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DEPARTMENT OF COMMUNICATION AND MEDIA | LUND UNIVERSITY 2016

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by Nils Holmberg

LUND
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Thesis for the degree of Doctor of Philosophy
Thesis advisors: Assoc. Prof. Helena Sandberg, Prof. Kenneth Holmqvist
Faculty opponent: Assoc. Prof. Jessica Taylor Piotrowski

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Effects of online advertising on children's visual attention and task performance during free and goal-directed internet use: A media psychology approach to children's website interaction and advert distraction

Abstract

This dissertation consists of four eye-tracking studies that investigate how salient online advertising and children's level of executive function contributes to their advert distraction. In Study 1, children aged 9 were instructed to surf freely on the internet while all advert material appearing on-screen was registered. The analyses examined how perceptual prominence in each online advert was related to children's visual attention. In Study 2, a mock-up advergame website was designed with controlled advert conditions, and children aged 9 and 12 were instructed to solve a number of in-game tasks. This study investigated the combined effects of perceptual prominence (e.g. abrupt onset) and content relevance (e.g. personalized content) on children's advert distraction. The results of the first two studies showed significant positive effects of advert saliency on children's visual attention. Due to the task-oriented research design used in the second study, it was possible to interpret these effects on visual attention in terms of advert distraction. Both studies showed that higher levels of inhibitory control in children significantly decreased the effects of advert saliency on visual attention and advert distraction.

The following two studies, investigated how advert animation affected children's online reading comprehension and information search on commercial websites. In Study 3, children aged 9 were presented with factual texts that they were instructed to read in order to answer comprehension questions. Each text was presented on a web page which also featured static or animated online adverts. In Study 4, children aged 9 were instructed to solve two online task types featuring concurrent online advertising: reading and information search. The results of these studies showed that animated online advertising had significant negative effects on children's task performance. In the third study, it was found that animated adverts had a negative effect on children's reading comprehension, and that this negative effect was stronger among children with low levels of inhibitory control. The fourth study found that advert animation had a significant positive effect on children's cognitive load across task types. Taken together, this dissertation project has studied children's online advert distraction in a wide range of realistic internet usage situations.

Key words

online advertising, children, website interaction, visual attention, distraction, cognitive load, eye-tracking, task-orientation, media effects, visual saliency, executive functions, media literacy, inhibitory control

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In the latter case the thesis consists of two parts. An introductory text puts the research work into context and summarizes the main points of the papers. Then, the research publications themselves are reproduced, together with a description of the individual contributions of the authors. The research papers may either have been already published or are manuscripts at various stages (in press, submitted, or in draft).

Cover illustration front: Detail of online advert (Paper III).

Cover illustration back: Photo of Nils Holmberg (Credits: Maja Petersson).

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Dedicated to Rosemarie

Contents

List of original papers

This thesis is based on the following research papers, referred to by their Roman numerals:

I **Children's attention to online adverts is related to low-level saliency factors and individual level of gaze control**

Holmberg, N., Holmqvist, K., & Sandberg, H. (2015)
Journal of Eye Movement Research, 8(2), pp. 1–10

II **Advert saliency distracts children's visual attention during task-oriented internet use**

Holmberg, N., Sandberg, H., & Holmqvist, K. (2014)
Frontiers in Psychology, 5, 51

III **Advert animation impairs children's online reading differently depending on their gaze control: An experimental approach to investigating children's media and information literacy on commercial websites**

Holmberg, N. (2016)
Media Psychology. Submitted

IV **Children's attention management on commercial websites: Effects of task type and advert prominence**

Holmberg, N. (2016)
Communications. The European Journal of Communication Research. In draft

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Sammanfattning på svenska

Denna avhandling består av fyra delstudier som undersöker hur internetreklam påverkar barns visuella uppmärksamhet. Syftet med studierna var att ta reda på om barn distraherades av internetreklam när de interagerade med webbsidor med hjälp av en vanlig webbläsare. Varje delstudie undersökte hur en specifik uppsättning variabler och faktorer gemensamt bidrog till att predicera hur barnen betraktade internetreklam som presenterades på ett antal webbsidor. De faktorer som varierades i samband med barnens internetanvänding var: 1) vilken webbaserad uppgift barnet skulle försöka lösa på nätet (fri webbsurfning, kommersiellt online-spel, textläsning på nätet, eller informationssökning), 2) webbannonsernas perceptuella och innehållsliga egenskaper (perceptuell prominens och innehållslig relevans), och 3) barnens demografiska egenskaper och individuella förmåga att kontrollera sitt blickbeteende. Studierna genomfördes på så sätt att barnen fick surfa på nätet samtidigt som deras ögonrörelser registrerades med hjälp av en särskild kamera som var monterad på undersidan av datorskärmen. Innan barnen fick surfa på nätet genomfördes ett så kallat anti-saccadtest för att fastställa deras individuella nivå av blickkontroll. Tidigare neuropsykologisk forskning har visat att anti-saccadtestet ger en god uppskattning av individuell förmåga till responsinhibering och exekutiv kontroll. Sammanlagt deltog 137 barn i åldrarna 9–12 år i någon av de fyra delstudierna, och alla delstudier genomfördes i barnens naturliga skolmiljö för att erhålla så god ekologisk validitet som möjligt.

