

# Visual attention during decision-making in natural environments

Kerstin Gidlöf



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# Abstract

This thesis investigates visual attention during decision-making in natural environments in four different studies.

The first study demonstrated that decisions in the supermarket were suboptimal and this did not seem to relate to the amount of products attended to, or the amount of time spent on each product. Consumers also failed to look at a subsection of products that better suited their preferences.

The second study investigated the 'central gaze bias' found in lab-based eye tracking. The results from a monitor setting were compared to a real supermarket shelf. The distribution of visual attention was significantly closer to the centre of the shelf in the monitor condition compared to the supermarket.

In the third study the visual behaviour of consumers buying (or searching for) products in a supermarket was measured and used to analyse the stages of their decision process. Existing models of the stages of the decision-making process were refined and revealed differences between a decision-making task and a search task. In particular the second (evaluation) stage of a decision task contained more re-dwells than the second stage of a comparable search task.

The fourth study took a closer look at interacting cognitive processes during decision-making and their impact on visual attention. Participants' visual attention during decisions was sensitive to evaluations made already during encoding and decisions were strongly characterized by preferential looking to to-be-chosen options.



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# List of original papers

**Paper I:** Gidlöf, K., Wallin, A., Mögelvang-Hansen, P. & Holmqvist, K. (2013). Material distortion of economic behaviour and everyday decision-making, *Journal of Consumer Policy*, 36(4), 389-402

**Paper II:** Gidlöf, K., Holmqvist, K. & Wallin, A. (2014). The centre might not be so shining after all - central bias from computer screen to the supermarket, Manuscript submitted for publication.

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**Paper IV:** Pärnamets, P., Johansson, R., Gidlöf, K. & Wallin, A. (2014). How information availability interacts with visual attention during judgment and decision tasks, Manuscript submitted for publication.



# 1 Introduction

Imagine yourself in your regular supermarket. You are standing in front of the pasta shelf and need to make a decision on what to buy for dinner. You have a vast array of options before you, each with their various pros and cons, and limited time. Moreover, humans have limited vision, so that you can only really take in one object at a time, and you have limited memory and most critically – limited attention to give to this task. How do you solve this task and how do you use your visual attention to do so? The short example above summarises what this thesis is about.

During my years as a student and researcher in cognitive science and later in decision-making, one question lingered in the back of my mind. When learning about the theories, models and strategies developed to describe the processes underlying decision making, I found that I wanted to know what people *really* do, in their everyday lives, far away from the controlled laboratory. Examples of real-world cognition were sparse in the literature, and I found this frustrating. This frustration and my interest in how we behave and interact in the real world was one of the main reasons to investigate eye tracking. Since vision is an active process, and eye movements are closely connected to the allocation of attention in a scene, they can provide a real-time indication of on-going visual and cognitive processes, and since eye tracking technology has advanced to the point where measures can be taken outside the lab during every day tasks, it can provide a measure of the uptake of information and decision making processes not otherwise possible.

Visual attention plays a critical role in almost all decisions we make (e.g. Armel, Baumel & Rangel, 2008; Chandon, Hutchinson, Bradlow & Young 2009; Glaholt & Reingold, 2009, 2011; Glaholt, Wu, & Reingold, 2010; Krajbich, Armel and Rangel, 2010; Krajbich & Rangel, 2011; Reutskaja, Nagel, Camerer & Rangel, 2011; Schotter, Berry, McKenzie & Rayner, 2010; Simion & Shimojo, 2006; Wedell & Senter, 1997). Measurable factors such as the

products you look at, the order in which you look at them, and for how long you do so can give us fundamental clues to basic processes underlying decision making. So, an eye tracker became my key tool for studying decision making in the real world. During the course of the studies in this thesis, my interest in and use of eye movement measures has gone from regarding them simply as a tool to better understand decision making, to an interest in understanding the relationship between eye movements, visual attention and cognitive processes in general. The realization that visual attention not only reflects the decision-making process, but also supports and critically influences it, underlies the results of this thesis.

The aim of this thesis is to better understand decision-making in natural environments, how visual attention is distributed during these decisions and how this relationship can be explored through eye movements. The studies presented aim to set the groundwork for a long-term goal of tracing and explicating decision processes in the real world. Before this goal can be reached, several issues have to be considered. Firstly, natural environments differ in many respects from the traditional environments in which decision-making has previously been studied. In this thesis I have chosen to put an emphasis on the decision environment since it has a great impact on both the decision process and the associated visual behaviour and, consequently, on how decision processes can be studied. Secondly, the measures used in traditional process tracing (a key methodology in decision making research) are often not applicable to natural environments, since the real world is messier in terms of what information is available, what stimuli are competing for attention, and how information is structured than a controlled, lab based experiment. We have approached this problem with eye tracking, which allows us to measure exactly what information is selected from the environment on a moment-to-moment basis, and constructed a new set of measures to study the decision process. Thirdly, visual attention serves not only as a way to passively acquire information from the environment but involves the deployment of highly complex attentional strategies, which may be conscious or unconscious. In this sense eye movements mirror and support the decision process providing a trace of the viewers' strategy-in-action as it is applied in the real world. Hence, this thesis calls for a shift in how we interpret the role of eye movements and visual attention during decision-making, and demonstrates the efficacy of this approach in practise.

Two strands of research form the backdrop for this thesis. Firstly, there is a strong tradition of process tracing in decision-making research (for a review see Shulte-Mecklenbeck, Kühberger & Ranyard, 2011). However, most measures used in extant studies are not applicable in a natural environment such as the supermarket. Secondly, decision-making is a special kind of task where the information is valued very differently in each case. One piece of information might be crucial for one person but not at all interesting to another, or crucial for one decision but not for another. This calls for a set of eye tracking measures that can be used to compare cognitive processes from one task to another, or one person to another, without relying on exactly *what* object is being visually attended to. Studying visual attention during a decision-making process in a natural environment such as the supermarket poses two major challenges; a challenging decision environment, and a challenging task. While deciding on which pasta to have for dinner may seem like an easy task and has relatively low emotional valence for most of us, the factors involved are far from simple. Apart from the cluttered visual scene, the decision-relevant information available from any one object differs; supermarkets regularly rearrange objects on the shelf in an attempt to manipulate the decision-making process, and contingent factors such as price vary from one visit to the next. Because of the high complexity (but low emotional valence) of such every-day decisions, grocery shopping in the supermarket was selected as good everyday complex decision-making task, with a high commercial interest in how decisions are made.

In the first paper, “Material Distortion of Economic Behaviour and Everyday Decision Quality”, we investigate the decision environment in the supermarket. We investigate the properties of this environment when it comes to number of products, how the products relate to each other and to the consumers’ preferences. We look at how consumers handle this natural environment, how they sample information and how good their decisions are. A ‘good’ decision is when there is consistency between the chooser’s self defined priorities or values and attributes of the product eventually chosen. Different shoppers may prioritise price, or local produce, or calorie content, or a whole range of attributes that describe a product’s value. There is high commercial competition for your attention in grocery stores, with large resources spent to try and influence you to attend and prefer certain options. We also investigate if differences in the distribution of visual attention lead to different decisions, and

if attending to products that better correspond to the shopper's preferences lead to better decisions.

