. In a study by Tversky and Kahneman, it was observed that professionals could reach incorrect conclusions by following their intuitions (1971). Sophisticated scientists were asked to choose the number of cases for a psychological experiment. Those that followed their intuitions failed to reach correct conclusions and often failed to apply rules with which they were familiar, and which they would have used if they had computed the answer instead. The main focus of HB researchers is thus to recognize that informal judgment is not always right, bias and errors appear to be consistent, and ultimately following algorithms consisting of formal models and rules may result in better performance.

The differences and similarities between the two approaches are delicate, and discussed in detail in an article written by advocates of both approaches (Kahneman & Klein, 2009). In terms of dual process theory, the Type 1 and 2 distinction can also be applied to these approaches. In the RPD model from the NDM approach, expert performance involves an automatic process that produces potential solutions that arise from experience (Type 1), and a deliberate process responsible for the mental simulation to 'test' the potential solutions and modify if necessary (Type 2). In the HB approach, Type 2 is used for the continuous monitoring of the reasoning that is involved in correcting intuitive Type 1 judgments that arise from simplifying heuristics instead of domain experience.

Essentially, both researchers agreed on many aspects, and both contrasting approaches appear to converge towards the same principles that account for the emergence of intuitions. What was left unexplained was the observed variation in correct expert judgments. To solve this question, Kahneman and Klein studied the experts and their environments more exhaustively. In their article, they made several claims to answer the question; 'under what conditions are intuitions of professionals worthy of trust':

- Intuitive judgments can arise from genuine skill – but they can also arise from inappropriate application of heuristic processes
- Skilled judges are often unaware of the cues that guide them, unskilled judges even more so
- Subjective confidence is an unreliable indication of the validity of intuitive judgments and decisions
- Determining whether intuitive judgments can be trusted requires an examination of the environment in which the judgment is made, and of the opportunity that the judge has had to learn the regularities of that environment

The complete list of claims can be found in their article, but the above illustrate one very important issue with is best described by the authors: "*To determine the validity of an expert judgment, the accumulated knowledge of the judge and the environment in which he or she operates needs to be considered"* (Kahneman & Klein, 2009). What they suggest is that experts can only be 'true' experts if their environment is somewhat stable and predictable. Klein and Kahneman describe these kind of environments as 'high-validity', with stable relationships between objectively identifiable cues and subsequent events and or possible actions. In highly irregular and unpredictable environments, judgments that end up correct (i.e. luck, randomness) may be falsely attributed to correct intuitive judgment. This phenomenon is most likely seen in gambling, forecasting, or the financial world. The problem with these kinds of judgments, is that they could result in the development of overconfidence and illusions of skill and expertise. These experts may have spent ten thousand hours in the same environment, and they may have a higher chance of correct judgments, compared to a novice. But, the fact remains that these judgements were not based on objectively predictable events, increasing the chance of false judgments and bias.

Thus, the kind of environment in which intuitive decisions or judgments are made, is highly influential in the ability to store 'valid' knowledge on which intuitive judgments or decisions are based. Furthermore, these claims clarify what it means to be an expert and warn about the danger of subjective expertise. Subsequently, this work could be seen as an argument for discriminating between expertise-based intuition and general intuition. Salas and colleagues (2010) made this distinction in an organizational context, perfectly illustrated in a Venn diagram, shown in figure 6.

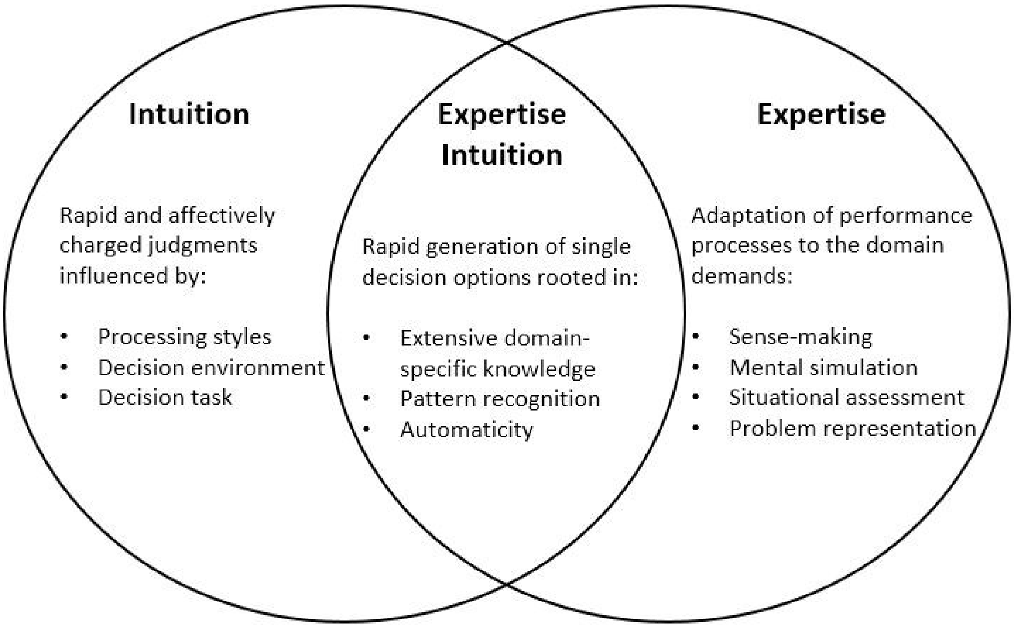

Figure 6. Venn diagram depicting overlap and distinction between intuition, expertise and overlap into expertise intuition (Salas et al., 2010).

2.3.5 The skill-rule-knowledge model

Dual process theories and the discussion of expertise and environment already broadened our understanding of intuitive decision making, but there is another perspective that should be taken into account. In earlier work by Rasmussen (1983), a three stratum model was proposed which could offer more insight on different levels of conscious planning. The Skill-Rule-Knowledge (SRK) framework is a model of human task performance which accounts for different levels of reasoning, and relates it to the amount of expertise or skill. It is specifically interesting because it addresses how intuition emerges from conscious action planning.

Concerning the claims by Kahneman and Klein (2009); the SRK model further elaborates the interaction between expertise and environment. Also, the model is informative about the type of cues that are recognized in a given context, and how these are processed.

Table 3. Skill, rule and knowledge based operation properties

Operation	Control	Processing	Experience
Skill-based	Non-conscious	Automatic	Expert
Rule-based	Non-conscious*	Mixed	Intermediate
Knowledge-based	Conscious	Analytical	Novice

*: *Based on explicit know-how; the implicitly used rules can be reported explicitly, yet the process happens without conscious awareness*

The SRK model distinguishes between three levels of operation (table 3): *Skill based behavior* operates on a non-conscious level and represents sensorimotor performance during acts or activities that occur as smooth, automated and highly integrated patterns of behavior (Rasmussen, 1983). This level of operation is only available to highly experienced people who possess the necessary knowledge and expertise within the given context or domain.

With *rule based behavior,* the performance of sequences of subroutines in a familiar work situation is controlled by stored rules (or procedures) which may be derived empirically during previous occasions or imitated from know-how as instructions (Rasmussen, 1983). This level of operation is used in contexts where extensive knowledge is lacking, the individual has to fall back on recognition of cues from the context and match them with rules accumulated from past experience. Rule based operation is processed rapidly and fairly automatically and without conscious awareness at the time of operation, yet the explicit know-how and implicitly used rules can be reported afterwards.

Knowledge based behavior is controlled at a higher level of consciousness, in which performance is goal-directed and based on knowledge that can be explicitly formulated. Especially in novel contexts, decision makers will have no rules stored from previous experience. They construct a useful plan of action, based on analysis of the environment. This plan of action is constructed by selecting possible considerations, and testing the effects against the goal, physically or conceptually (Rasmussen, 1983). After repeated exposure and experience, the internal representation of such an instantiation of goal-directed and knowledge based operation is suggested to be much alike the notion of mental models or scripts.

In real world situations, decision makers operate on any of these three levels and may switch between them depending on task familiarity (figure 7). Novices operating on the knowledge-based level may eventually include more rule-based processing when tasks become more familiar. When the decision maker has reached an expert level he will move to more consistent skill-based operation. But, as none of these levels are static, even an expert may encounter situations in which he has to fall back on rule or even knowledge based processing (Rasmussen, 1983).

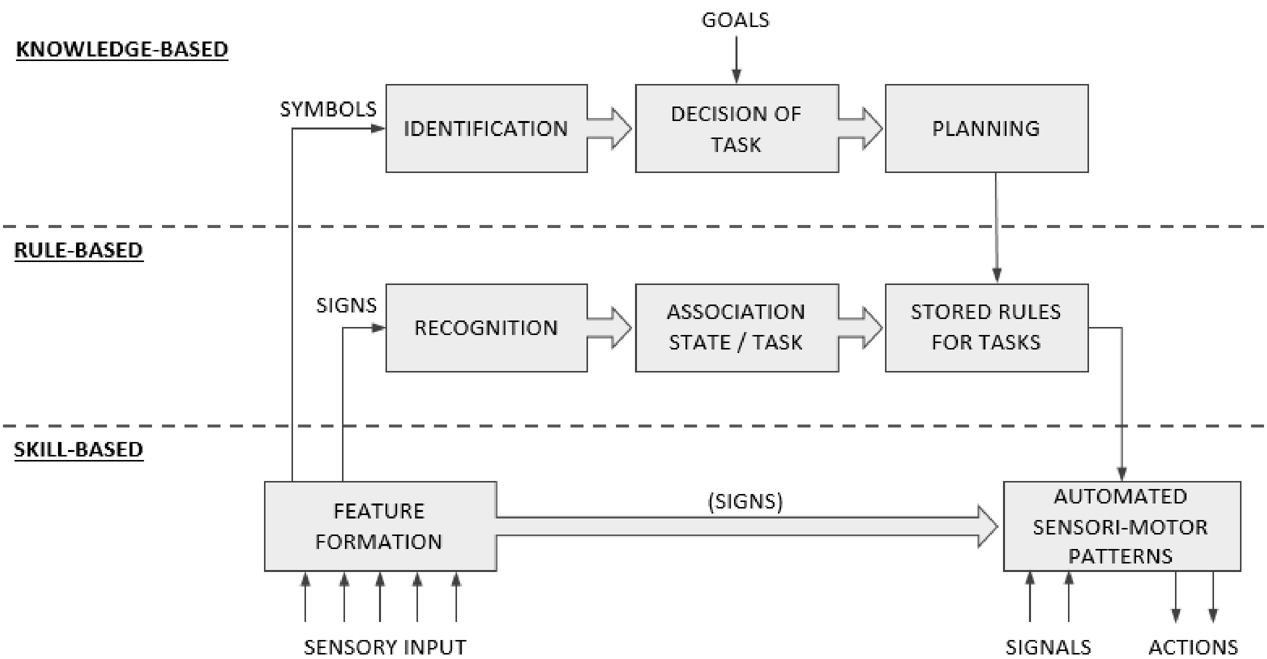

Figure 7. Skill-Rule-Knowledge model adapted from Rasmussen (1983)

2.3.6 Symbols, signs and signals

The above model abstractly illustrates the three levels of performance, from sensory input to action (figure 7). These levels are not alternatives and interact in more elaborate ways than represented in the model. Signs, signals and symbols indicate how the input information is perceived by the user. Rasmussen proposes that the way information is perceived depends on the context in which it is processed, directed by the intentions and expectations of the perceiver (1983). In this line of thought, *signals* are processed at the skill-based level and are perceived as continuous quantitative time-space indicators to guide complex automated behavior patterns. There is some interplay here with signs from the rule-based level outside the time-space control, where these can act as additional cues activating the automated patterns. *Signs* are indicators or cues in the environment that trigger situational scripts or behavior patterns from prior experience. They serve to activate or modify predetermined (previously learned) actions. *Symbols* are processed at the knowledge based level, and are used for practical causal reasoning to predict or explain unfamiliar environments. Symbols refer to concepts tied to functional properties, they are defined by their internal conceptual representation. Rasmussen further suggests that symbols, signs and signals are independent of the form in which they are presented (1983). A single form can be interpreted interchangeably as any of the three, dependent on the interplay between the contextual cues and the intentions and expectation of the perceiver, which again is based on experience.

Table 4. *Symbol, sign and signal representation and purpose, based on definitions by Rasmussen* (1983)

	Representation	**Purpose**
Symbol	Abstract construct related to and defined by a formal relation structure of relations and processes	Relate to knowledge-based real world relations or processes
Sign	State-indicator of environment with reference to certain conventions for action	Activate patterns of rule-based behavior
Signal	Dynamic variables indicating time-space relation in a dynamical spatial configuration in the environment	Regulate continuous skill-based behavior

2.3.7 Cognitive efficiency

Placing these theories in a real world context, one could wonder what the most natural and efficient mode of processing is, in the context of learning how to interact with the world around us. In terms of the SRK model, it is unlikely that individuals process everything with knowledge-based reasoning and then progress to form automatic skills by overlearning. It would mean a huge cognitive effort to learn everything from scratch by developing skills for each of the hundreds of situations that are encountered each day. Considering the limited cognitive resources and the fact that much of our sensory processing relies on delicate selection procedures, it would be logical if cognitive processing acts the same way with the two modes of operation as proposed with dual processing theory. One functioning as an initial quick abstract scan, and the other as a selective in-depth learning and skill development process. In terms of Kahneman, the first mode generates impressions, and the second mode is involved with monitoring the quality of both mental operations and overt behavior (Kahneman, 2003, 2011). With the distinction that the first mode is fast and efficient, and the second mode is slow and demanding in terms of cognitive resources invested. Thus, when judgments or decisions are made, intuition is always the most efficient mode, yet the moderating involvement of the deliberate mental processes is functioning as the failsafe to regulate resulting behavior, and fails more often than not.