Resultatet av studierna visar att barnens individuella förmåga till blickkontroll ökade med ålder. Detta resultat återspeglar att barn i åldern 8–10 år genomgår en omfattande kognitiv utveckling till följd av snabb tillväxt i hjärnans prefrontala cortex. Detta medförde att barn i 9-årsåldern generellt hade låg förmåga till viljestyrt blickbeteende och att de uppvisade stora individuella skillnader. Vid fri webbsurfning visade det sig att hög perceptuell prominens hos internetreklamen (t.ex. animering) ökade barnens visuella uppmärksamhet (Studie 1). När barnen spelade online-spel visade det sig att annonser som plötsligt dök upp på webbsidan (perceptuell prominens) hade ett positivt samband med hur mycket barnen tittade på annonserna, men relevant reklaminnhåll hade en ännu starkare effekt i samma riktning (Studie 2). Dock påverkade inget av annonsvillkoren barnens spelprestationer. Äldre barn (12 år) klarade speluppgiften bättre än yngre barn (9 år). En viktig metodutveckling i denna studie var införandet av uppgiftsstyrd interaktion med webbsidor. Denna forskningsdesign innebar att visuell uppmärksamhet riktad mot webbannonserna på ett tydligare sätt kunde kopplas till distraktion från uppgiften. Sammantaget visade de två första studierna att internetreklamen hade tydliga effekter på barns visuella uppmärksamhet och annonsdistraktion. De efterföljande studierna stävade efter att undersöka eventuella effekter av online-reklam på barns förmåga att lösa uppgifter på nätet, dvs. effekter på prestationer.

En webbaserad uppgift där barn behöver uppnå goda prestationer är läsförståelse. När uppgiften var att läsa texter på nätet och sedan svara på förståelsefrågor så upptäcktes att ani-

merade annonser som presenterades till höger om texten hade en generell negativ effekt på 9-åringars läsförståelse i ett efterföljande förståelsetest (Studie 3). Den negativa effekten av annonsanimering på läsförståelse var dessutom förstärkt hos barn med lägre förmåga till responsinhibering, vilket innebär att denna grupp tycks särskilt sensitiv för internetreklam. Animerade annonser medförde också en ökad distraktion i form av fler ögonrörelser riktade mot dessa annonser (fixeringar och saccader) jämfört med statiska versioner av samma annonser. I den sista studien jämfördes hur animerade annonser påverkade barns distraktion i samband med två olika webbaserade uppgiftstyper: läsning och informationssökning (Studie 4). Denna studie undersökte först hur uppgiftstyperna påverkade barnens kognitiva belastning, vilken uppmättes genom att analysera pupilldilatation. Resultaten visade att uppgifter baserade på informationssökning medförde en högre kognitiv belastning än läsning. Animerade annonser som presenterades samtidigt med uppgifterna medförde att barnens arbetsbelastning ökade ytterligare jämfört med statiska annonser. Barnens annonsdistraktion (visuell uppmärksamhet på icke-relevanta annonser) var högre i samband med uppgifter med lägre arbetsbelastning (läsning), vilket tolkas som att barn kan vara mer sårbara för annonsdistraktion vid automatiserade och/eller lågintensiva uppgifter som läsning.

De undersökningar som genomförts inom detta avhandlingsarbete visar sammantaget att barn i åldern 9–12 år på flera sätt är känsliga för innehållsliga och visuella egenskaper hos webbannonser. Genom att dessa undersökningar har utförts med hjälp av fysiologiska mätmetoder med hög precision (validitet) samt experimentella forskningsdesigner (reliabilitet) så bör resultaten kunna generaliseras till en större population av barn och till ett större urval av deras webbaktiviteter. Den främsta förhoppningen med denna avhandling är att resultaten ska kunna bidra till att ge beslutsfattare och näringsliv ett bättre underlag i arbetet med att göra den kommersiella webben mer användarvänlig för dess yngsta användargrupp. Ur ett mer forskningsnära perspektiv bidrar denna avhandling till den så kallade effektforskningen inom medie- och kommunikationsvetenskap. Genom att undersöka oavsiktliga korttidseffekter av webbannonser på barns visuella uppmärksamhet och uppgiftsstyrda webbinteraktion, visar denna avhandling på en kombination av teoretiska utgångspunkter och metoder som skulle kunna tillämpas på andra områden inom medie- och kommunikationsvetenskapen.