In the second paper, "The centre might not be so shining after all - central bias from computer screen to the supermarket", we investigate whether findings from consumer decision-making studies performed on computer monitors generalize to the actual supermarket. Specifically, we investigate the 'central gaze bias' found in lab-based eye tracking studies and compare the results from a monitor setting to a real supermarket shelf.

In the third paper, "Using eye tracking to trace a cognitive process: Gaze behaviour during decision-making in a natural environment", we discuss the use of eye tracking as a process tracing technique in natural environments. We refine existing models of the stages of the decision-making process based on observed changes in eye movement behaviour, measured in the real world. We also compare this to a cognitive process that is similar to decision making - or forms part of it - and identify the behavioural features that are unique to decision making in terms of visual attention.

In the fourth paper, "How information availability interacts with visual attention during judgment and decision tasks", we take a closer look at interacting cognitive processes during decision-making and their impact on visual attention. We also investigate participants' distribution of visual attention when the decisions and judgements are made in an environment with all information present vs. in an environment where they have to rely solely on memory of previously viewed and encoded objects.

This thesis begins by introducing the most frequently used methods of process tracing. In particular I will concentrate on what questions process tracing usually aims to answer. I then review factors known to influence the decision process and their correspondence with eye movements and visual attention. Thereafter, I will discuss the different roles of visual attention in decision-making and why we need a shift in how eye tracking is viewed in process tracing research. Finally I will introduce the novel methodology used in our studies, before presenting those studies in turn.



## 1.1 Process tracing in decision research

The aim of *process tracing* - a common methodology in decision-making research - is to understand the cognitive processes underlying decision-making. Data is gathered while the decision is being made in order to reveal the sequence of cognitive events that lead up to the final decision. There are several different techniques used in process tracing but the most frequent are *verbal protocol analysis* and *information display boards*.

### 1.1.1 Verbal protocols

Verbal protocol analysis can be done in two different ways; through concurrent verbal protocols, or through retrospective verbal protocols. In using concurrent verbal protocols, also called “think aloud protocols”, the decision makers are asked to verbally describe what they are thinking or doing during the decision. Retrospective protocols are collected after task completion but are based on the same principle of verbalisation. It is argued that verbal protocols can be used to better understand information integration during the decision process (Shulte-Mecklenbeck, Kühberger & Ranyard, 2011). A clear definition of information integration is lacking however, the one extant textbook on process tracing in decision research does not provide one (Shulte-Mecklenbeck, Kühberger & Ranyard, 2011). For the purposes of this thesis, *information integration* will be defined as collating information from the external world and/or from memory in order to have a cogent internal representation.

Verbal protocols have received a fair amount of critique, and the reliability and validity of the method has been questioned (Ericsson & Simon, 1993; Nisbett & Wilson, 1977). Thinking aloud while making a decision, when the person would normally not think aloud, represents a dual task and can affect the quality of the decision (Russo, Johnson & Stephens, 1989). It also requires an unrelated cognitive skill which renders the task of varying difficulty across individuals – that of metacognition. This limitation was recognised by Russo and Leclerc, 1994, when they stated that:

“To our considerable disappointment the verbal protocols could not be used to augment any of the present analyses. First, they were relatively sparse, only 4.90 statements per choice (before the required announcement). Second, the protocols revealed much more about the product attributes being considered than about processing operations. Unfortunately, attributes reflect the content of the choice process rather than its structure, which is the focus of the present paper.”

(From Russo & Leclerc, 1994)

Retrospective protocols, on the other hand, are susceptible to forgetting and confabulation since they rely on the memory of the decision maker (Johansson, Hall, Sikström & Olsson, 2005), which is an unreliable source of information regarding the actual (and possibly unconscious) strategies employed at the time of decision making. Being aware of one’s own strategies in cognitive tasks is a metacognitive skill in and of itself.

### **1.1.2 Information display boards**

Information display boards are matrices with information about the alternatives and their attributes displayed in cells. The information in each cell is hidden and the decision maker must actively acquire the information one cell at a time, by, for instance, turning a card over, or opening an envelope with the requested information written on it.

Mouse Lab (Payne, Bettman & Johnson, 1988) is a more up-to-date adaptation of information boards. This is a computer-based information board that displays information about the different options contained in a matrix upon hovering the mouse over that option/cell. This is intended to mimic the cost of information acquisition and limited simultaneous access to attributes’ values in the real world. All information board techniques make it possible to assess what information was acquired when making the decision and the order in which that information was accessed. A general goal of process tracing methods, most specifically of information boards, is to infer the strategies used to make the decision. This is possible through (for instance) a description of the process according to how the information is acquired, attribute- or alternative wise. Strategies are often described as compensatory or non-compensatory depending

on the order and depth of the information search. In a compensatory decision strategy, all attributes of one option are combined into a single value (possibly weighing each attribute according to preferences). The combined value of each option is then used to make the decision. A non-compensatory decision strategy does not make trade-offs among attributes. Instead, as soon as an attribute distinguishes between options, a decision is made (thus utilities are not combined into a single value).

### **1.1.3 Eye tracking as a process tracing method**

Several studies have used eye tracking (ET) to investigate different aspects of the decision-making process (e.g. Chandon, Hutchinson, Bradlow & Young, 2009; Pieters & Warlop, 1999; Riesen, Hoffrage & Mast, 2008; Russo & Leclerc, 1994; Russo & Rosen, 1975). As early as 1978 Russo argued that eye movement methodologies have several advantages not found in other process tracing methods such as information boards and verbal protocols. These advantages include the excellent detail and validity of the methodology. Compared to matrix-based tools, acquiring information with your eyes is “cheap” – i.e. not unnecessarily cognitively loading for the participant. Eye movements can also be recorded non-reactively, avoiding the need for the participant to respond in a certain way in order to record the information, and they are difficult for a participant to censor – unlike verbal recollection.

Almost every decision we make involves the acquisition of visual information. Visual processes are fundamental when the consumer is inspecting, searching and choosing products in the supermarket (Wedel and Pieters, 2008). Lohse and Johnson (1996) conclude in their comparison of mouse lab and ET as process tracing methods that:

“Computerized process tracing tools fundamentally alter the information-processing behaviour they are believed to track unobtrusively by limiting the ability of the decision maker to adapt their information processing behaviour dynamically to the demands of the data”.