In an evolutionary sense, intuition is suggested as a further developed mental process originating from our natural instincts, and is presumed a much older system then higher order reasoning (Pacini & Epstein, 1999; Reber, 1989; Stanovich, 2000). It would make sense, functioning as a rapid evaluation system that quickly picks up cues from the environment to make an assessment, and generate intuitive impressions and percepts that propel behavior. In this context, some kind of selection process would inform us whether to use resources (i.e. develop from knowledge to skill-based patterns) and when to make more efficient but rough estimations (i.e. intuition-based processing). This concept is not different from other forms of information processing where selective attention plays a role in resource management. For example in visual processing, which starts from a rough estimation (from periphery, noticing edges and contrast) to full detail (i.e. patterns, fidelity and color nuance). Another example is the social perception of other human beings, we initially have semi-automatic stereotypical assumptions that quickly assess the person, then 'decide' whether or not this person is worth the resources to learn to know them. If we choose so, and get exposed more to this person, a more advanced method of analysis is used to learn to the person's characteristics.

Another explanation for this resource management problem could be found in the 'building blocks' of intuitive processing; the stored representations of cue-pattern formations that make associative intuitive judgment possible. Things in the world around us appear in certain configurations or have abstract properties that can be understood on a deeper level, such as gestalts or schemata (Bowers et al., 1990; Johnson, 1989). The fact that our brain is sensitive to patterns, means there has to be some kind of abstract 'language' for understanding it. If such structures like gestalts or schemas influence the transfer of knowledge it may well be that these also serve to reduce cognitive resources (i.e. chunking). Secondly, there is the distinction between general and specific knowledge, because general knowledge can be applied for understanding of specific situations, which could also reduce cognitive resources. The above knowledge transfer considerations will be addressed in the next chapter, following the discussion of intuitive computer interaction.

2.3.8 Concluding on intuition

In this chapter, we have described several characteristics of intuition that have been extracted from definitions which have emerged from thirty-five years of research. Intuitive judgments and preferences come to mind quickly and effortlessly, much like percepts. Cue formations in the environment are recognized and matched with patterns stored in knowledge. If successful matches can be found, the associated rules for action outcomes are recalled and come to mind as judgements or preferences, in what are generally understood as *intuitions*. As such, the intuitive system feeds the higher level rational and analytic systems with mostly adequate and accurate information associated to the patterns, which ultimately lead to actions. These judgements and preferences are continuously generated, yet they are moderated by deliberate mental processes that are cognitively demanding. These higher level (reflective, algorithmic) processes can modify or override the lower level intuitions when cognitive resources are available. The iteration of experiencing similar situations can develop stronger intuitions, in the sense that these judgments or preferences and their outcomes (i.e. behavior, expressions, thoughts) can become more complex and easily accessible when the environment in which the decision maker operates becomes more familiar. In such cases, decision makers become experts in their specific environment (i.e. domain). Experts thus have a higher chance to generate valid intuitions compared to novices, yet this acts as a double edged sword. The expert's reliance on intuitions can become integrated into habit and higher level processes may become more lax when experts learn to trust their intuitions. This could results in biases and the erroneous use of heuristics and a lack of higher level moderation. When the cognitive demands of the situation (i.e. task) become higher, these type of errors occur more frequently. Additionally, the environment in which the expert became an expert is of concern because unstable, low-validity environments can result in the illusion of predictability, while it is actually just pure luck.

In all, not much has changed since Simon's definition (1981), although his ideas have been further elaborated and applied in different contexts. Yet, it was never the intent to redefine intuition. Instead the purpose of this chapter was to relate this cognitive exploration of intuition to recent developments of methods in human-computer interaction: intuitive design and the notion of image schemas (Hurtienne & Israel, 2007; Hurtienne et al., 2015; Hurtienne, 2009).

3 Intuitive design

In the previous chapter, intuition was explored from a cognitive psychological perspective, and defined as a fast, semi-automatic mechanism driven by pattern recognition and knowledge retrieval. In this article, we take the position that an individual is able to deliberately choose whether to act on an intuition or not. This is what makes human cognition distinct from animals, but this regulation is dependent on cognitively demanding high level mental processes. Experts in the field (master chess players, fireground commanders) show that the low-level cognitive systems can become more efficient when trained. Yet in terms of correctness, studies on expertise-based decision making warn about the negative impact of an unstable environment in which the decision maker attains knowledge on which intuitive judgments and decisions are based (Kahneman & Klein, 2009). In a sense, humans thus always produce intuitions, but these are only accurate when based on knowledge that is attained in predictable contexts and require continuous higher level moderation.

Broadly, facilitating intuitive use in a *computer context* has consequences for the type of environments (interfaces), and the kind of cues (features) that are processed. Careful design of both could ideally reinforce users to make more successful lower level intuitions, as such that the errors that result from a lack of high level moderation can be capitalized upon. In this chapter, such methods of design are discussed under the 'umbrella-term' intuitive design. First, we discuss ecological interface design, the first method that attempted to concretize the interface design problem along principles of the SRK framework into a design methodology. Second, we discuss the recent developments of intuitive design, and in particular image schema methods.

3.1 Ecological interface design

The ecological interface design (EID) framework by Rasmussen and Vicente (1992) was developed to deal with the problem of designing interfaces for complex work domains, and the authors went through several steps to solve this. The first step was to determine the type of demands associated with the control of complex systems. Their analysis revealed that unfamiliar and unanticipated events posed the greatest threat to system safety. The authors classified events in complex human-machine systems according to their degree of novelty from perspective of first operators and designers and defined three broad areas along a continuum. (1) Familiar events are routine in that operators experience them frequently, they have acquired the skills required to deal with these events through a substantial amount of experience and training. (2) Unfamiliar but anticipated events occur infrequently and thus operators will not have a great deal of experience to rely on. Yet, designers have built in means to deal with these through anticipated solutions to support operators. (3) Not all unfamiliar events are anticipated by designers, so in these events, operators must improvise solutions themselves.

The second step was concerned with formulating the generic structure of the interface design problem, which resulted in a minimal set of questions to which any approach to interface design must provide answers (Vicente & Rasmussen, 1992). The core of the interface design problem was structured along two questions, as illustrated by figure 8. First, what is a psychologically relevant way of describing the complexity of the work domain? Second, what is an effective way of communicating this information to the operator?

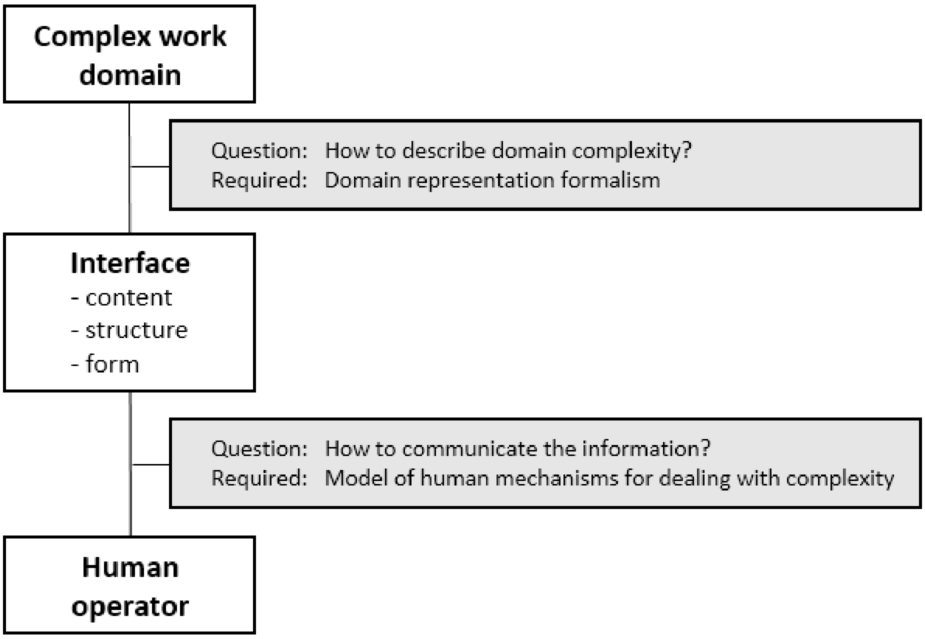

Figure 8. The structure of the interface design problem (Vicente & Rasmussen, 1992).

3.1.1 Abstraction hierarchy

The abstraction hierarchy provides answers to the first question, it is a framework for the identification and integration of a set of goal relevant constraints in a given work domain, where each level represents a different class constraint. The hierarchy can be seen as a set of models of the system, each defining a level of the hierarchy. Higher levels are representative of relational information about the systems purpose, while the lower levels are representative of more elemental data about physical implementation.

Five levels of constraints have been found useful to describe process control systems (Rasmussen, 1985): Functional purpose; abstract function; generalized function; physical function; and physical form. Representations with such characteristics are deemed to be advantageous because they provide two important benefits: to provide operators with an informational basis to cope with unanticipated events, and it provides a psychologically valid representation for problem solving (Vicente & Rasmussen, 1992). An important implication of such an abstraction hierarchy is that because higher order, functional relations are explicitly represented, it opens up the possibility for operators to determine when process constraints are broken. Additionally, such a hierarchy allows designers to identify which information an operator needs to cope with the full range of operating demands, including unanticipated events.

3.1.2 Levels of cognitive control

The EID approach adopts the SRK taxonomy of Rasmussen to explain three levels of cognitive control (1983). As such, cognitive control is suggested to depend on skill-based automated behavioral patterns, rule based cue-action mappings, or knowledge based problem solving operations based on symbolic representation. In terms of operation, only knowledge based reasoning (yet more error-prone) is capable of dealing with unfamiliar events, because rule-based reasoning is only activated in familiar situations when operators are attuned to the perceptual features of the environment. The level of cognitive control that is activated, depends on the combination of current demands of the task, the operator's experience, and the form in which information is presented. Additionally, operators may use higher levels of cognitive control even if the interface is designed to encourage lower levels, and as such interfaces should ideally also support higher levels of control to be effective. To achieve this in terms of design, one needs to understand which activities are associated with each level and how the different levels are related.

Rasmussen and Vicente state that performance of a realistically complex task usually is the result of simultaneous consideration of all three levels of cognitive control (1989). Yet, they argue that associated activities with each level are quite different from each other, as different tasks in different domains require other presentations of information. For the control of a complex work sequence, information that is presented to the operator will have at least three distinct functions: activation of skilled routines, control of the course of the routines, and monitoring the outcome of an activity.

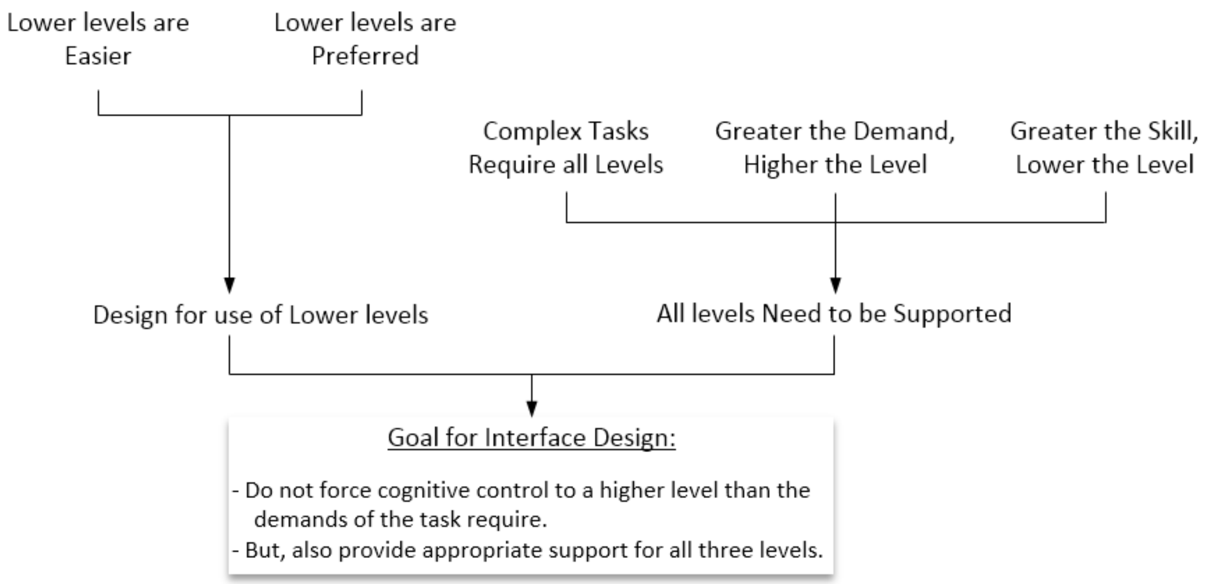

Figure 9. Levels of cognitive control associated with the psychological and functional demands of complex human-machine interaction (Vicente & Rasmussen, 1992).

What is of interest to designers in terms of utilizing the levels of cognitive control that interfaces must allow, can summarized in two arguments (figure 9). *"First, lower levels of cognitive control tend to be executed more quickly, more effectively, and with less effort than higher levels. Second, converging empirical evidence argues that people have a definite preference for carrying out tasks by relying on lower levels of control, even when the interface is not designed to support this type of behavior."* (Vicente & Rasmussen, 1992, p. 598).

3.1.3 Principles of ecological interface design

The goal of EID was to develop a single framework to simultaneously support all three levels of cognitive control. The framework consists of three general principles that correspond to the SRK model: skill-based behavior (SBB), rule-based behavior (RBB), and knowledge-based behavior (KBB). For a thorough description of the three principles and a discussion of the theoretical significance, consult the work of Vicente and Rasmussen (1992, pp. 598–600).

1) SBB To support interaction via time-space signals, the operator should be able to act directly on the display, and the structure of the displayed information should be isomorphic to the part-whole structure of movements.

2) RBB Provide a consistent one-to-one mapping between work domain constraints and the cues or signs provided by the interface.

3) KBB Represent the work domain in the form of an abstraction hierarchy to serve as an externalized mental model that will support knowledge-based problem solving.

The EID work is especially aimed at interaction design for highly complex systems. Even though the focus of this article is aimed at reaching the widest audiences possible, this work is valuable for its concretization of the interface design problem, its link to the SRK framework, and especially its approach concerning facilitation of cognitive control. Surprisingly, the intuitive design methods that are the main focus of this thesis do not refer to the ecological interface design framework at all. However differently, both methods essentially acknowledge similar design problems: (1) the fall back to low-level control due to cognitive strain and effortlessness, (2) the high-level demands of complex tasks. Still it would be interesting to investigate whether the image schema method would be accepted by adherents of EID.