Chapter 1

Introduction

This compilation thesis is presented within the academic field of media and communication studies. The main focus of the research has been to investigate how online advertising affects children's interaction with commercial websites. The study of advertising effects has traditionally been a subfield within media and communication studies (**Turow**, 2011), but the specific combination of children and online advertising poses new and interesting challenges, both on theoretical and methodological levels. On a theoretical level, online advertising needs a new conceptual framework that takes into account how these commercial messages fit within a so-called attention economy (**Davenport and Beck**, 2013). Such an attention economy is profoundly characterized by the fact that the cost of creating and distributing digital messages is considerably lower than during previous modes of mass communication (television, print). Low production costs causes the amount of digital information to increase exponentially, but by the same token, the amount of human attention available for all this information gets smaller. Due to a growing information overflow and the scarcity of attentional resources (in terms of eyeballs), online advertising is increasingly penetrating the world wide web, and the techniques utilized in order to capture users' attention are becoming ever more sophisticated. Global ad expenditure is predicted to grow 4.7% during 2016, reaching US$579 billion (**ZenithOptimedia**, 2015). Online advertising will account for nearly one-quarter of these investments, making it the fastest-growing advertising medium. This international trend is closely paralleled in a Swedish context, where a total of SEK12.9 billion was spent on online advertising in 2015, which accounts for about 25% of all advertising investments (**IRM**, 2015).

When there are increasing trends in both the number of online users, and their frequency of access to immersive online services (**Danielsson**, 2014), online advertising also grows more pervasive. In Sweden, the number of internet users has increased every year since 1995, and in 2015 around 80% of the population accessed the internet once or more every day. In the

adult population, an average of 21 hours are spent on the internet each week (**Findahl and Davidsson**, 2015). In the younger population, a similar increasing trend can be found. Half of the 6-year-olds use the internet every day, and among 10-year-olds the same statistic is 75%. Thus, as commercial online media steadily become more integrated into children's everyday lives, this situation poses new methodological challenges concerning how to gain insights into children's interaction behaviors. Such insights are needed in order to evaluate how children cope with the attention economy of commercial websites, and how their attentional resources are impacted in such media environments. It has been suggested that one type of response strategy to information overflow consists in so-called media multitasking (**Rideout et al.**, 2010). This behavior attempts to mitigate information overflow by monitoring several media at the same time (e.g. watching television while texting) or several channels within the same medium (e.g. chatting on social media while searching information online). However, since human attention is essentially serial in nature, such multitasking actually amounts to rapid task-switching (**Wallis**, 2010; **Vega**, 2009), which require considerable cognitive flexibility, and which may result in lower task performance (**Gazzaley and Rosen**, 2016; **Baumgartner et al.**, 2014; **Mark et al.**, 2005). Research methods providing detailed measurements of visual attention, such as eye-tracking, are useful in order to investigate children's attention management on commercial websites (**Holmqvist et al.**, 2011).

This dissertation describes the undertaking of a series of studies to investigate the effects of online advertising on children's interaction with commercial websites. Since online advertising is a broad and somewhat amorphous concept (**Martinez**, 2016; **Sandberg**, 2014), this advertising category was defined as display advertising, which has consistently proved to be one of the most pervasive and profitable types of online advertising (**IAB**, 2015). Although such online display advertising can potentially affect users on a number of different levels, from brand awareness to commercial persuasion, the current research focuses on how salient advert properties such as animation attract children's visual attention, and to what degree their attention to adverts distracts them while they are trying to perform various tasks using the internet. Previous research in this field has established that online advertising often contains high levels of perceptual prominence (**McMahan et al.**, 2013; **Azimi et al.**, 2012; **Cheng et al.**, 2012), and that these visual features frequently cause attentional distractions among adult internet users (**Kuisma**, 2015; **Simola et al.**, 2011). In adults, this causal relationship between obtrusive online advertising and visual distraction has been carefully studied using experimental procedures and sensitive equipment that measures participants' eye movements with a high level of detail. However, similar research on children's reactions has hitherto been practically non-existent.