(From Lohse & Johnson, 1996)

Russo (1978) also mentioned several drawbacks with the eye movement methodologies including high costs, problems with transportability and ease of use, but there have been many developments in ET technology in the interim, and these drawbacks no longer exist. The ET systems of today are far from the invasive, cumbersome and expensive systems previously used. Mobile units provided by many manufacturers are easy to use, can be worn as a pair of glasses, and give a possibility to trace processes outside the laboratory in the sorts of environments people usually make decisions in. Yet, as recently as 2011, Willemsen & Johnson claim that:

“Modern eye tracking devices can be used to observe eye fixations unobtrusively, even allowing for free head movements, but still these have to be used in laboratory environments and are fairly expensive and not easily adapted to group settings or dispersed locations”

(From Willemsen & Johnson, 2011)

This shows the lack of knowledge about eye tracking in this field of research. The recent advances in eye movement research in natural environments in psychology (e.g. Hayhoe & Ballard, 2005; Smilek, Eastwood, Reynolds & Kingstone, 2007; Kingstone, Smilek, Eastwood, 2008; Foulsham, Walker & Kingstone, 2011) show that this view is out-dated and the possibilities of eye tracking technology are poorly understood outside the domains in which the technology is traditionally used.

Perhaps because of such misunderstandings, ET has not been utilised to any great extent in process tracing research. In many accounts, the use of ET is not even mentioned and if mentioned, is often described only as a specific form of information display board interaction, using the eye movements instead of the mouse to “open” the cells in the matrix (e.g. Lohse & Johnson, 1996; Riesen, Hoffrage & Mast, 2008). Hence, ET is primarily seen as a method for tracing information *acquisition*. I will argue that eye movement measures can also serve as a trace of information *integration*. Since the main methods for information integration (such as verbal protocols and self-report questionnaires) have received strong criticism (e.g. Nisbett & Wilson, 1977), this thesis argues that ET, in combination with other methods, can be a successful way to advance the field.

Measures used traditionally in ET research usually don't take into explicit account that different pieces of information are valued very differently in each case, that every object has a subjective value. This is especially the case in decision-making where the information needed to make decisions might differ with preferences or goals. If one wants to compare different decision-making processes, it is crucial that this is taken into consideration. If two decision makers look at the same objects in the same order but do not share the same preferences or goals, it is highly unlikely that they share the same cognitive processes. This calls for a new formulation of traditional eye tracking measures for the comparison of one decision to another, where these aspects are considered.

Many process-tracing studies seek to understand the effect of task, environment and personal factors such as preferences, goals and previous experiences on the decision process. This emphasises the relevance of adapting the methods to a natural setting. In the following chapter I will discuss several disparities between the decision environments traditionally used in process tracing research and natural ones such as the supermarket, and how these disparities can affect the decision process and related eye movement behaviours.

## 1.2 Factors influencing the decision and corresponding eye movements

Let us now return to the supermarket and the hundreds of different types of pasta on the shelf in our example. Decisions on which pasta to select, made in front of that shelf, are going to be guided and constrained by that specific context. Understanding the interaction between eye movements and the visual environment in the supermarket as a decision making context is specifically interesting since the visual domain is so important and influential in these decisions. The global consumers' decisions are highly influenced by product packaging (Innventia, *Packaging 2020 – Innventia Global Outlook Report, 2014*) and the decisions are usually based on a few criteria with limited information acquisition (Dickson & Sawyer, 1990; Hoyer, 1984). Understanding the

context where decisions are usually made is therefore of great importance to understanding the underlying processes driving them.

First of all, a supermarket is a much more visually complex and unconstrained environment than a matrix with written information or a few pictures of products presented on a computer monitor to a stationary, focussed individual. The effect of stimulus-driven and goal-driven control of visual attention will differ between these environments (Orquin, Bagger & Loose, 2013).

Secondly, the level of familiarity is very different if we compare the supermarket to traditional decision tasks where options, usually novel or fictitious, are presented in an unfamiliar environment such as in a matrix, as pictures on a computer monitor or in a mock-up shelf (Chandon, Hutchinson, Bradlow & Young, 2009; Payne, Bettman & Johnson, 1988; Pieters & Warlop, 1999; Russo & Leclerc, 1994).

Thirdly, there are a large number of options to choose from. In paper I in this thesis, participants in a Danish supermarket chose between 91 different jars of jam, 22 varieties of milk, and 35 types of pasta, and these options vary broadly on a large number of relevant attributes. In the same study, the different jam containers displayed information on 90 attributes such as fruit and sugar content, preservatives and country of origin. The Food and Marketing Institute states that the average number of distinct items carried in a supermarket in the USA in 2013 was 43,844 (information available at: <http://www.fmi.org/research-resources/supermarket-facts>, 20 Nov. 2014). In contrast, traditional experimental decision making tasks usually present from two to about twelve different options (e.g. Bettman, Johnson, Luce & Payne, 1993; Mackenzie, Glaholt & Reingold, 2011; Reisen, Hoffrage & Mast, 2008; Reutskaja, Nagel, Camerer & Rangel, 2011; Russo & Doscher, 1983).

Finally, the two environments imply vastly differing presentation formats. Many of the traditional process tracing methods make sure that the decision maker has all relevant information available when making the decision and options are often presented on computer monitors in a highly structured manner. This contrasts starkly against the information situation in the supermarket, where information is structured in different ways and can be hard to find. The same attributes are rarely available for all alternatives.

There are certainly many factors influencing the decision and corresponding eye movements, but the aim here is to focus on the aspects that can affect both decision-making and the associated eye movements and that would make a difference in a natural environment such as the supermarket.

### **1.2.1 Bottom-up and top-down influences**

When deciding which product to select from a shelf of alternatives, huge resources are spent on trying to attract your attention to low level features such as the size, colour, shape and contrast of packaging. The assumption is that these low level, bottom-up features have an influence on your decision-making. Of those options that do attract your visual attention, you will select a sub-set to submit to higher (top-down) processing. What you value in these objects will come into play when you investigate details such as the words or other information printed on the package or display; the price, or the list of ingredients, for example.

Since high quality visual information is only available within a very restricted portion of our visual field (about 2° of visual angle – around the size of a thumbnail on an outstretched arm) we need to constantly and actively move our eyes and our bodies to redirect our fovea to pertinent details of the visual space. We direct our eyes to interesting or informative areas of our visual field (Henderson, 2003) but what does this mean?

When we are standing in front of the pasta shelf in our supermarket, there is an interplay between what we want to buy and what visually attracts our attention. We are not only affected by colours, shapes, and special offers but enter the supermarket with a set of memories, experiences, states (hungry?) and preferences. This interplay between bottom-up and top-down factors (also called stimulus-driven and goal-driven, or exogenous and endogenous control of attentional resources), is controlling the distribution of attention (Teeuwes, 2010; Corbetta & Shulman, 2002). Top-down control is volitional, bottom-up control is largely automatic.