3.2 Intuitive computer interaction

Two lines of research are introduced which have been concerned with defining the intuitive use of products, and the question how theories of intuitive processing can be utilized to improve design methodologies. The aim of this section is to connect the theoretical exploration from the first chapter with two recent tools, the continua of knowledge and intuitive interaction. These tools help explain how interfaces could be made intuitive, but also offer insight in some issues that come with it. Secondly, these two research groups have contributed immensely to put the development of image schema theory on the map as a potentially powerful method for tapping into more general, abstract knowledge.

> *"Intuitive use of products involves utilizing knowledge gained through other experience(s). Intuitive interaction is fast and generally non-conscious, so people may be unable to explain how they made decisions during intuitive interaction." (Blackler, 2008, p. 120).*

The Queensland University of Technology (QUT) definition of intuitive use was reached through literature review of intuition and various relevant fields related to intuitive interaction such as: HCI, usability, cognitive psychology and interaction design. Much of this research was conducted by several different researchers on four different continents, after testing diverse products, interfaces and experiments. These studies all confirmed that prior experience is the most important contributor to intuitive use and that it is a fast, non-conscious process (Blackler & Hurtienne, 2007; Fischer et al., 2015; Hurtienne, 2009; O'Brien, 2010).

Intuitive interaction was strongly linked with familiarity (Blackler, 2008; Hurtienne & Blessing, 2007; Mohs et al., 2006; O'Brien, 2010). Prior exposure to products with similar features helped participants to anticipate and perform better on several tasks. Familiar features are used more intuitively, people with higher technology familiarity are observed to perform better on tasks, as well as faster and with fewer errors (Blackler et al., 2010). Technology familiarity is deemed an instrumental variable in facilitating intuitive interaction with interfaces, and although other individual difference factors such as age (O'Brien, 2010) may play a role, technology familiarity is the most consistent factor that also can be realistically addressed by designers (Blackler & Popovic, 2015).

> *"Intuitive use is given when users can apply their prior knowledge using a minimum of cognitive resources to effectively solve their task". (Husslein et al., 2007)*

This complementary definition was proposed by the Intuitive Use of User Interfaces (IUUI) group at the TU Berlin. When usability and human factors experts were asked to relate 'intuitive use' to the seven dialogue principles of the ISO standards (9421-110), the most closely associated dialogue principles were: 'conformity with user expectations', 'self-descriptiveness, and 'suitability for the task' (Scholz, 2006). This analysis and a general review of usability criteria led to a tentative definition of intuitive use: *"A technical system is intuitively usable if the users' unconscious application of prior knowledge leads to effective interaction"* (Mohs et al., 2006). The research groups have made concrete steps towards a design methodology. Two continua were developed; one to explain *which* types of knowledge can be drawn upon to make intuitive interactions possible and another to explain *how* this knowledge can be transferred. These continua have proven to be useful in a design context and may give developers guidance to construct interfaces that can be used intuitively.

3.2.1 Continuum of knowledge

Developed by the IUUI research group, the continuum of knowledge illustrates how prior knowledge stems from different sources (figure 10). These sources are classified along a continuum from innate, sensorimotor, and cultural to expertise knowledge (Blackler & Hurtienne, 2007). Blackler and Hurtienne describe the four levels of knowledge as follows: (1) *Innate knowledge* is generally acquired through activation of genes, or during the prenatal stage of development and is generally drawn upon by reflexes or instinctive behavior. Innate knowledge is useful to be elicited through intuitive interaction as its innate nature implies universal application and non-conscious processing. (2) *Sensorimotor knowledge* is similar to the aforementioned concept of embodiment. This knowledge entails abstract concepts and principles that are learned very early in childhood through continuous interaction with the world, such as gravity, speed, time, and mass. Again, because of its potentially universal application, drawing on this knowledge can be instrumental for eliciting intuitive interaction. Scientific concepts such as affordances (Gibson, 1979) and image schemas (Johnson, 1987) similarly belong to this level of knowledge. (3) *Cultural knowledge* is specific knowledge influenced by the cultural conventions and customs. Even though not much research has been conducted about the influence of culture in this particular context, the authors recognize its importance. Examples can be found in different standards of design, interpretation of colors, icons, or gestures. (4) *Expertise knowledge* is the most specific level of knowledge in this continuum. This is specialist knowledge contained and acquired within an individual's specific profession or hobby, and gathered through years of experience.

The last three levels may be influenced or extended by specialist knowledge of tools and technologies. For instance, using a wooden stick to reach further would be an extension at the sensorimotor level. Using cell phones or computers would be an extension at the cultural level, and more expertise specific tools (such as with specific software for doctors, designers or finance) extend at the expertise level. Knowledge about tools appears to be an important reference when designing user interfaces (Blackler & Hurtienne, 2007). Interface features that are analogous to instantiations of tool knowledge may be more easily and intuitively understood, as the basic principles or mechanisms are already integrated in users' knowledge.

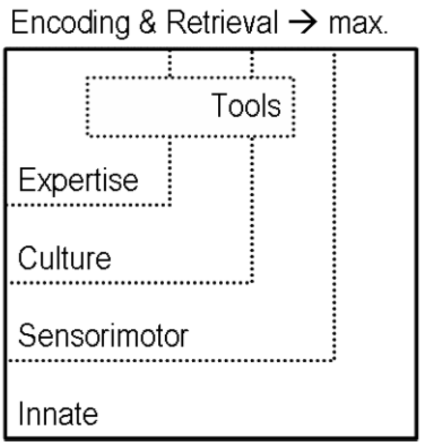

Figure 10. Continuum of knowledge (Blackler & Hurtienne, 2007)

The continuum comes with an inherent dimensionality; from top to bottom, the frequency of encoding and retrieval of knowledge increases. Secondly, the degree of specialized knowledge decreases from top to bottom, and with it the number of people within the general population that possess it. Additionally, the authors stress an important prerequisite for any of these knowledge levels to be eligible for intuitive use, which is that it must be unconsciously applied by the users (Blackler & Hurtienne, 2007). This notion can also be found in connectionist theory; associations that have been made repeatedly, become memorized knowledge because their connections become highly trained, the links between neurons grow stronger (Greenfield, 2000; Reason & Mycielska, 1982; Simonton, 1980). With this, a third dimensionality arises: from top to bottom, the knowledge is increasingly more likely to be applied without conscious awareness (i.e. only able to verbalize afterwards). In light of this, Blackler and Hurtienne, propose a few advantages for limiting intuitive interaction to the lower levels of the knowledge continuum (2007).

- The lower the level of knowledge, the larger and more heterogeneous the user groups eligible to intuitive use.
- Refer to rules generated from findings about the general sensorimotor human knowledge structure, instead of having to analyze specific prior knowledge.
- At lower stages, the encoding and retrieval appears more frequent, and is more easily non-consciously processed. In high mental workload situations, a fallback on these lower stages of the continuum may occur.
- More non-conscious processing of interface elements in general means less workload on cognitive processing capacity (and more workload available for the task that the interface aims to support).

3.2.2 Continuum of intuitive interaction

The continuum of intuitive interaction is based on empirical work by Blackler and Hurtienne (2007) which has resulted in three principles for intuitive interaction that may assist designers and developers:

1. Make function, location and appearance familiar for features that are already known. Use familiar symbols and/or words, put them in a familiar position and make the function comparable with functions users have seen before.
2. Make it obvious how to use less well-known features by using familiar things to demonstrate their function, appearance and location.
3. Increase the consistency throughout the interface so that function, appearance and location of features are consistent between different parts of the design. Use redundancy in order to maximize the number of users who can intuitively use the interface and the ways in which they can choose to complete their tasks.

The principles have been placed in a continuum, and are related to several abstract methodical concepts. The purpose of this continuum is to inform the intuitive design of any level on the continuum, and for users with differing levels of technology familiarity (figure 11).

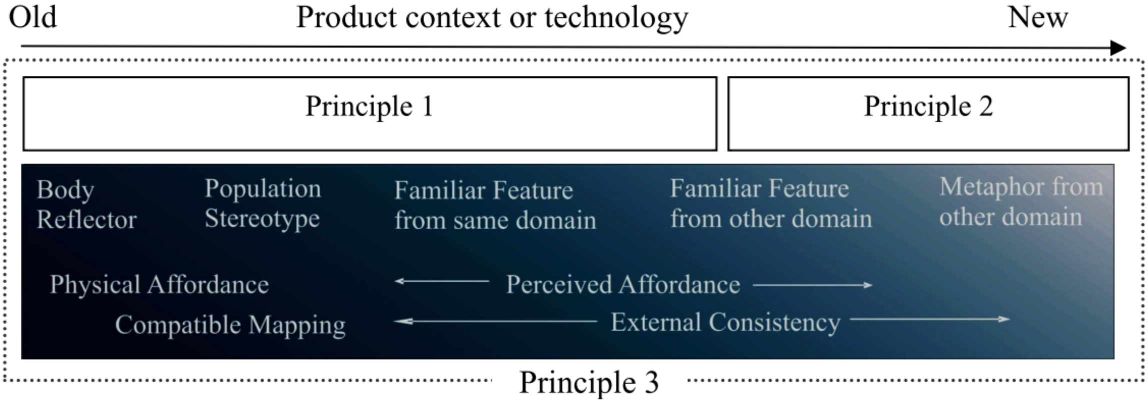

Figure 11. Continuum of intuitive interaction (Blackler & Hurtienne, 2007)

Body reflectors are based on embodied knowledge and are deemed the simplest form of intuitive interaction. They are described as products or parts that resemble the body because they come into close contact with it (Blackler & Hurtienne, 2007). For example, a video game joystick with indents for the fingers and a button on top intuitively implies how to grab it. *Population stereotypes* operate on a more complex level, and are embedded in knowledge from an early age and usually derived from experience or culture. Principles such as clockwise increase, a red or green (traffic) light, or a block arrow pointing right meaning 'play' or 'start'. *Familiar features from same domain* are artefacts or features that are known from usage in similar contexts. Things such as a file menu in editing software, or an 'on' button for television screens or monitors always on the bottom right position. *Familiar features from other domains* are artefacts or features known from other contexts that are not similar, but still make sense when transferred into the novel domain context. Examples are the colors green and red that can be transferred to other domains (green=yes, red=no), or a floppy disk icon that indicates you can save a file. *Metaphor* application is the most complex form of intuitive interaction, and used to explain a completely new concept in light of a familiar context. Metaphors are grounded in experience and allow retrieval of useful analogies from experiential knowledge. The desktop is an example of such a metaphor and possibly the most commonly known one among computer users, closely followed by *window,* and other examples as: *folder, file, gallery, clipboard, and the shopping cart.* All of these are used to help understand a novel feature by placing it in a context that is familiar and so can be transferred to the novel domain. *Compatible mapping* refers to the relationships of controls and the object they are controlling. A system with a greater degree of compatibility will result in faster learning and response time, fewer errors and a lower mental workload. Mappings rely on past experience and are completely ingrained cultural norms that are known by a particular population (Blackler & Hurtienne, 2007).

3.2.3 Affordances

Affordances have been used to describe the properties and potential application of both physical and virtual interface objects and were originally defined by Gibson (1977). To Gibson, affordances are relationships, they are a part of nature and do not have to be visible, known or desirable. It has since been a popularized term within the design community, but according to Norman, it has deviated from its original definition (Norman, 2004). To clarify the situation he distinguished between perceived and real (physical) affordances. He states that especially for design, interest goes out to whether the user perceives some action to be possible or not. Screen-based features do not have real affordances, they have perceived affordances, which are based on prior experience with similar things (Norman, 2004). In later work, Norman calls for restraint in the use of the term affordance, in his words: "Forget affordances: What people need, and what design must provide, are signifiers." (2008, p. 17). Norman claims a signifier is some sort of indicator, a signal or cue in the physical or social world that can be interpreted meaningfully. He continues that signifiers indicate critical information, even if the signifier itself is an accidental by-product of the world (Norman, 2008).

3.2.4 Combining both continua

In recent work by McEwan, Blackler, Johnson, & Wyeth (2014) , the two continua are combined into a single model (figure 12). They argue this proved to be a valuable combination as both continua complement each other. The continua of knowledge inform about which degree types of knowledge are susceptible to intuitive use, and the continua of interactive use explains the degree to which methods are applicable for it. For example in the IUUI continuum, physical affordances are deemed the most accessible due to the embodied nature of the accessed knowledge, and as such the non-conscious accessibility and low cognitive workload requirements to process them. The knowledge continuum complements this with the sensorimotor stage of knowledge, which is similarly early learned, non-consciously accessed knowledge with low cognitive workload processing.

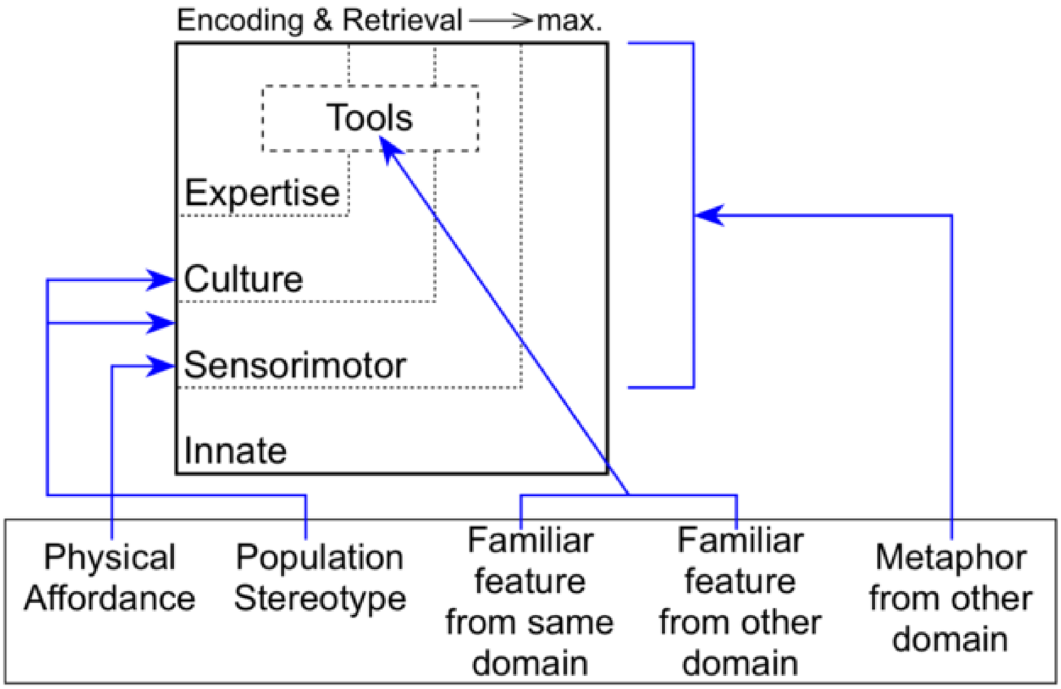

Figure 12. Combined continua of knowledge and intuitive use (McEwan et al., 2014)

3.3 Knowledge transfer

The link between knowledge transfer and intuitive design has recently emerged in a study to assess intuitive use of devices by Blackler, Popovic and Mahar (2010). The industry standard of this assessment currently involves observing participants who use a test device after they have responded to a technology familiarity questionnaire. Recorded user sessions were analyzed and the experimenter manually isolated features (e.g. options, camera zoom) to assign corresponding behavior to a set of heuristics. Feature use was considered intuitive when it displayed at least two of the following heuristics: subjective certainty of correctness, expectedness, latency, (verbalized) relevant past experience, and absence of evidenced (verbalized) reasoning (Fischer et al., 2015). Technology familiarity assessments revealed that features whose function or appearance is similar from previously used devices, tend to be used more correctly and intuitively (Blackler et al., 2010; Hurtienne, Horn, Langdon, & Clarkson, 2013). However, an important distinction can be made between familiarity with specific devices and general technology familiarity. Blackler et al. (2010) showed that participants who had broad familiarity with technology, but little experience with digital cameras performed more intuitive uses than participants who had little technology familiarity but high familiarity with digital cameras.