The current doctoral thesis wishes to address this lack of empirical research, and in doing so, advance both the field of media and communication research on online advertising, and the field of media psychology research on children's visual attention. For several reas-

ons, it can be expected that online advertising has more pronounced distractive effects on children than on adults. One of the primary reasons for this is that rapid brain growth and cognitive development in children makes them less able to inhibit reflexes to look at salient stimuli and recover from attentional distractions. Potentially, this renders online advertising particularly harmful in situations where children try to pursue goal-directed interaction on commercial websites featuring salient display advertising. According to recent internet usage surveys, Swedish children start using the internet for information search, school work, and other goal-directed activities around 8–10 years of age (**Findahl and Davidsson**, 2015; **Medierådet**, 2013). Thus, this particular age group merits special attention in terms of examining unintended effects of online advertising.

This general research question has been investigated in four separate studies, and the implementation and results of these studies form the basis of the present thesis. In order to parallel previous research on advert distraction in adults, these studies have utilized similar research methods, consisting of web-based experimental procedures for controlled presentation of online advertising stimuli, and eye-tracking equipment for measuring causal effects on visual attention. A significant benefit of this implementation is that these methods allow us to measure and quantify advert distraction, which in turn, allows us to make meaningful comparisons between adult and child populations. Using this research framework, the included studies have focused on several realistic scenarios in which children use the internet, and carefully investigated how a set of online advertising factors affect children's visual attention and website interaction. In order to increase the ecological validity of this research, all studies have been undertaken in the children's natural school environment. A total of 137 children aged 9–13 years participated in this dissertation project, which is part of a larger research project called *Children, advertising, and internet* (**Sandberg**, 2014). This research project builds on previously developed methods and study designs described in **Gidlöf et al.** (2012) and **Sandberg et al.** (2011).

1.1 Research motivation: Children's advert distraction

There is no shortage of evidence that online advertising can be distracting and disturbing to internet users (**Kuisma**, 2015; **Sveriges Annonsörer**, 2016). Several interview studies with children point in this direction (**Martinez**, 2016; **Martinez et al.**, 2013), as well as a number of empirical studies on adults (**Simola et al.**, 2011). There are potentially many contributing factors to these negative experiences of online advertising. First of all, advertising in any medium, from print to television to internet, can be perceived as disturbing for the simple reason that these commercial messages are often presented as an interruption to some primary media activity, and that advertising in general requires media audiences to cope with persuasive messages that are intended to attract attention and to change people's attitudes and consumption preferences. Second, in the context of online advertising, the

spatial layout of many web pages means that a multitude of salient adverts are often presented alongside regular content (**Pasqualotti and Baccino**, 2014), and the interactive nature of this medium means that users are frequently trying to pursue some kind of informational task which requires sustained attention, e.g. text reading. If an animated online advert is presented adjacent to a text that is being read, this situation can create an advert distraction that leads to higher cognitive load and lower reading comprehension (**Simola et al.**, 2011). The fact that online advertising is only getting more pervasive and technologically advanced (e.g. behavioral targeting), due to rising investments in this commercial medium, could also contribute to higher levels of online advertising distraction.

The main motivation of this thesis project was to gain a greater understanding of if, and how, children were distracted by online advertising while they engaged in various kinds of website interaction activities. In media and communication studies there are a number of approaches to this research question. Most commonly, researchers would interview children and ask them if they perceive online advertising as distracting, or alternatively a survey study could be performed. These approaches could be combined with various types of content analyses of online adverts. Another approach would be for researchers to observe children while interacting with web pages through media ethnographic methods, and report evidence of children's distraction from online advertising. Although these media and communication research approaches have their benefits, and have produced valuable insights, they also have some important shortcomings in the area of children's online advert distraction. As for interviews and surveys, the biggest problem with these methods is that they rely on children's self-reported experiences of distraction, which may suffer from various biases. In the case of media ethnographic observations, the main problems are that the researcher's presence influence the children's internet usage situation, and that observations run the risk of being biased and subjective to the researcher. Furthermore, children's advert distraction may not be directly observable. While potentially having a high degree of validity, the general problem with self-reported data and subjective observations is that these methods have a lower level of objectivity, reliability, replicability and generalizability. These deficiencies can impede any impact of the research outcomes on policy, legislation and industry, which may be important when it comes to children's potential online advertising distraction.