Bottom-up, exogenously driven visual attention is often discussed in relation to visual saliency. In the decision environment, there are certain elements that attract our visual attention more than others. This ‘attraction effect’ depends on

low-level visual features such as form, colours, edge density and contrast. Saliency has been formulated as a topographical map, guiding visual attention based on these low-level visual features (Itti & Koch, 2001). Several ET studies have demonstrated that we tend to direct our gaze at regions with higher bottom-up visual saliency than control regions (Tatler, Baddeley & Gilchrist, 2005; Parkhurst, Law & Niebur, 2002). Bottom-up control is claimed to be more dominant in the beginning of stimulus onset, where early visual processing involves orientation to the scene. Theeuwes (2010) argues that visual selection is completely stimulus driven at first encounter with the scene. Only after 150 ms can top-down, cognitively driven processes start to influence the visual selection. In this theory, over time, top-down processes take over the control of eye movements (Theeuwes, 2010; Parkhurst, Law & Niebur, 2002). But Tatler, Baddeley & Gilchrist, (2005) did not find this decline in bottom up control with viewing time, and argue that there is an intermediate level representation of the scene that does not change over time, but rather it is the interpretation of this representation that changes during the course of the task. Saliency also coincides with regions judged as more interesting and semantically important by human viewers (Elazary & Itti, 2008; Henderson 2007), and these factors are top-down factors. In the context of the supermarket this could mean that the design of the packages has its largest influence in the beginning of the task, as the consumer is entering the aisle. Together these results suggest that packaging might have less of an influence on attention (and hence less influence on the decision making process), the longer the consumer spends inspecting products. Milosavljevic, Navalpakkam, Koch & Ragel (2011) have shown that visual saliency is most influential in rapid decisions, in which it is more influential than preferences, and that this influence increases with cognitive load. The effect is strongest when individuals do not have strong preferences. In contrast, the influence of bottom-up guidance in a matrix based decision environment should be relatively limited. With information presented only in written format, visual saliency cannot guide our attention since there is comparatively little difference in the low-level visual features of textual elements (Orquin, Bagger & Loose, 2013).

Top-down driven visual attention implies endogenous, goal-driven control of the distribution of attention, and depends on characteristics of the decision maker such as expectations, experiences, task and goal (Corbetta & Shulman, 2002; Orquin, Bagger & Loose, 2013; Yarbus, 1967). Top-down control of



visual attention was demonstrated in the seminal works of Yarbus (1967) where he showed that the eye movements of a participant viewing Repin's painting "Unexpected Visitors" varied to a high degree depending on the judgement to be made of the picture. By manipulating the goal of viewing, Yarbus showed that eye movement behaviour is not only driven by attributes of the visual world (bottom up saliency) but also *by the subjective intentions of the viewer*. Task dependencies and top-down control of eye movements have also been demonstrated in a decision-making context. Glaholt, Wu & Reingold, 2010 performed a study in which different decision tasks yielded different patterns of eye movements while the stimulus display was held constant. Top-down control of eye movements can also be attributed to the tendency of participants to direct their gaze towards options and attributes with higher importance to their decision (Glaholt & Reingold, 2009; Glaholt, Wu & Reingold, 2009; Pieters & Warlop, 1999; Reisen, Hoffrage & Mast, 2008; Russo & Leclerc, 1994; Wedel & Senter, 1997). Similarly, the distribution of fixations on our pasta shelf would presumably differ depending on whether we are searching for a specific product or just browsing through the options, trying to find something interesting to buy.

The relative influence of top-down vs. bottom up control of eye movements can also be related to familiarity with the scene (Henderson, Weeks & Hollingworth 1999; Hollingworth & Henderson, 2002). When standing in front of our now very familiar pasta shelf, we have, over time, acquired information about the usual placement of the products. We know where the cheap products are to be found and where our favourite brand is located and this stored knowledge will influence the distribution of our fixations and guide them to more informative regions (according to our values) of the shelf.

### **1.2.2 Familiarity**

In a familiar environment where we make decisions repeatedly, our visual attention will change over time and the relative influence of bottom up factors will decrease (Orquin, Bagger & Loose, 2013). With experience, we learn to attend to things that are important to us and to ignore less relevant information (Droll, Gigone & Hayhoe, 2007; Haider & Frensch, 1999; Jovancevic-Misic & Hayhoe, 2009; Meisner & Decker, 2010). However, the results from paper I

presented in this thesis demonstrate that consumers in a supermarket might fail to attend to the most relevant information/products despite this environment often being familiar.

Familiarity can also help guide visual attention in the sense that visual context information constrains what to expect and where to look, facilitating search for and recognition of objects embedded in complex displays. For instance, if we were in an office looking for a pen we would probably direct our eyes to the desk first because past experiences with that kind of environment have taught us that the desk is the place where a pen usually can be found. This *attentional guidance*, or facilitation effect, derived from past experiences, was coined *contextual cueing* (Chun & Jiang, 1998). These expectations and facilitations can be translated to the supermarket shelf where products are placed in a specific manner. Shelves are usually structured according to price and products that share different attributes such as brand or flavour are often placed together. Consumers can adapt to this structure over time and it is likely to help them guide their attention to the preferred products.

Performance in visual search tasks is also strongly influenced by familiarity (Greene & Rayner, 2001; Wang, Cavanagh & Green, 1994). If objects in the display are familiar, for instance real letters compared to letters rotated 90°, the process will be faster and facilitate the visual search. The design of several products is certainly well known to the consumer; a preferred brand might have a special colour that the consumer recognises and most brands have specific design features. If the results from these visual search studies would generalise to the supermarket this would mean that consumers familiar with their environment could speed up their search process.

Bettman (1986) suggests that consumer decisions are guided by a mixture of memory and stimulus based information, with some information available in the decision environment and some only in memory. Knowledge from previous purchases can be kept in memory and be used to trim the process (Russo and Leclerc 1994, Hoyer 1984). The more often the product is purchased, the more information can be recalled at the next purchase. This is supported by the fact that decisions from familiar product categories (products purchased more frequently) take less time and involve fixating on fewer alternatives (Russo and Leclerc 1994).

As the consumer grows more knowledgeable about the product group, the need to search for information in the product display decreases. Consumers with a larger prior knowledge may not need to process all available information in order to make a satisfactory decision. On the other hand, consumers with poor prior knowledge are less motivated to process all information, because it may feel overwhelming. Bettman and Park (1980) propose an inverted U shaped relationship between prior knowledge and information acquisition. Consumers with a moderate knowledge would then acquire the most information.

### **1.2.3 Number of options**

Given the large number of options in the supermarket, we may expect consumers to feel frustrated as decisions made from large assortments are experienced as more difficult (Iyengar and Lepper, 2000; Chernev, 2003). Extensive arrays of options lead to overloading the limited attentional capacity of the human mind. In a study by Malhotra (1982), participants showed negative effects of overload, as in, participants made sub-optimal decisions (according to their preferences) when faced with ten or more options. This kind of overload can also result from a high number of relevant attributes pertaining to each option. When having to encode information on 15 or more attributes, consumers also show effects of overload (Malhotra, 1982).

Although many studies indicate that a large assortment may lead the consumer into a difficult and demanding decision situation, other studies suggest that consumers do not actively avoid those situations. Iyengar and Lepper (2000) found that people are more attracted to larger product displays. They presented two different displays of jam, one with six alternatives and one with 24. More consumers stopped in front of the large display, and thereby considered making a decision, than did the consumers who were presented with the smaller display. On the other hand, more consumers presented with the smaller decision set purchased a product than consumers presented with the larger display.