These results led to the hypothesis that intuitive use involves a knowledge transfer from familiar domains (i.e. general technology experience) onto new devices (Blackler & Hurtienne, 2007; Blackler et al., 2010; Fischer et al., 2015). They concluded that clarifying the way in which prior knowledge is transferred onto new devices could be important for the development of new approaches for assessing intuitive use which are less time consuming than observational analyses or surveys, and more importantly less subjective (Blackler et al., 2010).

3.3.1 Active user paradox

Problems with knowledge transfer have received attention in Carroll and Rosson's work (1987), under the umbrella-term: *active user paradox*. They discriminate between a production and assimilation paradox, of which especially the assimilation bias is of interest for our discussion of knowledge transfer. The production paradox entails the users' end-product focus and difficulty making the trade-off to either learn how to use software (and lose time by exploring and training) or just try it out (and lose time due to inefficient use of the program). In these observed cases, the latter usage is most dominant as they allow rapid but reckless and inefficient learner-directed progress. When introduced to new applications, novice users consistently avoid learning functionality (manuals, help-function, or local experts). This premature approach consists of using self-conceived heuristics and loose hypotheses for problem solving, which turns out is not very efficient. The same applies for expert users, albeit more subtly and with a stronger focus on balancing time investment with throughput. They either invest time and reap the benefits of learning more efficient methods in the long term, or suspend throughput via known but generally inefficient methods. In their observations, Carroll and Rosson found that many expert users were not exploring and did thus not find those functions which could have made their job much easier (1987). Essentially, users fail to see the long term benefits of investing time learning the software.

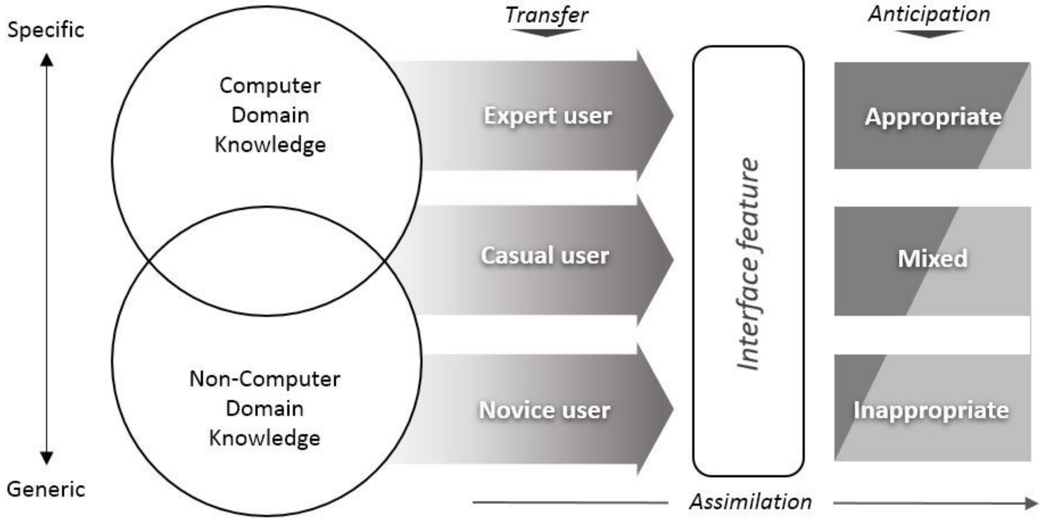

Figure 13. Illustration of assimilation bias, showing knowledge sources that influence knowledge transfer (assimilation) and resulting feature anticipation.

The assimilation paradox involves users' pre-existing knowledge outside the computer domain, which interferes with anticipation of functions for a new system (Figure 13). This cross-domain knowledge transfer may impair understanding due to ineffective intuitions (such as using Microsoft Word as a typewriter instead of a word processor). Novice users can be viewed as experts in their work domain, but novices in computer use (Carroll & Rosson, 1987). These users approach software with the intention to use it for the tasks involved in their work, but their pre-existing knowledge hampers their understanding of functions by wrongly attributing structural features to the software. In terms of intuitive reasoning, the perceptive system picks up cues that are matched with knowledge representations (*it is a typewriter*) which do not transfer well on the tasks provided by the novel software (*it really is a word processor*). The novice user gets an intuitive impulse which is not sufficient, because the knowledge first needs to be 'updated'. Because of the production bias, this update-process often never occurs, at least not without external motivation.

Expert users have broad prior knowledge of computer systems. The problem for these users is inappropriate transfer during remapping of similar function goals, where prior established behavior patterns inhibit learning of new patterns. Even though these problems decrease when the old software is abandoned, a second longer-lasting effect is that prior knowledge can blind users from fully anticipating functions. This is especially problematic since users may be completely unaware of this problem, they think they know everything they need to know and it gets the work done. This habit is where intuition becomes blinding, and software developers should not underestimate this behavior.

In the current digitally enhanced society, discriminating between novice and expert users does not suffice anymore. Instead we should assume that the number of people with basic computer experience has increased considerably (in the 'westernized' world). Finstad (2008) reacted to these developments with proposing a third class of users, the casual users. These are users of intermediate expertise, who are competent with using a limited set of applications without a primary reliance on them. According to Finstad, the production bias is less of an issue with these users, as they are much less motivated by throughput. Cognitively, casual users can be viewed as experts that are proficient in a few things, and are susceptible to assimilation bias because of this limited but concrete experience (2008). However, the number of novices is rapidly evolving into casual technology users and it could well be that in a couple of years, the distinction between casual and expert users will be the industry standard.

3.3.2 Surface and structure features

While Carroll observed that prior experience is often erroneously applied to understand a novel application, Finstad takes one step further by analysing *which kind of* knowledge inappropriately transfers. He distinguishes between knowledge about structural features and surface features of an application. Structural features are related to the result of a certain goal or function of the application (i.e. archive button shows all archived content). Surface features have to do with how it is presented to the user (i.e. archive is accessed through a button, hyperlink or icon).

Finstad's results show that having expert prior knowledge results in a more efficient understanding of discrepancies in structural features compared to having casual knowledge (2008), which is in line with previous studies that emphasize the differences between experts and novices (Chi, Feltovich, & Glaser, 1981; Shneiderman & Mayer, 1979; Shneiderman, 1976; Wiedenbeck, 1985). When discrepancies are encountered in surface features while structural features remain consistent, expert and casual users perform similar (figure 14). In general, experience may impair understanding, when users encounter familiar surface features but dissimilar structural features. Users can be prompted to apply analogous prior knowledge (and anticipate consistent structural features), by recognition of consistency in surface features in the interface. However, this does not apply when structural features are inconsistent with what they expect, based on experience with other applications.

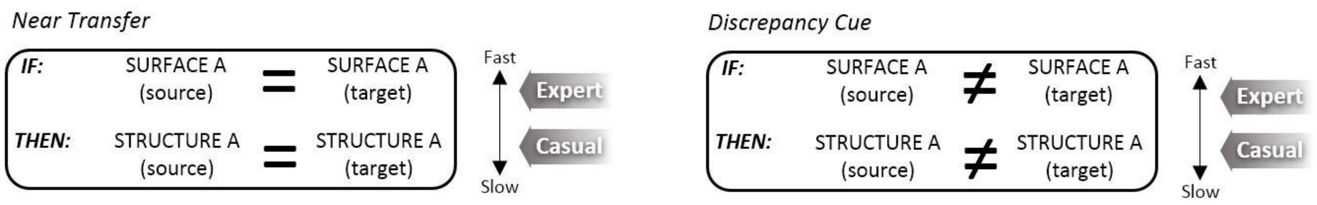

Figure 14. Appropriate transfer with near transfer and discrepancy cue signaling inconsistency.

Consistent surface features elicit anticipation of similar structural features (figure 14). If the structure is inconsistent, the expectations do not match and solving this problem takes longer. Experts perform better than casual users in these cases, because casual users do not have the experience to realize 'it must be wrong' and thus get lost more easily. Surprisingly, when both surface and structural features are inconsistent, both user classes perform faster than when only the structural features are inconsistent.

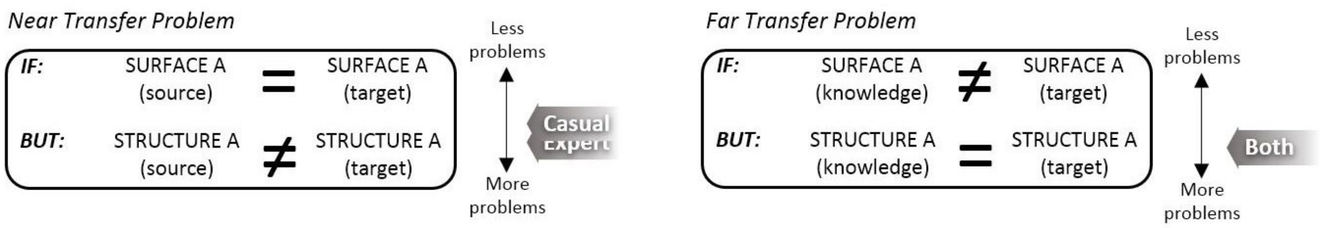

Figure 15. Inappropriate near and far transfer problems.

When surface features are consistent, they expect the structural features to be consistent as well, and get confused when this is not the case (figure 15). Additionally, experts spent more time on novel systems with inconsistent surface and consistent structural features, than on novel systems with no consistent features at all. It is likely that their prior experience lets them think that the inconsistence of the surface features rules out the possibility of consistent structural features. This is again in line with Carroll & Rosson's (1987) observations; prior knowledge does seem to confuse users, but as it turns out, only in specific cases.

3.3.3 Near and far transfer

Two types of knowledge transfer are directly relevant to the understanding of intuitive use: near transfer and far transfer. The terms *near* and *far* are derived from how 'deep' the transfer is processed, near transfer indicates that a source and target are similar on the surface, while far transfer is based on similarity of the underlying means-goal structure (Fischer et al., 2015; Gick & Holyoak, 1980, 1983). This phenomenon is demonstrated with a two-stage procedure in which participants are presented with a source problem and its solution, and subsequently have to solve a target problem. Transfer occurs when participants spontaneously reuse the source to solve the target, without being told about their similarity. Near transfer has been demonstrated to occur robustly, however, it even appeared to occur between structurally incompatible problems that were surface-similar (Holyoak & Koh, 1987).

In general terms, this means that users are led by the appearance of things and logically assume that when appearance is similar, the underlying functions must also be similar (and conversely). This notion is strengthened by the observations with far transfer problems where participants could not transfer knowledge between two structurally analogous problems with dissimilar surfaces (Gick & Holyoak, 1980, 1983). Gick and Holyoak demonstrated that surface-dissimilar devices can still be used intuitively. In their study (1983), participants were asked to first compare two problem instantiations of a convergence solution in writing, before solving the actual problem (i.e. successful far transfer). Their results showed that participants who emphasized the convergence solution in their comparisons could solve the problem, and the participants who instead focused on details of the source stories did not. The authors explained this by attributing the finding to the induction of a schema. When several instances of structurally similar problems have been studied, schema induction occurs, meaning that similar structures (patterns) are encoded as constant, while differing attributes are encoded as variables. What this means, is that the resulting representation can be transferred to instances that are new and superficially different. This coded representation, the *schema,* acts like a mediator for the transfer of knowledge onto new devices that have dissimilar surface features (Fischer et al., 2015).

3.4 Image schema theory

Hurtienne and Israel (2007) proposed a relatively new approach for designing Tangible User Interfaces (TUI). Their aims were to go beyond the paradigm of WIMP (windows, icons, menus, pointers) interaction and instead utilize people's experience of using real world objects. One of the arguments for this approach is uttered by Ishii and Ullmer: "general GUI's fall short of embracing the richness of human senses and skills people have developed through a lifetime of interaction with the physical world." (2001, pp. 240–241).

This led to propositions which utilized the concepts of embodiment and metaphor, to build interfaces that were tangible (grabbing, moving, and pinching). In a comprehensive framework on Tangible Interaction by Hornecker and Buur (2006), four themes were introduced; tangible manipulation, spatial interaction, embodied facilitation, and expressive representation. The first being the most basic quality, as given by their material representation. The second, spatial interaction refers to interactions as movements in space. Embodied facilitation refers to access points and constraints which stimulate and guide interactions, and expressive representation emphasizes the importance to provide tangible access to the salient parts of the model, so users can perceive the coupling.