An increase in the number of products beyond a certain limit does not seem to increase the information load. Malhotra (1982) found that the effect of information load was constant within the range of 10 to 25 options. The same constant load was found when the number of attributes was varied from 15 to

25. Malhotra's results indicate that participants used some kind of heuristic or chunking strategy to adapt to the increasing amount of information. Such strategies would ideally allow the consumer to make satisfying decisions while minimizing the cognitive effort. Payne, Bettman and Johnson (1988) found that individuals change their information processing strategies from problem to problem, depending on the changing structure of the decision environment. They also propose that humans possess an ability to assess decision environment properties.

The effect of overload and experienced difficulty in decision environments with large assortments can, for example, be moderated by the availability of readily articulated attribute preferences (Chernev, 2003). Consumers with strictly defined preferences such as 'low-cost Italian pasta with high fibre content' can easily and quickly discard the majority of the product display.

The number of options and attributes will also affect eye movements and visual attention. When a large number of objects compete for visual attention, attentional mechanisms must rapidly prioritize and select information that is relevant for the task at hand. The pasta shelf in our supermarket will, for instance, present us with a very cluttered visual environment, where it can be difficult to distinguish different products and where information is hard to find. Hence, these environments can give rise to crowding effects - an inability to recognize objects in clutter. Crowding depends on the eccentricity of a target object and how densely spaced the surrounding objects are and will therefore seriously impact virtually all everyday tasks, since many natural scenes are visually cluttered (Whitney & Levi, 2011).

#### **1.2.4 Presentation format**

Looking past number of options and level of familiarity, the structure and format of the decision environment also plays an influential role in the decision making process.

Many of the traditional process tracing studies in decision-making research are highly structured with options and attributes presented in columns and rows (e.g. in the Mouse Lab Payne, Bettman & Johnson 1988). In contrast, information about different options can be difficult to find or even absent in

everyday environments such as the supermarket. The structure and format of information presentation can itself alter the decision process (Mueller, Lockshin & Louviere, 2010). For instance, packages promote acquisition by alternative, and while searching for intended information, other information can be acquired by accident. Matrices facilitate more goal directed information search due to their structure (VanRaaij, 1977).

It is also worth noting that we behave differently in a lab compared to when we go about our everyday tasks (see Kingstone, Smilek, Ristic, Kelland Friesen & Eastwood, 2003). Participants act differently when they pretend to buy milk or try to judge which one of two different products is the most healthy compared to when they actually stand in front of the dairy shelf in the supermarket and will actually consume their choice. What consumers want in a real world situation and what they say they are interested in when asked by a researcher are two different things (Mueller, Lockshin & Louviere, 2010).

However, most studies of consumers' visual attention during decision making are performed in a lab, where options are presented on a computer monitor, or in rare cases, on a shelf representing the decision environment. During the last decade, the use of eye tracking in marketing and consumer decision-making studies has rapidly increased (see Wedel & Pieters, 2008 for a review). The majority of these studies are performed on computer monitors (e.g. Pieters & Warlop 1999; Chandon, Hutchinson, Bradlow & Young 2009) or as projections on a wall (Tonkin, Ouzts & Duchowski, 2011). To answer research questions regarding the impact of package design, this can be a quick and effective means of understanding what is attended to.

Presenting stimuli on a computer monitor can, however, be problematic. The few studies that have compared gaze allocation in the real-world to a similar monitor setting generally find that we do not exhibit the same visual behaviour in front of a screen compared to when we are immersed in the real world, even when other factors are kept constant. t'Hart, Voeckeroth, Shumann, Bartl, Schneider, König and Einhäuser (2009) compared eye movement recordings made during various real world free exploration tasks with free viewing of the videos from the mobile eye tracker presented on monitors. Eye movements from the lab were only 60% correct at predicting real-world gaze allocation. Similarly, Foulsham, Walker and Kingstone (2011) investigated whether people distribute their gaze in a similar way when walking around in the real world

compared to when viewing a video clip taken from the perspective of a walker, and found significant differences in distribution of gaze, objects fixated, and in the timing of fixations. Tonkin, Ouzts and Duchowski (2011) found that search in a physical environment is significantly faster than search in a virtual environment. Tonkin et al (2011) also point out that the size of the visual field is likely to influence visual search since a small field is likely to restrict parafoveal preview benefit.

Another issue when performing studies on a computer monitor is the central bias; when we look at a stimulus on the computer monitor, we tend to look more in the centre of the screen compared to the outer areas. This centralization of visual attention occurs irrespective of the task and visual properties of the stimulus (Bindemann, 2010; Tatler, 2007). This tendency is also present in monitor-based consumer decision studies. Products in the centre of the screen are chosen more frequently and have a higher probability of receiving visual attention (Atalay, Bodur & Rasolofarison, 2012; Hutchinson, Bradlow & Young, 2009; Pieters & Warlop, 1999; Reutskaja, Nagel, Camerer & Rangel, 2011). If you look at the results from these monitor studies it would be natural to conclude that a central position is the best placement of a product. But as seen in paper II in this thesis, this is not so straightforward in the real world.

#### **1.2.4 Generalizability**

Taking all this into consideration, from number of options and attributes, level of familiarity and biases than can occur when presenting stimuli on a computer monitor, the general question is how well the results from previous studies can be generalized to an environment where everyday decisions are made, such as the supermarket. Paper I in this thesis show that consumers ignore a large part of the assortment in the supermarket (they do not fixate them) and spend relatively little visual time on the packages they actually attend to. In that same study, we found that consumers fixated roughly fifty percent of all pasta packages on the shelf and the options receiving visual attention were on average observed for one and a half seconds. The products in the jam category received even less attention; consumers fixated roughly a third of all products and devoted on average 0,75 seconds to each package. As a comparison, 0,75 second

is roughly equivalent to the time it takes to read three words. An average fixation on a word is around 250 ms and a saccade takes about 40 ms (Rayner, 2009). Fixations on pictorial elements are usually longer (Rayner, 2009) so if a consumer chooses to look at a picture on the package during that time, there would not be much time left for anything else.

The question is whether results obtained in the lab generalise to natural settings, and whether the same measures reflect decision processes in these environments. Unlike artificial decision environments, the real world offers people the possibility to adapt to the environments they encounter on a regular basis. It is also in these environments that decisions really matter. If the studies made in more artificial environments do not generalize to natural environments they are of a limited practical use, even if they can give us some insight into the cognitive mechanisms involved in the decision.

## 1.3 The different roles of visual attention in decision making

Visual attention has become an increasingly important aspect in decision-making research (see Orquin & Mueller Loose, 2013 for a review). In recent years, there has been a shift in how visual attention and eye movements are viewed in relation to decision-making. Visual attention is no longer viewed as having only a passive role of acquiring information but also as having a more active role in reflecting, influencing and supporting the decision process. Visual attention can shape on-going cognitive processes facilitating memory retrieval (Johansson & Johansson, 2014) and affect decision outcomes (Shimojo, Simion, Shimojo & Scheier, 2003).

### 1.3.1 Gaze cascade and DDM approaches

Several investigations focus on how eye movements unfold over the course of the decision process and specifically on attentional shifts towards the chosen object (e.g. Glaholt & Reingold, 2009, 2011; Glaholt, Wu, & Reingold, 2010; Krajbich, Armel and Rangel, 2010; Krajbich & Rangel, 2011; Schotter, Berry,

McKenzie & Rayner, 2010; Simion & Shimojo, 2006; Wedell & Senter, 1997).

Shimojo, Simion, Shimojo and Scheier (2003) monitored the gaze position while participants performed a two-alternative forced decision and found that in approximately the last 5 seconds leading up to the decision, there is a bias in the looking behaviour towards the item that is finally chosen. Shimojo et al (2003) put forward a model coined the *Gaze Cascade Model* in which the cascade part of the name indicates a positive feedback loop between what we look at and what we prefer. The observed gaze bias is produced by an interaction of the *mere exposure effect* and *preferential looking*. Results from paper IV in this thesis replicate the finding that decisions are strongly characterized by preferential looking to to-be chosen options.

However, Glaholt and Reingold (2011) conclude that a strict version of the gaze cascade model is not entirely valid, and that the results fit best into a framework where dwell duration reflects an early screening process, encoding potential alternatives (i.e. orienting), while the bias in dwell frequency nearer the decision reflects a later stage of evaluation when participants are comparing alternatives.

Drift diffusion models are a related concept that assumes that decisions are made by accumulating evidence in favour of the different options (Krajbich, Oud & Fehr, 2014; Krajbich & Rangel, 2011). The combined evidence for each option is compared to that for the other options and when the relative evidence reaches threshold one of the options is chosen. Attentional drift diffusion models (aDDM) (Krajbich, Lu, Camerer & Rangel, 2012; Towal, Mormann & Koch, 2013) include the influence of visual attention. In aDDM the evidence accumulation depends on where the individual is looking. Krajbich and Rangel (2011) argue that fixations drive the drift process e.g. the evidence accumulation. The item that receives more fixations offers the possibility to accumulate more evidence and hence is the one that first reaches the threshold.

There are some problems with DDM and aDDM specifically if used in natural environments. aDDM does not take into account why we fixate something - it tends to ignore the visual properties of the different items and assumes that fixations are stochastic. However, we know that fixations are not random; they



are driven by top-down or bottom-up processes. Towal, Mormann & Koch (2013) demonstrate that DDM can be improved and better explain fixation patterns and decisions by including visual saliency and subjective properties (values). aDDM also infers that the last fixation before the decision is always on the chosen item. However, the results in paper III in this thesis as well as results from the study by Russo & Leclerc (1994) demonstrate that this is not the case in consumer multi-alternative decision-making tasks. DDM traditionally deals with binary decisions and there is a debate about how to extend it to multi-alternative decisions. There has been some successful advances (Krajbich & Rangel, 2011) but only extended to trinary decisions. The authors admit that the processes described will break down (due to working memory limitations) when the decision set exceeds more than a handful of items, and that we will need other algorithms to describe those processes. DDM does however extend to simple purchasing decisions where price information is included (Krajbich, Lu, Camerer & Rangel, 2012).

Both gaze cascade- and attentional drift diffusion models demonstrate that visual attention reflects the decision process. People spend more time on the chosen item and the timing of fixations can provide information about people's preferences (Krajbich, Oud & Fehr, 2014). Both models also show the influential role of visual attention on the decision. By manipulating the relative amount of visual attention to different options, it is possible to affect the outcome of the decision (e.g. Armel, Beaumel & Rangel, 2008; Krajbich, Beaumel & Rangel, 2011; Pärnamets, Johansson, Hall, Balkenius, Spivey & Richardson, 2014; Shimojo, Simion, Shimojo & Sheier, 2003).

### **1.3.2 Interacting cognitive processes**

When making a decision in a familiar environment such as the supermarket, we are not only influenced by the information presented on the products on the shelf but also by our memories of those products. Our previous encounters with the products may also have taught us what to look for in the visual environment. We might search for a box of cereal of a specific colour since we remember the preferred brand has this distinction. Hence, a number of different cognitive processes are involved while making a decision and will have an effect on visual attention. In papers III and IV we have started to tap into

these differences. For example, visual search and decision-making share many common properties: both require the matching of target templates held in working memory to samples in the external world, and the ability to inhibit distractors that do not match the target's visual characteristics (cf. Duncan & Humphreys, 1989; Treisman & Gormican, 1988). However, whereas in visual search a unique target template is set from the outset, in decision-making the item looked for is updated based on on-going visual input and associated cognitive processing.

Standing once again in front of our pasta shelf we will remember things about both the set-up of the display and the specific products on offer from previous encounters. We will remember that the quality of the pricey pasta we bought last time did not really live up to our expectations and that the pasta from brand X is more healthy but has a funny texture. Hence, we do not need to acquire all information at each visit to the supermarket, and we may not have the same information in memory from one encounter with the item to the next. So how will decisions partly based on information stored in memory affect process tracing and eye movements? Will consumers not look at options placed in their consideration set? No - they probably will nevertheless. The evidence comes from a study by Renkewitz & Jahn (2013) in which participants had to make decisions strictly from memory. During the decisions participants tended to fixate on the positions where information was previously visible. They also displayed eye movement patterns typical for different decision-making strategies. These findings extend previous research in the "blank screen paradigm" in which participants during recall tend to look at locations where the information was originally presented (Altmann, 2004; Johansson, Holsanova, Dewhurst & Holmqvist, 2012; Richardson & Spivey, 2000). Looking at the position where information was previously present can also increase the likelihood of successful remembering (Johansson & Johansson, 2014).

## 1.4 A new approach to eye tracking as a process tracing tool

Trying to trace a decision process in a natural environment such as the supermarket poses several challenges. It is not possible to do the same types of analysis as those available in a more traditional process tracing set up. The environment is differently structured, so the regular measures used in e.g. information boards cannot be employed. However, investigating specific decision strategies is not within the scope of this thesis. I have come to the conclusion that other process measures are more suitable and of more relevance in a natural decision environment, than those comparing acquisition of information alternative-wise or attribute-wise such as the Payne Index (Payne, 1976). But, searching for information based on a single attribute is not equivalent to searching for information on a single alternative if we are, for instance, dealing with product packages (van Raij, 1977). Technically, it is not even possible to explore the acquisition of information at a single attribute level directly in the supermarket due to the resolution of the scene cameras and the precision of a mobile eye tracker. Data aggregated and averaged over the whole task, such as average fixation duration, number of fixations, number of refixations etc., do not properly explicate cognitive processes in the context of decision-making (see paper III). We need a new set of measures to better understand the decision making process in natural environments.