Earlier work with TUI has been criticized (Hornecker & Buur, 2006) for relying too much on physical one-to-one mappings (i.e. using physical objects to model physical systems). However, in their paper, Hurtienne and Israel instead propose a method for mapping physical manipulations to more abstract data. To answer the question; what would be the Windows, Icons Menus and Pointers of such an approach? Hurtienne and Israel propose a taxonomy of subjectively meaningful patterns, which are cognitively processed at the sensorimotor level of knowledge; image schemas and their metaphorical extensions (2007).

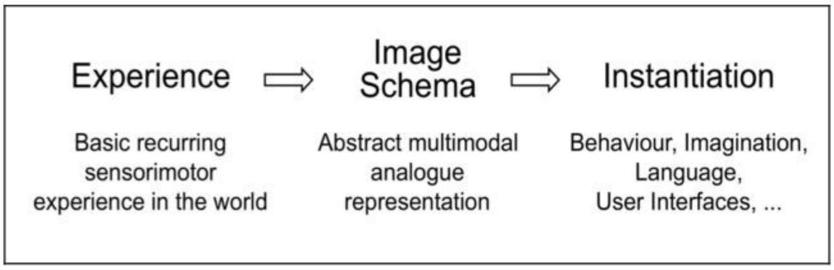

Figure 16. Acquisition, representation, and instantiation of image schemas (Hurtienne & Israel, 2007).

3.4.1 Image schema

The term *image schema* was first introduced by philosopher Mark Johnson: "An image schema is a recurring, dynamic pattern of perceptual interactions and motor programs that gives coherence and structure to our experience." (1987, p. xiv). He explains that recurring and similar interactions with the world leave traces of these experiences in the brain (figure 16). These traces resemble the perceptual and action processes that generated them, albeit in a highly abstract representation. The use of the term image schema is theoretically distinguished from the schema theory initially proposed by Frederic Bartlett (1932) by the addition of the term 'image' (Anderson & Pearson, 1984). Johnson explains this as *image* schemas being continuous structures or patterns of an organizing activity of *imagination*, by means of which we order and unify our perceptions, motor programs, spatial orientations, temporal sequences, and so forth. Yet it is surprising that neither Anderson, nor Johnson refer to each other in this respect. Additionally, the literature concerning intuitive design and 'image schema design', does not refer to the principles of schema theory by Anderson (1984), yet they appear to be closely related. As shown below, the key elements of a schema according to Bartlett (1932), and in Anderson's schema theory are essentially similar to principles proposed by Johnson (Hampe, 2005; Johnson, 1987, 1989).

1. An individual can memorize and use a schema without even realizing of doing so
2. Once a schema is developed, it tends to be stable over a long period of time
3. The human mind uses schemata to organize, retrieve, and encode chunks of important information
4. Schemata are accumulated over time and through different experiences

Bartlett (1932) suggested that human beings possess generic knowledge in the form of unconscious mental structures which he called schemata, and these structures produce schematized errors in recall when they interact with incoming information. He argued that through schemata, old knowledge influences new information. The image schema theory is further distanced from schema theory by its application of concrete examples and connection with primary metaphors (Hurtienne et al., 2015). Still it remains unclear in what way these two linguistic theories are influenced by each other.

Table 5. *Image schemas grouped by similarity*

Group	**Image Schemas**
BASIC SCHEMAS	SUBSTANCE, OBJECT
SPACE	UP-DOWN, LEFT-RIGHT, NEAR-FAR, FRONT-BACK, CENTER-PERIPHERY, STRAIGHT-CURVED, CONTACT, PATH, SCALE, LOCATION
CONTAINMENT	CONTAINER, IN-OUT, CONTENT, FULL-EMPTY, SURFACE
IDENTITY	FACE, MATCHING
MULTIPLICITY	MERGING, COLLECTION, SPLITTING, PART-WHOLE, COUNT-MASS, LINKAGE
PROCESS	SUPERIMPOSITIONS, ITERATION, CYCLE
FORCE	DIVERSION, COUNTERFORCE, RESTRAINT REMOVAL, RESISTANCE, ATTRACTION, COMPULSION. BLOCKAGE, BALANCE, MOMENTUM, ENABLEMENT
ATTRIBUTE	HEAVY-LIGHT, DARK-BRIGHT, BIG-SMALL, WARM-COLD, STRONG-WEAK

The most used example for an image schema is that of a container; our experience with containers in everyday life, for example glasses, rooms or boxes, has resulted in a mental representation of a CONTAINER image schema (figure 16). Everyone has an abstract idea what it is, and that it consists of an inside, an outside and that these are separated by a boundary. It has become general knowledge that does not have to be explained for it to be understood. The image schemas represent abstract knowledge that in a wider sense could be seen as building blocks of all knowledge construction. Many types have been identified, such as physical schemas of substance, objects and containment, or their relation and orientation within space such as force, identity, attributes, and multiplicity (Hampe, 2005; Hurtienne & Israel, 2007; Johnson, 1987), see table 5 for an overview. In addition to Johnsons work, several studies have confirmed that people indeed activate image-schematic metaphors when they interact with technology (Blackler, 2008; Hurtienne, 2009; Macaranas, Antle, & Riecke, 2012). For an extensive overview of image schema related studies, and its application in design, see Hurtienne et al (2015).

3.4.2 Entailments

Image schemas are schematic in nature, they capture the traces of sensory-motor experiences, and as such are not just symbols or icons. These traces exist beneath conscious awareness and can be represented in either visual, haptic, kinesthetic, or acoustic ways. Image schemas are abstract, holistic gestalts (Lakoff, 1987; Johnson, 1987). Its characteristics are obtained from the experiential 'entailments' that form part of their meaning (Hurtienne 2006, p. 46). These entailments can be abstract qualities or properties, which could be interpreted as such depending on the context and situation in which the image schema is encountered or applied. In the example of the container: the container could provide protection from the external environment, its boundary could limit the contents, and the content's location is determined by the location of the container. Just by thinking of a container, these entailments come to mind and are implicitly understood. Other schemas have more abstract conceptual entailments, such as force and counterforce, or center and periphery, these do not relate to physical objects or substances but instead to abstract relations between them.

3.4.3 Metaphorical extensions

Hurtienne and Israel argue that the actual strength of using image schemas in design lies in their metaphorical extension, which helps structuring of abstract concepts. The origins of image schemas stem from work in cognitive linguistics (Johnson, 1987; Lakoff, 1999). Johnson and Lakoff argue that everyday experiences with objects in spaces have eventually been coded in words (e.g. *up, down, in, out*), not only to describe these experiences, but to describe the abstract concepts they represent. As such, these words can be used metaphorically and represent how we conceptually understand the world. Thinking about abstract domains seems hardly possible without using conceptual metaphors. Hurtienne et al. argue if image schemas are responsible for the structuring of most metaphorical mappings, then they are regularly involved in thinking about abstract domains and concepts (Hurtienne et al., 2015). Most notably, the multi-modal applicability of the abstract schemas in everyday thinking results in a frequency of usage that becomes quickly integrated and submerges beneath conscious awareness.

Metaphorical extension and image schemas co-occur and these gain more complex relations over time. Repeated co-activation of an image schema with a specific subjective experience or judgment eventually leads to a connection between these two. Grady (1997) argues that the subsequent permanent co-activation of these structures in the brain makes it possible to activate such subjective experiences without the physical stimulus being present. In a sense, the physicality of the image schema is correlated to the subjective qualities. Quantity of substance for example is connected to a verticality schema (up-down), however, these connections over time become generalized and the schema of verticality gets transferred to quantities of all sorts, even non-physical ones (Grady, 1997).

This phenomenon is also described by the invariance hypothesis, which states that image schemas are fundamental in structuring more complex and abstract expressions which are not examples of primary metaphors (Lakoff, 1999). For example, one could describe the performance of a business as traversing a hill: *We hit a peak last year, but it's going downhill ever since.* The expression does not directly come from the image schema of verticality as source domain, but this schema is still responsible for the generation of it. In lien with the invariance hypothesis, image schemas form the *basic structure* which is transferred from the source domain to the target domain (Grady, 1997).

These theories place metaphorical understanding in a new perspective, because a computer metaphor such as *desktop* appears not to be merely understood *because we transfer the knowledge of a physical desktop to the computer domain.* Additionally, the metaphor seems to serve as a vehicle for the transfer of several image schemas that lie at the heart of the metaphor-based understanding of a desktop. A desktop is a *container*, it contains several *objects*, and these again have relations which could also be understood through image schemas (i.e. *center-periphery, force, paths, merge, and collections*). The power of image schemas is that they are so abstract that they can be used to instantiate many different metaphorical extensions. In a context of interface design, this abstract language of image schemas leaves enough room for designers to decide how to instantiate these. Moreover, this means that direct mimicking of established interfaces is no longer the only way to make novel intuitive interfaces implicitly understandable.

3.4.4 Application in design

For additional insight in the method and results of using image schemas in design, a thorough overview is provided by Hurtienne et al. (2015). For the purpose of clarity, we give a short summary. The method is integrated in the principles of contextual design (Beyer & Holtzblatt, 1999; Holtzblatt, 2009), extending the first step (contextual interviews and interpretation) with image schema tagging, the construction of image-schematic metaphors and clustering. The contextual interviews are then transcribed and the designer annotates sentences, phrases, and words that are key to the natural usage of a specific product with image schemas. This is an unusual task for untrained designers, as it involves taking every user expression literally. Hurtienne et al. (2015) argue that image schemas can reveal themselves via prepositions (e.g. *in, inside* may instantiate a CONTAINER image schema) or verbs (e.g. *block, prevent, refrain* may instantiate a BLOCKAGE image schema). Consider the following example sentences from an interview transcript in the context of designing an interface for a radio application.

<u>Interview transcript</u>

1. SR4, BR3, and Kaiserslautern are the radio stations that I listen to.
2. I turn down the volume when the radio news comes on.
3. My favorite song is running on channel four.

With image schema tagging, the relevant image schemas that structure the user's mental models of the domain are extracted from the sentences. The next step is to connect the abstract concepts that image schemas stand for and making explicit which primary metaphor was instantiated, this is documented in the form of TARGET DOMAIN is IMAGE SCHEMA.

<u>Image schema analysis</u>

1. [Radio stations that I listen to] are COLLECTIONS of stations. [Directing my attention to a radio station] is putting the station at the end of a PATH.
2. [Setting the volume] is ROTATION, [loud] is UP, and [soft] is DOWN.
3. [Broadcasting] is SELF-MOTION [on] a PATH, and [items that can be listened to] are in CONTACT

The above analysis indicates which kind of image schemas are used and guides designers in creating features that are intuitive to use. The next steps in the process do not deviate much from the regular contextual design method, including the construction of an affinity diagram, wall-walk and paper mock-ups. These steps are described in depth by the work of Hurtienne et al. (2015).

3.4.5 Image schemas and intuition

Connecting the image schema theory with the explored psychological properties of intuition and intuitive interaction processes, there are good reasons to argue that the abstract schemas lend themselves well for intuitive processing. The abstract image schemas reside at a lower cognitive level of knowledge, within the sensorimotor domain. They are processed with ease in terms of cognitive effort, by being regularly involved in thinking, the schemas and primary metaphors have become non-conscious and effortlessly accessible to the intuitive mind. For example, when someone perceives a cookie box, the CONTAINER image schema is immediately recognized and understood. When this person wants the cookie (the substance), he knows the cookie box (boundary) holds them inside. To get to the cookie, this person implicitly understands that there must be an opening somewhere to get the cookie out. This example of a container as building block of understanding, albeit quite basic, demonstrates that the schema is intuitively understood. In real world context, the container schema can be identified in many different things and concepts in the world around us. The same holds for the other image schemas, and in a sense, everything around us can be understood as formations of many different schemas. Imagine a house as a big container with many sub-containers (rooms), which contain objects and small containers with substances and all these have relations and interactions that can be represented with image schemas. Because image schemas develop from everyday basic sensorimotor experiences, they are better understood by different user populations who can make sense of it through universal understanding of the abstract image schematic language. Finally, as we have argued previously in this article, image schemas can be accessed effortlessly and without deliberate conscious control. Since most users interact with devices to perform many daily tasks, we can assume that most users do not always have sufficient cognitive resources, and more often than not tend to interact with them depending on lower-level mental processes in favor of high-level moderation.

4 Discussion

4.1 The sweet spot for design

In the above two chapters, many aspects of intuition and intuitive design have been explained and the popularity of intuition in a design context has increased. Most noteworthy, it has become clear that intuitive design has progressed from a focus that aimed to elicit intuitive use by familiarity (based on similarity with earlier products and technology). The most recent views try to steer away from this approach (Blackler & Hurtienne, 2007; Hurtienne & Israel, 2007; Hurtienne et al., 2015) , mainly because it is paradoxical, as illustrated by Raskin: *"If a design is to be superior, it must be different. Therefore, it cannot be intuitive, that is, familiar. (…) That quality of a new interface paradigm that is commonly titled 'intuitive' may well turn out to be one of the worst qualities it can have."* (1997, p. 18). Instead, the current focus is on eliciting fluid interaction based on a good fit between intuitive processing and knowledge structures such as image schemas and primary metaphors.

The aim of this concluding chapter is to argue *why* understanding of intuition is so important for interface design. The interaction between user and computer is essentially consisting of multiple continuous loops of information-transfer where both interact as sender and receiver. Why is intuition the sweet spot for this transfer? This is best explained as a two way effect, at one side found in the characteristics of the users' cognitive processes involved with interpreting information in a computer environment. At the other side in the composition of the interface, which elicits transfer of information that is carefully attuned to intuitive processing.

In terms of processing, we have explained that intuitive processing is happening for better or worse, and since the focus on similarity-based designs has offered good results for interaction, designers have gotten away with it for a long time. However, designs that mimic established standards do not capitalize on the qualities of the intuitive system. Such interaction could be better described as capitalizing on overlearned habit, 'because it always worked like that'. Yet, with increasingly natural input such as touch and gestures, interfaces need to be more carefully attuned to the low level intuitive mechanism to make interaction truly fluid and natural. Especially during complex tasks with high cognitive demands, such as operating a car-radio or using a cellphone while doing something else.

4.2 Capitalizing on intuition

The characteristics of the intuitive system and its emergence in human cognition have been explored in the first chapter. In this section, several aspects of intuition are highlighted to explain their benefits in design. To reach the widest audiences, we consider intuition the most fitting mode between the conscious controlled problem solving at one end, and non-conscious automatic learned skills and reflexes on the other end (figure 17).