Several studies have used eye tracking to investigate visual attention during decision-making. Some focus on identifying certain aspects of the process underlying the decision; in particular how information is acquired and integrated, and how decisions are based on the integrated information (Riesen, Hoffrage & Mast, 2008; Lohse & Johnson, 1996; van Raaij, 1977; Russo & Leclerc, 1994; Russo & Rosen, 1975). Others focus on the distribution of consumers' visual attention in various shelf layouts (e.g. Chandon, Hutchinson, Bradlow & Young, 2009) and under different time constraints and motivational conditions (e.g. Pieters and Warlop, 1999). These studies generally consider eye movements only in terms of their ability to point towards

what objects were looked at, and not as a source of detailed information on subjective cognitive processes.

A few studies have started to use ET to look at process tracing and the decision process in different ways (e.g. Glaholt & Reingold, 2011; Russo & Leclerc, 1994; Shimojo, Simion, Shimojo & Scheier, 2003; Krajbich, Lu, Camerer & Rangel, 2012; Towal, Mormann & Koch, 2013). Russo & Leclerc (1994) used eye tracking to study different stages of the decision process. Subjects made decisions among real products presented on a shelf in the laboratory. Three stages of the decision process were observed and interpreted as orientation, evaluation and verification. During the orienting stage the subjects attained an overview of the options available by a series of fixations on single options. This stage was concluded by the first refixation on an option. The evaluation stage was comprised of comparisons of the different options and was characterized by refixations on several options. This stage was terminated when a decision was made. The verification stage followed directly after the decision and resembled the orienting stage with a series of fixations on single options.

However, there are several problems with the Russo & Leclerc (1994) approach. First of all, the theoretical motivation for their segmentation is questionable. Secondly, stimuli and set-up deviates in several important ways from decision making in the supermarket. Third, participants did not make a real decision in the sense that they had to select a product to pay for, take home and consume. And finally, they did not compare their data with similar tasks that did not involve decisions.

#### **1.4.1 Our approach to eye tracking as a process tracing tool**

In order to address the limitations of previous studies and to better suit the demands of a natural environment, we propose a novel model to segment the decision process in to stages (c.f. Russo & Leclerc, 1994). Comparing participants behaviours over time can be tricky, especially if the length of the recordings differ across participants. The stage approach allows us to compare participants that vary in terms of how they evaluate and approach the same aspects of the visual environment: a product that is suitable and interesting for one participant may not be for another, yet if the same stages are used we can

identify their selection strategies. Our model enables us to take a closer look at how the decision-making process unfolds over time and its relationship to visual attention. The details of that model are presented in paper III but one clear distinction from Russo and Leclerc (1994) is that we used visual attention to the chosen item to separate our stages. One advantage of aDDM and gaze cascade models is that they build upon subjective measures of the options to better understand the decision process. They also include information about the chosen option and the visual attention to this option.

We also do not know if the stages, and more specifically the visual attention during these stages, proposed by Russo and Leclerc (1994) are unique to decision-making or reflect search in general. In our study we compared a decision-making task to a search task, and it was only our model that could reveal the differences between these tasks. Specifically, the evaluation stage of the decision task contained more re-fixations than the search stage. This finding is replicated in paper IV in this thesis, with a higher re-fixation frequency in the decision-making tasks.

In this context, we emphasize that stages are not clear cut, but rather that processing is dominated by these functions at these stages. It is highly likely that a certain amount of search behaviour and orientation is present throughout the decision process, and paper IV demonstrates that evaluation of the alternatives can start early in the process, already during the encoding of the alternatives.

Since we used a mobile eye tracker for all of our studies in the supermarket, the analyses we were able to perform were limited from the beginning. The output you get from a mobile eye tracker is a scene video with an overlaid gaze cursor, representing the gaze position of the participant, and a file with the x and y coordinates of the position of the eyes. The x and y coordinates are difficult to use since they do not correspond to coordinates in the real world but to coordinates in the scene video. Since the participant is free to move around, what is present in the scene video is constantly changing and the coordinates of an object in the scene video can change between two samples. Hence, all data was coded by hand by going through the video frame-by-frame registering the position of the gaze cursor in the video. This type of coding makes it very difficult to separate the data into single events such as fixations and saccades; therefore we chose to code the eye movements as dwells within single areas of interest (AOIs). Glaholt and Reingold (2011) point out that a sequence of

dwells also relate more to traditional process tracing measures being more similar to a single “look” in an information board display.

AOI based analysis also suited the purposes of our studies in the supermarket (papers I, II and III) since we were mostly interested in which options would receive visual attention. Attention to single attributes were less important and technical limitations of the mobile eye tracker in terms of accuracy also rendered such an approach inadvisable. As mentioned above, the supermarket is often a familiar environment, and the decisions made there will be partially based on information stored in memory. Although these memorized attributes may not require fixation, the options possessing these attributes probably will be fixated.

# 2 Introduction to the papers

## 2.1 Paper I - Material Distortion of Economic Behaviour and Everyday Decision Quality

### 2.1.1 Research question

The Unfair Commercial Practices Directive; European Parliament and Council 2005 clearly links material distortion of economic behaviour to whether consumers make transactional decisions “they would not have taken otherwise”. This makes it clear that misleading information and unfair commercial practices have to be viewed against the background of what consumers otherwise do, i.e., what their purchase decisions look like when no potentially misleading information or no unfair commercial practices are in place. The aim of this paper is to provide some of this background: How do consumers sample information when making an in-store purchase decision? How successful are consumers in purchasing the products that best meet their purchase intentions when only a representative amount of misleading information or potentially misleading information is present?

### 2.1.2 Procedure

Participants were recruited in a supermarket in the Copenhagen area and fitted with a mobile eye tracker. They were asked to do their shopping as normal but were encouraged to buy pasta and/or jam if they had a need for it. All participants paid for their own purchases. After the shopping they filled out a detailed questionnaire asking them about their preferences for various attributes of the products they had bought. The eye-tracking data were analysed frame-

by-frame for dwells (Holmqvist, Nyström, Andersson, Dewhurst, Jarodzka & Van de Weijer, 2011, p. 227) from selected segments of the gaze-overlaid video, namely, around the pasta, jam, and milk shelves.

### **2.1.3 Results**

To assess how successful the consumers were in purchasing a product that best meet their needs, the sum of the weighted value of each of the options' attributes was calculated, this is the option quality value. Participants selected products very close to a mean option quality value. In the milk and pasta categories, the selected products were slightly better than the mean and for the jam, slightly worse than the mean product. Only in the milk category, did participants look at a selection of products with significantly higher option quality values than the complete set of products. The decision quality did not seem to relate to the amount of products attended to or the amount of time spent on each product.