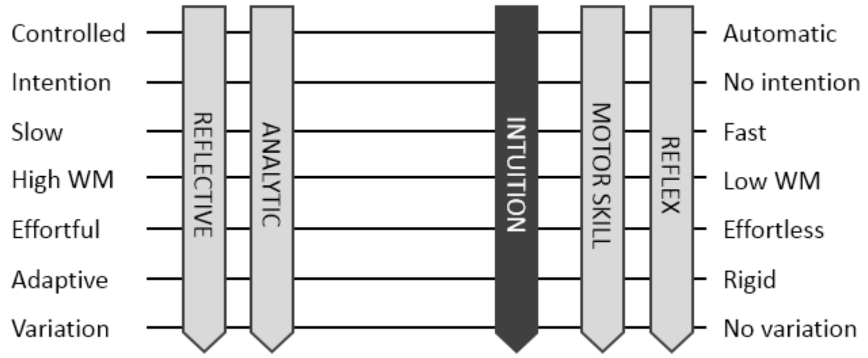

Figure 17. Human processing continuum with added axis indicating overall variation in performance between individuals.

4.2.1 *Conscious awareness*

Due to the increased technology integration in daily life, we operate electronic devices highly frequently and often while doing something else or to control a complex machine such as a television or microwave. This has the consequence that we simply cannot always be fully focused and aware while using them. In such cases, being able to interact with devices in a semi-automatic mode, without consciously focusing on understanding its interactive features is very convenient. Especially in professional contexts, where high work pressure, throughput focus and tiredness all have deteriorating effects on awareness and cognitive focus. Another benefit of intuitions operating beneath conscious awareness, is that the intuitions themselves seem inherent and feel natural to the user. Apart from fluent interaction this has the benefit of increased satisfaction and self-confidence when the intuitions turn out to be correct.

4.2.2 *Cognitive efficiency*

Intuitive processing has the best balance between highest efficiency and least prior learning investment. As shown in the continua (figure 17), the cognitive workload decreases from left to right. More automated skills such as reflexes or motor sequences are more rigid and specific, and dependent on heavy overlearning. On the left side, reflective reasoning and problem solving are considerably less efficient because these depend on focus and cognitive resources. In a professional context, a cognitive efficient mode of reasoning is preferred because users need all their cognitive focus for the task at hand. The less energy spent on figuring out how the interface can facilitate these tasks, the more time and energy is left to actually do the work.

4.2.3 *Multimodal*

Gestalts such as image schemas and metaphors are multimodal and can be understood and interpreted intuitively in many ways, depending on context and previous knowledge. This is also the strength of explaining image schemas as a meta-language, because they convey concepts and relations which are otherwise difficult to comprehend (Lakoff, 1999). Intuition is essentially based on pattern recognition which is not inherently flexible, yet the processing (moderation, regulation) of intuitions by higher level reasoning is what makes intuitive reasoning seem flexible.

4.3 Dark sides of intuition

There are some dark sides of intuition, and it is the job of designers to acknowledge and mitigate them. The intuitive system does what it does and while it is dependent on knowledge, it does not discriminate nor validate it. Human functioning on a daily basis or in work contexts is dependent on the interplay between Type 1 and Type 2 reasoning. There is a constant interplay between impressions formed by the lower level perceptive and intuitive mental processes, and the higher level processes that monitor, moderate and reflect on them. Because the higher level processes are cognitively demanding, they risk deteriorating due to work strain, tiredness, or generally not focusing. This results in unmoderated intuitions slipping through and a higher chance of errors.

As Kahneman and Klein (2009) argued, individuals can develop intuitions based on predictions that have emerged from unpredictable contexts or environments. When the intuitive response comes to mind, higher level cognitive analysis could potentially correct these errors before a response is made. But when work pressure and fatigue increase, high level reasoning may deteriorate and force individuals to fall back on low level processing. In such cases, unpredictable environments can become hazardous grounds for fruitful intuitive decision making. Additionally, it is difficult to control whether people act on their intuitions or not. Even experts can ignore their intuitive impulses or instead rely on their intuitions too much (illustrated by the contrasting positions by Klein & Kahneman).

Second, the transient nature of intuition makes it hard to concretize how intuitions work exactly and what the boundaries of 'an intuition' are. For instance, when we speak of an intuitive decision, is that not a paradox? According to the tripartite model of the mind it is not the decision itself that is intuitive, but only the information that comes from the autonomous (Evans & Stanovich, 2013), or Type 1 system (Kahneman, 2003; Simon, 1981). The whole decision is made through interplay with the reflective and algorithmic minds, which is not universally 'intuitive'. Do expert intuitions eventually come to contain responses that could be characterized as 'encapsulated' Type 2 reasoning outcomes? It is demonstrated that with increased experience, experts make decisions very rapidly (Kahneman & Klein, 2009), and it seems logical that higher level analysis outcomes become encapsulated within intuitions. In the case that it does, the term intuitive decision may be accurate after all. This distinction is illustrated in figures 18A and 18B, in the second figure, decisions submerge beneath awareness when type 2 analysis becomes optional. There, the decision maker deliberately chooses to reflect upon the predicted outcome that fully emerged from the intuition. In cases where work-pressure and consequent fatigue increase, this 'double check' can be left out (Kahneman, 2003, 2011; Rasmussen & Vicente, 1989).

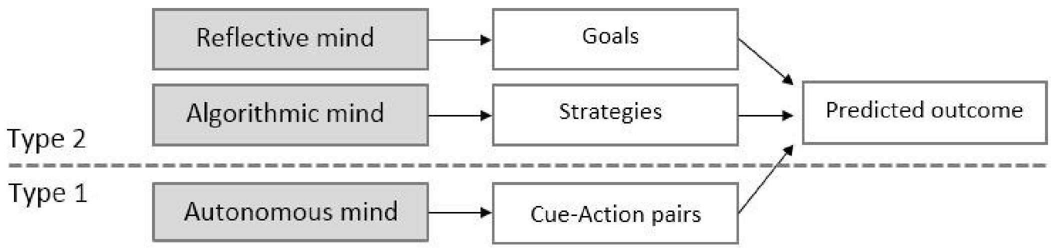

Figure 18A. Type 1-2 distinction without non-conscious higher level processing. Predicted outcome and consequent action are operated in full awareness.

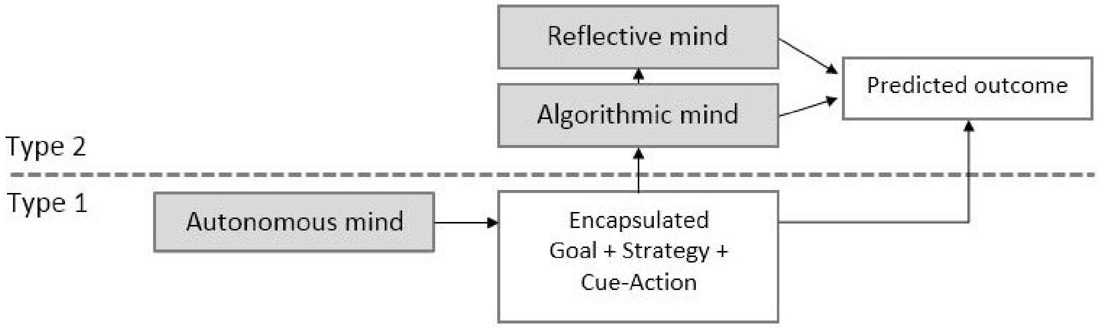

Figure 18B. Type 1-2 distinction with non-conscious higher level processing. Predicted outcome and consequent action emerge to awareness from non-conscious encapsulated knowledge. Type 2 processing is optional.

Third, there is the issue with knowledge transfer, because apart from specific knowledge of an environment, general rules are also learned. This general knowledge could transfer to other domain contexts. This is an issue because it becomes difficult to discriminate between general and specific knowledge, or to predict which kind of knowledge is tapped on by the intuitive systems. It seems probable that in novel situations where specific cues fail to elicit intuitions, general knowledge could provide a frame of reference that could be intuited upon. However, the exact interplay between general and specific knowledge is difficult to ascertain. Also demonstrated by the Active User Paradox, the application of general knowledge can become dominant and disrupt a more knowledge-based approach to explore new features (Carroll & Rosson, 1987).

4.3.1 Problems with computer environments

In the context of human computer interaction, many interactions are guided by intuition. Apart from the abovementioned problems inherent to the cognitive mechanism, intuition can cause problems when its environment becomes unstable. If the input devices (mouse, keyboard, touch) combined with the interface constitute the external and internal environment of a computer user, the question is if this environment is of high-validity. According to Kahneman & Klein (2009), these environments need to have stable, objective and potentially predictable cues that lead to subsequent events or actions. In a computer environment, the basic purpose of input devices and interfaces is to facilitate actions or events (goal directed tasks). Ideally, each computer environment is more stable and potentially predictable than any real life environment, because behind every button is an action.

The notion of a high validity environment and expertise in using computer interfaces is of interest because it means that this is fruitful ground for intuitive judgment and decision making. However, it is a double-edged sword, because intuitive processing can also become debilitating for fluent interaction. Because computer environments are constructed by humans, they are diverse and dynamic. Besides, many computer programs are highly specific, and it is not always possible to correctly transfer knowledge from one to the other. In the case that it is, intuitive processing can be enhancing. In the case it is not, it becomes debilitating, users will expect to find certain actions and events behind certain cues (buttons, clickable links, and navigation) which could be problematic if such expectations are not met (Carroll & Rosson, 1987; Finstad, 2008; Fischer et al., 2015; Holyoak & Koh, 1987).

The consequence for design, especially in established environments is a high pressure on familiarity mostly by similarity. There are many examples, for instance Whatsapp messenger, that are so deeply embedded in our computer lives that it will be hard to deviate from those standards. Competitors must be hard pressed to come up with something fresh and wonderfully user-friendly, to motivate people to invest energy to adapt and adopt to new standards. What happens when household brands deviate from their own standards is a familiar story to the Windows users among us. Either totally overhaul the interface and make it really fresh and intuitive, or stick with the standards and improve incrementally. A bit of both is often confusing and disrupts the habituated expectations that have been learned and reinforced over many years of use. It also deteriorates exploration of new features because the old learned patterns are stronger and take less cognitive energy to process, familiarized users do not show a tendency to explore new features when the familiar context elicits habituated responses (Carroll & Rosson, 1987).

Finally, there is the issue with designing novel features. Because in these cases there is no example, thus users do not have any former knowledge of using it. The solution to this problem can be found in a deeper understanding of how knowledge is transferred. In a wider sense, knowledge transfer is a core-concept of human computer interaction, especially in terms of design. Ultimately, using a computer is about the understanding of functions that solve specific tasks, and the interface serves to relay this information to the user. So when there is neither specific nor generic knowledge about a new feature, intuition can be based on more abstract knowledge structures that are universal and easily transferrable.

4.4 Implications of image schemas

Image schemas are dependent on sensorimotor experiences, and are not dependent on specific domain knowledge. This means that designs based on image schemas may mitigate (or avoid) many problems with far-transfer because it is not necessarily based on that kind of transfer. The research on image schema based design methods is still quite young, but produces promising results already (Blackler et al., 2010; Hurtienne et al., 2015; Hurtienne, 2009). With image schemas, a new abstract dimension of feature comprehension has opened up to interface designers. In particular facilitated by recognition based on early learned sensorimotor knowledge that is integrated in our abstract comprehension of those things and situations that every person has encountered before. Intuitive methods and in particular image schemas have several promising characteristics for interface designers and software developers, which are described and argued below.

4.4.1 Low-level accessibility

Image schemas are suggested to operate on a low cognitive level, meaning they are processed near spontaneous and effortlessly. This may be its greatest strength considering the fact that most people cannot always engage in deliberate higher level monitoring of the impressions produced by the intuitive systems. As such, interface feature design based on image schematic principles could ideally capitalize on this fall-back onto lower level reasoning. The abstract and multimodal properties of image schemas give way to instantiate many different metaphorical extensions, which leaves much room for designers to decide how to instantiate them (Hurtienne & Israel, 2007). Additionally, the principles of image schema design can be smoothly adopted into existing methodologies (Hurtienne et al., 2015).

4.4.2 Inclusiveness

Inclusive products are products that are ubiquitous, they can be used by the widest range of users regardless of background, age, knowledge or abilities. Being based on abstract sensorimotor experiences, the image schemas can be understood independent of computer domain knowledge, which is especially important when wide audiences are considered. Progressing interface design towards more image schema focused approaches should result in interfaces that can be understood independent of prior computer knowledge or familiarity with similar devices or software. This opens up a whole new range of users that have never been in contact much with the digital domain. Yet, there is still a long way to go, and combatting the established standards will take time. Still, the plea for image schema design does not per se discard similarity based design, because the current state of the technology proves it works, and similarity-based designs continue to feed our intuitive systems sufficiently for fluid interaction. Nonetheless there are still many examples of interfaces that just do not click and take much time to comprehend and learn. To include the most, if not all users as a viable audience, image schema design methods show potential, and deserve more extensive investigation within HCI.

4.4.3 Innovation-proof

Interfaces become increasingly important to safeguard fluent interaction between humans and technology. The reach of technology has widened its audience considerably, and the overall usability of interfaces has increased to make technology more accessible. However, it feels as if a focus on universal standards and similarity has become the dominant approach. Familiarity with prior technology use is a big factor in this, and on the surface it would seem that standardization and similarity is the way to go. However in the long term, this approach may rigidize and threaten innovation in interface design overall.

In a recent paper, this problem is illustrated as a *tension* between innovation, inclusiveness and intuitiveness (Hurtienne et al., 2015). The authors state that technology is dynamic and progressing at a steady pace, and new functionality and interaction possibilities emerge that never before have been possible. Yet, they argue how these new functionalities can be conveyed to the users, when the design is reduced to mimicking previous technology not capable of these functionalities? Innovative products go beyond the state of the art in that they are new, advanced and original. Products need to be stimulating, novel and exciting to be noticed in the jungle of devices, applications and websites (Hassenzahl, 2003). Future design methods that implement image schemas could offer the solutions to reduce this tension, because they enable understanding independent of former computer knowledge.