## **2.2 Paper II - The centre might not be so shining after all - central bias from computer screen to the supermarket**

### **2.2.1 Research question**

How consumers distribute their gaze when shopping in a supermarket is an important question for marketers as well as researchers. Previous research has shown that consumers tend to fixate more on the products in the centre of the display. However, these studies have almost exclusively been performed on computer monitors where looking at the centre of the screen is a known bias. We wanted to know if such a bias would also be present in the actual supermarket or if it is a result of showing stimuli on a computer screen.



### **2.2.2 Procedure**

The study was performed in two parts, the first in a supermarket and the second part in front of a computer monitor. Consumers, recruited in a supermarket, were fitted with a mobile eye tracker and were asked to select a cordial mixer that they would consider buying. This was done during their regular shopping in the supermarket. The chosen product was handed over to the experiment leader. In the monitor condition, participants' eye movements were recorded using a remote eye tracker. Photos of the shelf were taken in the supermarket and used for the monitor condition and participants were asked to make a decision by clicking on the chosen product.

Both the original and a reorganized setup of the shelf were used. The reorganization was made by turning the organization of the shelf "inside out" so that the products in the middle of the shelf was moved as far out as possible. This was done to ensure that the distribution of fixations in the scene did not depend on the setup of the shelf and the placement of the most popular products.

### **2.2.3 Results**

The proportion of total dwell time in each AOI was calculated for each participant in all conditions. A dwell is a collection of one or several fixations, including the intervening saccades, within a certain area of interest, from entry to exit. The presentation format had a great impact on visual attention and the proportional dwell time of the participants were spent significantly closer to the centre in the monitor condition compared to the supermarket condition in both the original and the reorganised condition. There were also significant differences in the distribution of dwells on the horizontal axis between the supermarket and the monitor condition, with a larger proportion of dwells in central positions in the monitor condition compared to the supermarket. This holds for both the original and the reorganized setup of the shelf.

## 2.3 Paper III - Using Eye Tracking to Trace a Cognitive Process: Gaze Behaviour During Decision Making in a Natural Environment

### 2.3.1 Research question

In this study we sought to investigate consumers' decision making in the supermarket and what differentiates a decision process from a visual search process. The aim was to uncover the timeline of gaze behaviour in a decision-making task and to devise a model of the decision making process based on this information. Traditional metrics used to trace decision-making processes are difficult to use in natural environments that often contain many options and unstructured information. The stages proposed by Russo and Leclerc (1994) were used but because of the problems of delineating the first and second stage based simply on the first re-fixation, we also put forward an alternative method for splitting up the stages based on the process tracing literature with eye tracking (see figure 1). As the gaze cascade model demonstrates, that following the first fixation on the selected item it cumulatively receives more attention until it is eventually chosen, we used the time the chosen item is first fixated as a cut-off for when the initial overview screening ends and the evaluation phase begins. In our model the evaluation phase is thus more narrowly defined compared to Russo And Leclerc (1994). This is important since it arguably the evaluation stage that will differentiate decision-making from other cognitive processes, such as search behaviour. Furthermore, we permit re-dwells in all stages and can thus use them to achieve more information about how the stages develop over time, and possibly about task difficulty (given the role of re-fixations discussed by Gilchrist and Harvey, 2000).

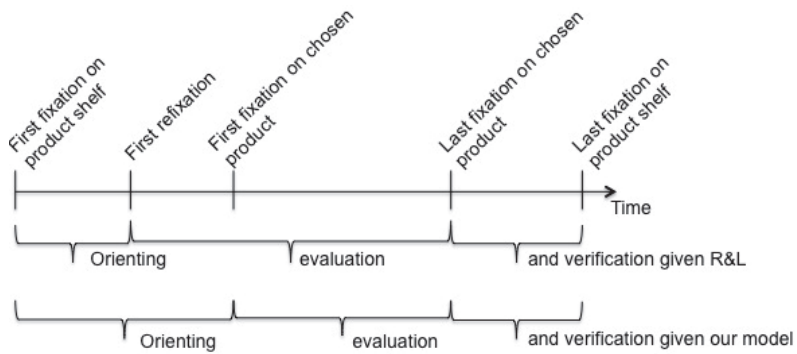


Figure 1. Decision stages as proposed by Russo & Leclerc (1994) and the one proposed in this paper

### 2.3.2 Procedure

Participants were recruited in a supermarket and fitted with a mobile eye tracker. Each participant was asked to do either a search task or a decision task. For the search task participants were asked to go the pasta shelf, find a specific pasta from a popular brand (specified in the instructions) and return it to the research assistant. All participants were asked to find the same pasta. For the decision task participants were asked to buy a pasta product of their decision and proceed with their shopping.

### 2.3.3 Results

Unlike previous attempts in this direction (i.e. Russo & Leclerc, 1994), our methodology revealed differences between the decision-making task and the search task. In particular the second (evaluation) stage of the decision task contained more re-dwells than the second stage of the comparable search task.

## 2.4 Paper IV - How information availability interacts with visual attention during judgment and decision tasks

### 2.4.1 Research question

During a decision in the supermarket, several cognitive processes such as decision-making, memory, search and judgements are likely to co-occur. In this study we were interested in the impact these processes will have on visual attention respectively and how visual attention can support decisions in a pre-encoded setting. In particular we aimed at differentiate how visual attention to and on products is employed during a decision task and a judgment task and how visual attention during those two tasks depends on the visual availability of relevant information.

### 2.4.2 Procedure

Participants' eye movements were recorded using a remote eye tracker while they were asked to make either a decision about which out of three, previously encoded, products they would buy or to make a judgment about an attribute, e.g. which jam had the lowest sugar content. We used both judgment and decision tasks since they depend on the same attribute information. This allows us to compare the tasks in order to identify visual attention patterns specific for decision-making. Those two tasks thus represent the least complex and the potentially most complex ways in which products can be selected based on their attributes. During their decisions or judgments, participants were sometimes faced with a full task environment containing all the information required to solve the task and sometimes with one in which the relevant attribute information was absent.

### **2.4.3 Results**

We find that participants' visual attention during decisions is sensitive to evaluations made already during encoding and that decisions are strongly characterized by preferential looking to to-be chosen options. When the task environment is rich enough participants engage in advanced integrative visual behaviour and improve their decision quality. In contrast visual attention during judgments made on the same products reflects a search like behaviour in information rich environments and a more focused visual behaviour when information was missing.



# 3 Concluding remarks

The aim of this thesis is to better understand decision-making in natural environments, how visual attention is distributed during these decisions and how this relationship can be measured in eye movements. The studies outlined have progressed from first orienting to this new combination of decision-making and eye movements in a natural environment, and then looking in closer detail at the process and its explication via eye movements.

The result of these studies is a new model of decision-making and its empirical support through the application of eye movement research. This model offers fertile ground for similarly investigating decision processes in other natural environments. These studies also show how eye tracking technology can be applied outside the traditional domains in which it developed, to great effect. While convenient mobile eye tracking is a relatively recent technical advancement, its exploitation in decision research is only beginning. This thesis has attempted to bring about a beneficial combination of methods towards an understanding of complex decision-making in every day tasks.





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