4.4.4 Artificial environments

One of the dark sides of intuition that has been discussed is the fact that unstable, unpredictable environments can produce intuitions based on stored knowledge that is not trustworthy. In the real world, this is a problem for instance in the financial business, with potentially devastating consequences. However, this is not a problem for computer contexts because these environments in fact are artificial and can be modified. From the work by Klein and Kahneman (2009), we highlight the argument that the environment has to be of high-validity (i.e. stable, predictable cue-action patterns) for intuition to work. In terms of computer interfaces this predictability is its definition, computers essentially exist by virtue of predictable patterns of zeroes and ones. Once programmed, a button is always going to activate the same thing, it will never change unless reprogrammed. Thus by being an artificial environment, it has the potential to be tailored to be as stable and predictable as we want. From this we extract that over time, these environments can facilitate low-level intuitions that are based on reliable cue-action patterns.

4.4.5 Affective motivation

The history of technological innovation shows a remarkable trend in how the general public reacts to innovation. Most new inventions have evoked some form of unrest or anxiety, as what is new threatens the known and expected. For example, when the steam train was introduced in 1825, people protested as they feared for the foundations of houses and the wellbeing of their cattle (which presumably would suffer and die from the stress caused by passing trains). Also, there were serious doubts if the human body was capable to travel at such incredible speeds (30 mph). Many new inventions received a similar treatment, such as televisions ('fear of ruining one's eyes'), telephones ('an instrument of the devil') and of course computers. Surprisingly, all these inventions are currently integrated in our everyday lives. Apparently, something about novel technology scares people, which is often described as the innate fear of technology, and labelled *computer avoidance* (Kernan & Howard, 1990) or *apprehensiveness* (Chidambaram, 2000). In the context of internet use, issues such as environmental instability, user competence, security, trust and privacy have all been cited as factors contributing to consumers' apprehensiveness (Hoffman, Novak, & Peralta, 1999; Susskind & Stefanone, 2010).

Fear of technology makes sense from an evolutionary perspective: humans have always been dependent on the awareness of any novel stimuli, to anticipate potentially dangerous situations. However, the fact that people tend to irrationally project fearful, harmful or other negative properties into their perception of a technology is not explained by this perspective. It is likely a counter-reaction to our innate desire to predict and control our direct environment. When a new technology is introduced, it could threaten the familiar contexts and expectations that people have gotten used to. In the past couple of years, however, technological advancement has rapidly increased in frequency and impact. The outbreaks of panic and anxiety have reduced in scale and length, instead becoming shorter negative buzzes with magnitude that follow up in rapid succession (i.e. Snapchat, Uber, Glass, drones). It is possible that the general public has become more resilient to technological change.

Another explanation is that fear of technology has reduced because devices have become more ubiquitously accessible to users. Studies of technology acceptance have attempted to unravel this subjective negative affection towards digital devices (see appendix B for a short review). Among many factors, one of the key constructs is the perceived ease of use (Davis, 1989). It would be worthwhile to examine its relation with intuitiveness, because in theory it makes sense that intuitive interfaces are more positively received. Interfaces that help make technology more accessible to use may help mitigating general computer avoidance. Due to being independent of former technology knowledge, image schema based design is especially of value to those groups of users that are not technology savvy. With the additional benefit that intuitively tangible features elicit satisfaction and improve self-confidence (Macaranas et al., 2015). Because the image schemas are ubiquitously understood (if properly implemented), they in theory have the potential to seamlessly produce intuitive understanding which feels integral and effortless to the user.

4.5 Final recommendation

In all, we hope to have highlighted the importance of progressing intuitive design towards a more user-central approach. Instead of relying on prior technology knowledge, intuitive interaction can be achieved with other, more naturally understood designs. Image schemas seem to be the perfect match for the intuitive system, yet the recent results are at an early stage. Nonetheless they have proven to be promising so far, especially because the cognitive characteristics indicate that image schemas may be part of, and responsible for those aspects of recognition that we call intuition. The low-level characteristics of such image schemas suggest accessibility as a failsafe on which users can fall back to, in situations where deliberate reasoning is not accessible, either due to time, cognitive or attentional constraints.

Hopefully, we can stimulate software designers and developers to embrace this new knowledge as the basis for new methodologies. Yet, there is a long way to go to combat the encroaching similarity paradigm because even though it is a shortcut, it works. We warn for the long term consequences of such a method, because eventually the standards become rigid and stale. Consequentially, the digital landscape risks turning into an uninspiring blob of similar looking interfaces that deteriorate innovation and dull the minds of computer users.

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Appendix A

This thesis is loosely inspired on a collaboration with an e-commerce startup project that asked us to investigate metaphors and intuitive design for the purpose of a finding a new metaphor for their fresh ideas. Yet, over time the startup project has not come to fruition, and both parties have gone separate ways. In this appendix, the ideas and principles of the project are described.

E-commerce project description

Initially, the e-commerce project had just been through the first conceptual stages of development, as such many of its features were not yet established or in a very early conceptual stage. However, the focus and ideas were quite clear from the start. At first, the project aimed to mitigate the recent wild growth of commercial websites by providing a third-party platform, connecting several brands and retailers to the shoppers. The multitude of online shops come with different registration forms, payment options, delivery procedures and other obstacles to the shopping flow. The project owners have recognized this problem, by aiming to provide a single solution that transforms the shopping flow into a more streamlined experience with minimal administrative user action.

Their second selling point was an emphasis on user experience, attempting to make online shopping more convenient and accessible. The project owners proposed: 'customers don't log in to the shops, but the shops log in to the customers'. What this idea suggests is that with intelligent system design, users could be motivated to advertise themselves as prospective customers via their profile. As long as they are given the means to express their preferences and objections in a clear and open way, and as long as retailers and brands abide to these, a healthy customer relationship can be constructed that is a win-win situation for both parties. Additionally, they emphasized convenience in shopping, which pleads for a smooth and intuitive interaction with the interface.

From ideas to design challenges

The idea on which this current e-commerce platform is built is refreshing; turning the customer-advertiser relation around. This idea could evolve into an intelligent application that allows users to create a specific profile, 'advertising' themselves as prospective customers with specific wishes. Ultimately, this enables retailers and brands to connect with the right customers, by combining data of the user profiles and usage statistics such as purchase history, favorite products, and peer reviews. However, such a system also faces some notable challenges, it places extra stress on several features such as its recommendation system, the search engine, and overall design qualities such as intuitiveness and overall usability. Ultimately, for the system to thrive, it needs input and information from its users. It is thus quite dependent on customers' motivation to use this kind of technology and.

Because of the myriad of features and subsystems that need to be designed, this thesis is focused on a selection of design challenges from a cognitive psychological user perspective. Interest goes out to understanding the users' motivation and behavior while interacting with the system, by reviewing technology acceptance (Davis, 1989) and the active user paradox (Carroll & Rosson, 1987). Additionally, human intuition and its effects on computer interaction is reviewed to explain how users interact with interfaces in a natural and intuitive way, and more specifically, to offer principles that may guide interface designers.

Due to the early conceptual stage of development and the rough nature of the projects goals and features, it is unclear how the application will work exactly. For instance, which features are planned in which screen exactly, or how do they work and interact? Therefore, this thesis shall focus on several characteristic key ideas and features of the project, which serve as reference points throughout this article. The ultimate goal is to conclude with propositions for several design challenges and provide theoretically grounded solutions and principles that may support developers to anticipate and overcome these challenges in early development. In terms of value, it is more cost efficient to think about user-centered early in the development cycle, instead of noticing problems during evaluations of the software in later stages.

Project description

First, the e-commerce project in question needs some explanation to give insight into what kind of system is being developed here. It should be noted that some of the features and ideas may have been carried a little further than originally intended by the developer. This should be perceived as the inevitable side-effect of inference, and anticipation on how this application would most likely function.

In broad strokes, the project is quite similar to many e-commerce web stores. Users log into the store with a personal account, search products with a search engine, and receive smart recommendations. They can compare products, save them for later purchase, mark their favorite products or brands and purchase products through a single registration procedure with subsequently fast checkouts. Where the project becomes innovative, is in the notion to have users specifically choose which brands or retailers they want to get offers from, providing increased autonomy for the user and a high amount of control of what is advertised to them. Additionally, the project could innovate in terms of promoting transparency and trust to the customers, depending on how far they will take that. In the following, the project is explained in more depth.

Project principles

Primary to the features, the project owners have developed a few general statements related to system wide functioning. While these statements are abstracted and generalized, they represent an important focus throughout the project.

Mobile focused. The project owners argued for a heavy focus on mobile development. According to their market research, mobile shopping has never really taken off and suffers from a high percentage of shopping cart abandonment. Their explanation for this behavior is that on most accounts, the checkout and especially filling in forms is still fiddly and often not designed specifically for mobile application. Aside from the usual differences with mobile development, the limited screen space in particular places some extra constraints on the interface design overall, especially in terms of usability. One advantage of mobile applications in particular is to make use of the habitually accepted mechanism of push notifications, which are ideal for personalized flash sales.

Rewarding input. With the idea to combine multiple trusted retailers into one application, and ambition to become a leading e-commerce hub for the Netherlands, the project is dependent on a returning customer base. The project owners know this, and have devised a system that extrinsically rewards users for input (product evaluation, profile completion) the choice to pick up orders instead of delivery, and for using the platform in general. Somewhat related to the savings stamps collected at supermarkets, customers can build up points that can be traded for leisure activities and other special products. Aside from the question if such motivation will have the desired effect, in theory it is an extra incentive to bind customers and reward them to invest in the application.

Convenient experience. Primary to rewarding users extrinsically, the shopping experience should be rewarding on an intrinsic level. The project owners explained this with a metaphor; the trusted local corner shop of the early nineties. This grocer knew who you were, which products you usually bought and which type brands you preferred. In other words: they aim to provide intrinsic satisfaction with a shopping experience that is perceived as trusted and reliable, and can be interacted with intuitively and with ease of use. These principles are to be applied system wide, and exert the most pressure on interface design, and procedurally on the interactive features of the application.

Adoption. Even though the developer did not explicitly state this, an inherent principle of any software is the ambition to be used and adopted by many people. Therefore, stimulating adoption is one of the overarching principles of this project. From a marketing perspective, e-commerce leans heavily on three major principles; attracting visitors, converting them to customers, and retaining them on the long term.

Key features

Personalized dashboard. Users will be provided with a personalized dashboard that shows all the brands and retailers that this users has allowed connections from. It will have functions to cluster items and further allow full control of how the items are ordered on this screen, which have a direct impact on the storefront presentation. This dashboard is an important hub for the users, it allows fine-tuning of the user profile and insight in the users' preferences, favorites, purchase history and settings, which have a major impact on the overall functioning of the application.

Personalized storefront. The storefront will be the default entry point for the stores' main functionality. It will combine a search engine with a matrix-based presentation of products. The exact products that are shown are recommendations and offers, directly influenced by the dashboard configuration and usage statistics. However, the specific operation of the storefront upon first encounter, and whether it will start as a clean slate or give default recommendations based on general popularity, is unclear at this time.

Recommendation system. As is customary and utterly necessary with contemporary web stores, a recommendation system will be developed to assist the user in browsing the potentially enormous number of products. This system is directly dependent on two types of input, the explicitly customized dashboard configuration and the implicit usage statistics of the user. Additionally, a third type of input may be used that is based on user statistics of the user's peers (if applicable), or the general population.

Search engine. The search engine is stated to be easy to use and responsive, similar in its functioning to Google search. The search engine can be complemented (to an extent) by the recommendation system, to allow presentation of related results based on the user profile and statistics. The results are expected to present products related to the search in a clear and concise manner, explicitly showing brand, retailer and most importantly the products' name and price. Additionally, it is most likely that these results can be sorted through several metadata filters to help narrow the search.

Product presentation. The clear presentation of the product and its metadata are critical to any web store, as it has the biggest risk of becoming messy due to the number of features that can be implemented here. Features that have been explicitly stated by the developers are a product comparison feature, save for later, add to cart, fast checkout, and product evaluation details. Metadata assumed to be presented are: product name, price, brand, retailer, delivery details, and product rating. Additionally, details such as when the product is placed in the store (novelty), personalized recommendation based on peers (i.e. which peers also purchased), and presentation of similar or complementary product recommendations are also considered.

Product evaluation. Product evaluation is a powerful feedback mechanism that is informative for the brands and retailers but also for the customers. However, for it to have merit, it needs a lot of input, a rating based on 10 votes has less impact than a rating based on 1000 votes. This relies on a convenient and usable feedback system that allows users to rate products with ease. The developers already stated that they have a system in place to reward users for completing a products' feedback. How the feedback system will accommodate the evaluations is not yet decided, it could be a grade from 1 to 10, or the common 5 star rating system. Neither is it clear whether customers are allowed to elaborate on their rating as is commonly encountered in the form of text-based reviews or recommendations, but for the purpose of completeness, let's assume this is the case.

Appendix B

Technology acceptance

One of the first models for technology adaptation was proposed by Fred Davis (1980) to assess why users accept or reject information technology. This model is an adaptation of the theory of reasoned action (TRA) by Fishbein and Ajzen (1975) that has proven effective in explaining human behavior in many contexts. Davis suggests that beliefs about perceived ease of use (PEU) and perceived usefulness (PU) in computer use, determine the attitude towards actually using it (fig x). PU is described as “the degree to which a person believes that using a particular system would enhance his or her job performance” (Davis, 1989, p. 320); PEU is described as “the degree to which a person believes that using a particular system would be free of effort” (Davis, 1989, p. 320).

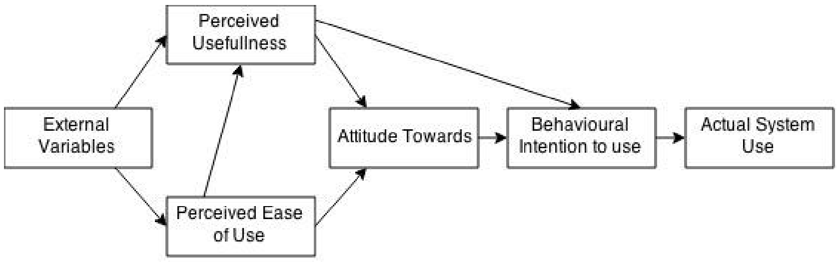

Figure 1. Early technology acceptance model (Davis, 1989)

Explanatory power of TAM

The TAM has been tested in many empirical studies and the tools used with the model have proven to be of quality and yielded statistically reliable results but the model is far from perfect (Legris, Ingham, & Collerette, 2003). Legris and colleagues have conducted an extensive review of articles published from 1980 to 2001 about TAM (Legris et al., 2003). They conclude that the original model (figure 1) has evolved over time, with the adaptation by Venkatesh and Davis (2000) gaining the most attention (TAM2). Nonetheless, the model managed to explain only 40% of the variance in use, among others, Legris and colleagues recommend that more components need to be included to explain a bigger portion of this variance (Lee, Kozar, & Larsen, 2003; Legris et al., 2003).

Furthermore, Legris et al posit that one limit of the model is that it has mostly been tested among university students in laboratory studies (2003). Also, the software examined and used mostly consisted of office automation or system development applications. Another identified limitation is the way how TAM measures TA; it does not directly measure system use, but the variance in self-reported use. According to Legris and colleagues, greater emphasis should be put on correct measurement of system use (2003). In a later meta-analysis by Sun and Zhang the differences in explanatory power between field studies and laboratory studies were assessed (2006). They demonstrated that laboratory studies have relatively higher explanatory power than field studies. Additionally, field studies with students as subjects showed higher explanatory power than studies with professionals, who were assumed to face more complex and dynamic factors in field contexts (Sun & Zhang, 2006). This implies that the models should more accurately account for variations in contextual (during testing) and moderating factors.

Implications

In a meta-analysis of the TAM, the main constructs (perceived ease of use and perceived usefulness) are analyzed in terms of direction, magnitude, and statistical significance (Ma & Liu, 2004). Their findings showed strong relationships between PEOU and PU, and between PU and technology acceptance. Respectively, both relationships had large mean effects in terms of magnitude. In line with earlier findings, the relationship between PEOU and TA is weak, with a medium magnitude. The three mean effects were all significantly positive ($\alpha = 0.01$).

The authors conclude that usefulness is critical for adoption of new technologies. They imply that developers should focus on improving the system acceptance with useful and features and functionalities. Even though many results show a weak relationship between perceived ease of use and technology adoption, developers should keep in mind that the ease of use of a system has a strong impact on the perception of its usefulness.

Unified theory of technology acceptance

Venkatesh and colleagues reviewed the existing user acceptance models to assess the current state of knowledge of technology acceptance and the models' explanatory power (Venkatesh, Morris, & Davis, 2003) . Their results, comparing eight user acceptance models showed explanatory powers of hardly 40 percent. From this comparison, conceptual and empirical similarities across the eight models were used to construct a Unified Theory of Acceptance and Use of Technology (UTAUT). This new theory was tested empirically by the authors, and was claimed to account for 70 percent of the variance in intention to use. The UTAUT includes performance expectancy, effort expectancy, and social influence as three direct determinants of intention to use. Additionally, two direct determinants of usage behavior were suggested; intention and facilitating conditions. The included moderating influences (experience, voluntariness, gender, and age) were also confirmed as integral features of the model (Venkatesh et al., 2003).

Limitations

The increase of 30 percent explained variance in technology use is noteworthy. However, a limitation to the unified theory is how the scales for measurement of the core constructs were operationalized. By using the highest-loading items from each of the scales, content validity may be reduced. The authors warn that these measures should be viewed as preliminary, and they suggest more focus on content validity when new scales are constructed to revalidate the model (Venkatesh et al., 2003). This may have implications for future modifications to this theory.

Another point of critique concerns the amount of moderating factors. In a study by Chin et al, it was confirmed that including moderating factors can enhance the model's explanatory power, but the effect was expected to be limited (Chin, Marcolin, & Newsted, 2003). Similarly, the results from Venkatesh et al (2003) have shown that the inclusion of moderators significantly increased the predictive validity of six of the eight models, but only for four moderators. However, Sun and Zhang believe there are more moderating factors with empirical evidence than the four that were studied (2006).

User diversity

The key in finding the missing components to further explain the variance of TAM in explaining system use, may be found in individual differences of the users. The importance of individual differences in HCI research was first suggested by Dennis Egan (1988). Even though this research was not particularly focused at user attitude, it should widen our perspective, Egan argued for more focus on individual differences for three reasons: (1) Individual differences account for a substantial amount of performance variability. (2) A system that is more sensitive to the capabilities of different users would increase the general accessibility. (3) By understanding user differences, we become better at predicting user behavior. He concludes with: *"Designers have an important role in determining what kinds of systems are developed in the future, and, correspondingly, who will be able to use them."* (Egan, 1988, p. 565). Ten years later Dillon and Watson reported the following conclusion in a historical review of user difference research: *"The study of individual differences is as old as psychology itself, and one may wonder how it has remained so marginal to mainstream HCI which is usually receptive to psychological theory."* (Dillon & Watson, 1996, p. 620). In their review of 100 years differential psychology, they emphasize that *"what sets certain users apart in cognitive terms can constrain the number of potential design solutions"* (Dillon & Watson, 1996, p. 632). Many user diversity levels are suggested, such as performance, experience and search strategies, mental abilities, attitude and motivation and psychosocial traits (Dillon & Watson, 1996; Egan, 1988). In line with these calls for more focus on individual factors, Sun and Zhang extended the technology acceptance theory by integrating these as moderating factors (Sun & Zhang, 2006).

An integrated model of technology acceptance

In their meta-analysis of moderating factors in user technology acceptance, Sun and Zhang compared the explanatory power of TAM across existing models (2006). The results (table 1) illustrate the overall limited explanatory power of the existing models, consistent with earlier findings from longitudinal studies by Venkatesh et al. (2003).

Table 1
Comparisons of explanatory powers of TAM and other models

Compared models	Representative studies	Explained variance in TAM	Explained variance in compared models	Is TAM better?
TRA	Davis et al. (1989)	After 1-h introduction: 47% 14 weeks later: 51%	After 1-h introduction: 32% 14 weeks later: 26%	Yes
TPB	Mathieson (1991) Taylor and Todd (1995a) Chau and Hu (2002) Chau and Hu (2001)	69.3% 52% 42% 40%	60.1% 57% 37% 32%	Yes No Yes Yes
TAM2	Venkatesh and Davis (2000)	40%	60%	No
TTF/integrated TAM with TTF	Dishaw and Strong (1999)	36%	41%/51%	No
Extended TAM	Moon and Kim (2001)	Attitude: 0.332 BI: 0.349	Attitude: 0.371 BI: 0.382	No

A second goal of their analysis was to examine the moderating factors that they assumed to be accountable for both the limitations of explanatory power and inconsistencies between prior studies (Sun & Zhang, 2006). With their study they *"call for more research attention to individual and contextual factors that are often neglected in technology acceptance studies."* (p. 54). They agree with Venkatesh' conclusion that including moderators can increase the explanatory power of TAM and TAM2 by nearly 20 percent. Based on these findings, Sun and Zhang propose an integrated theoretical model that includes ten moderating factors, organized into three groups: organizational factors, technology factors and individual factors. As illustrated in figure x, the model extends upon the unified theory proposed by Venkatesh et al (2003).

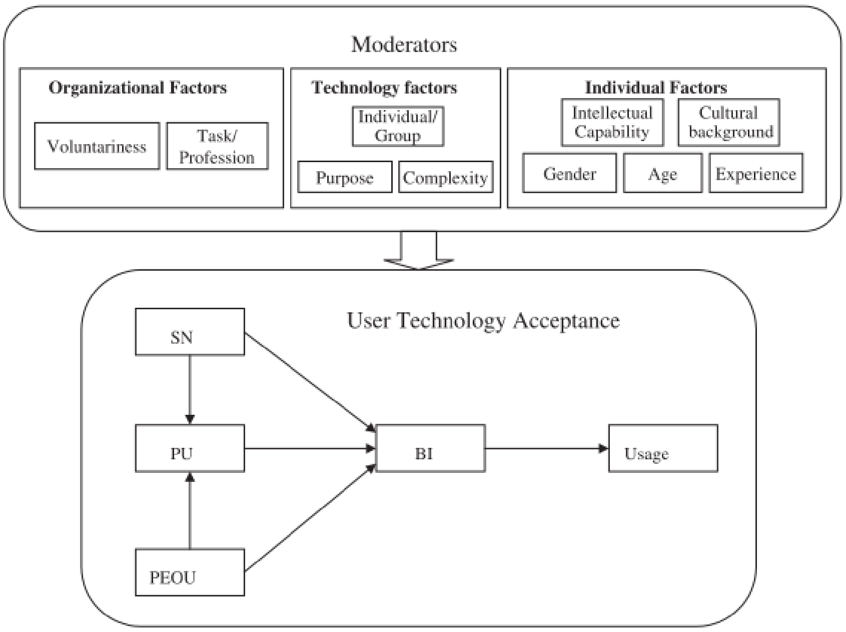

Figure 2. Integrated theoretical model of technology acceptance including moderators (Sun & Zhang, 2006)

Limitations

The moderating factors in this table are developed and theorized, based on empirical results of the 54 reviewed articles. Even though the results in this study show great consistency with results from several other meta-analyses (Lee et al., 2003; Legris et al., 2003; Ma & Liu, 2004), the authors mention that bias may be possible. Secondly, the authors note that the relationships between the moderating factors have not been considered, and may need further refinement. Moreover, the authors state that the current technology acceptance models are conditional. They urge that practitioners should pay particular attention to the inclusion of individual and contextual factors when using these models to predict user acceptance of a specific system (Ma & Liu, 2004).

Technology readiness

Parasuraman proposed a technology readiness construct that refers to: "people's propensity to embrace and use new technologies for accomplishing goals in home life and work" (2000, p. 308). He posits that the literature concerning adoption of new technology strongly suggests that consumers simultaneously have favorable and unfavorable views about technology-based products or services. In an extensive qualitative research on peoples' reactions to technology, no less than eight paradoxes have been identified (Mick & Fournier, 1998). The authors conclude that technology may trigger both positive and negative feelings; for example, technology can facilitate feelings of intelligence or efficacy, but it can also lead to feelings of ignorance or ineptitude. Parasuraman (2000) argued that the relative dominance of the two types of feelings is likely to vary across individuals and as such can be placed along a hypothetical technology beliefs continuum (positive to negative).

Studies show that users' beliefs or feelings about technology correlate with the intention to use it (Eastlick, 1996; Dabholkar, 1996). On the basis of this theoretic framework, the Technology Readiness Index (TRI) has been constructed, which is a multiple-item scale with validated psychometric properties that can be used to gain an in-depth understanding of the readiness of their customers to embrace computer based technology. The TRI measures an individual's readiness to use new technology according to four personality traits: optimism, innovativeness, discomfort and insecurity. Parasuraman (2000) states that a person with optimism and innovativeness and little discomfort and insecurity is more likely to use a new technology (and thus represented with higher TRI scores).

The technology readiness notion may have merit by including personality to predict why users embrace new technology. In a more recent study, Walczuch and colleagues have further explored the link between personality traits and technology adaptation readiness (2007). They proposed a combination of TRI and TAM (figure 3) because the personality traits from the TRI were assumed antecedents of the cognitive dimensions of TAM and this combination had not been attempted before (Agarwal & Prasad, 1998; Fornell & Cha, 1994).

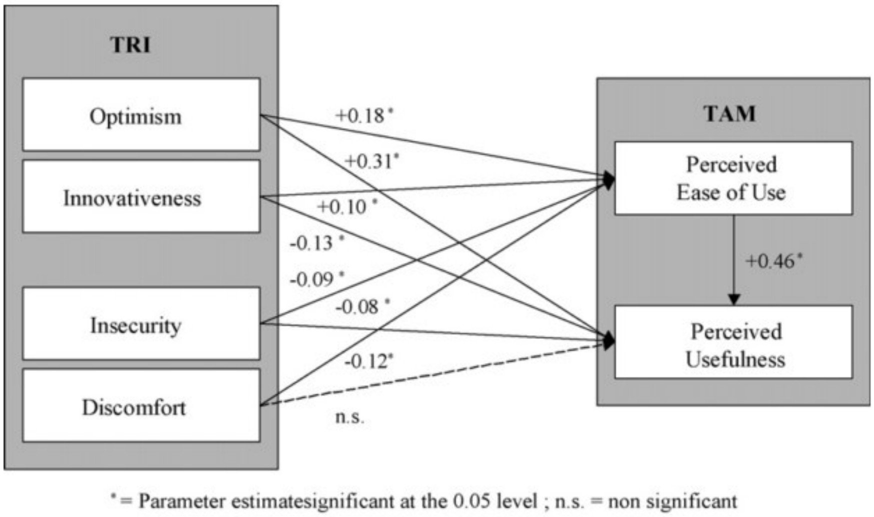

Figure 3. Combined TRI and TAM frameworks (Walczuch et al., 2007).

Walzcuch's results indicate that personality indeed makes a difference in the adoption process of new information technology (Walczuch et al., 2007). Optimism has the strongest impact on perceived ease of use and perceived usefulness; optimistic users appear to confront IT more openly and positively and are less likely to focus on its negative aspects. Furthermore, discomfort has been found to have a negative impact on only PEU, and insecurity negatively impacting both PU and PEU. Another remarkable finding is that the innovativeness trait seems to negatively impact perceived usefulness. Walczuch explains this as a more critical perspective towards technology, since these users are very aware of the newest developments and possibilities paired with a high expectation of technology (Walczuch et al., 2007). In all, these results demonstrate significant effect of personality on technology acceptance. However, more studies may be needed to extend these findings' generalizability, as its sample was taken from a single organization in a financial context.

Implications

From a management or developer perspective, these results are difficult to translate into applicable design principles or guidelines. Since most software projects are not meant for users with a certain specific personality characteristic, we can only try and focus on mitigating the negatively impacting characteristics *discomfort* and *insecurity*. Users that score high on the discomfort scale perceive a lack of control and are easily overwhelmed by complex technology (Walczuch et al., 2007). Developers could anticipate on this by providing informative feedback and augment ease of use in the software.

Users that score high on the insecurity scale show an increased tendency to avoid the use of computers due to their innate fear of technology, i.e. apprehensiveness (Chidambaram, 2000). It may be possible to reduce this fear on the long term, by making every encounter with technology as pleasant and intuitive as possible, which helps not only computer illiterate users, but computer users in general.

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