Whether online advertising can distract children, and negatively affect communication outcomes such as reading comprehension and task performance, is a research question that belongs to the field of media and communication studies. However, in order to provide answers to this research question, there is a need to introduce new methods to this research field, that can produce more detailed, objective and generalizable results with regard to children's online advertising distraction. This thesis seeks to address this issue by introducing two new methodological approaches in order to investigate children's advert distraction. First, the present research introduces physiological eye-tracking equipment in order

to provide detailed real-time measurements of children's visual attention while interacting with websites and online advertising. Second, this thesis combines eye movement measurements with experimental research designs, which allow us to investigate causal effects of online advertising properties on children's visual attention, website interaction, and online task performance. By applying these research methods, we hope to provide new insights to the media and communication research field that deals with children and advertising, both on an empirical and on a theoretical level. First and foremost, however, this research on online advert distraction is intended to benefit the children who are using the internet every day, by means of suggesting how the commercial online environment could be improved. The research into reliable measures of children's online advert distraction undertaken in this thesis have progressed in three successive steps, which are discussed from a media and communication perspective as well as a media psychology perspective in this introductory chapter. These three stages are outlined below.

Even if the overarching aim of this thesis is to shed light on children's advert distraction, there is currently no viable method to directly observe the mental processes of advert distraction. Instead, this phenomenon has to be approached in a stepwise (and somewhat reductionist) fashion. In the first and most basic step, we have to uncover the relationship between various properties of online advertising and children's visual attention. In this step, we start out by investigating if there is any kind of systematic association between visual properties of online adverts and the location of children's visual attention. This is done by measuring children's eye movements (fixations and saccades) while interacting with a number of commercial websites containing authentic advertising. Then, quantitative measures of visual saliency in adverts are related to where children looked on-screen, to explore if adverts with high levels of visual saliency (e.g. animation) are associated with high levels of visual attention in children (fixations). Using experimental methods we then proceed to investigate if there is also a causal effect. Importantly, children's visual attention to salient online adverts does not necessarily mean that they are distracted by adverts, this can only be examined in later stages.

The second stage towards an analysis of children's online advert distraction was to collect data about individual differences between children. In media and communication research, it is debated whether children in different age groups, and within the same age group has varying levels of susceptibility (or vulnerability) to advertising (**Kunkel**, 2010; **Lapierre**, 2013). In order to clarify if this could also be the case regarding children's online advert distraction, we compared visual attention to adverts in different age groups, and collected data about individual differences in children's internet usage habits and development of executive functions. Crucially, in this stage we introduced a physiological measure in order to investigate children's voluntary control over their visual attention. By means of an anti-saccade task (**Munoz and Everling**, 2004), we measured children's individual level of executive function (gaze control), and investigated if this measure moderated the effects

of salient online advertising on children's visual attention. Thus, this measure was used as a control variable to indicate individual differences in children's susceptibility to advert distraction.

With the aforementioned two research steps in place, we could proceed to investigate the main research question concerning children's online advert distraction. In order to investigate the cognitive processes of advert distraction, we had to introduce a functional dimension to children's visual behavior while interacting with commercial websites. This was achieved by presenting children with online tasks that they were asked to solve while interacting with web pages. By introducing these web-based tasks, we elicited goal-directed website interaction in the children who participated, and based on these tasks, the content of the web pages could be divided into task-relevant regions (textual information, advergames etc) and task-irrelevant regions (online adverts). With this spatial and functional distinction in place, we could proceed to use eye movement measurements as indicators of children's online advert distraction. Two types of eye movement measures were used to indicate advert distraction: 1) visual attention measures on the task-irrelevant advert area (fixations, dwell time), and 2) cognitive load measures in the task-relevant part of the web pages (pupil dilation). In addition, children's online advert distraction was also measured as task performance measures (e.g. reading comprehension and information search accuracy). Because of the experimental design of the web-based tasks, all effects of online advertising on children's advert distraction measures were causal in nature. The results on children's online advert distraction are related to an ongoing discussion within media and communication studies concerning the distractive effects of children's media multitasking habits, which includes situations when children have to manage attention on websites which contain concurrent and adjacent display advertising.

1.2 Structure of the thesis

A doctoral thesis at a university in Sweden takes either the form of a single, cohesive research study (monograph) or a summary of research papers (compilation thesis), which the doctoral student has written alone or together with one or several other author(s). In the latter case the thesis consists of two parts: 1) a thesis introduction that introduces the research work, puts it into context, and summarizes the main points of the papers; and 2) a reproduction of the research publications themselves, together with a description of the individual contributions of the authors. The research papers may either have been already published or are manuscripts at various stages (in press, submitted, or in draft). The current dissertation is submitted as a compilation thesis, and this section will explain and motivate the structure of the first part – the thesis introduction – often referred to in the Swedish academic system as the "kappa" (literally meaning a "coat" surrounding the research papers).

The thesis introduction (or "kappa") will be organized into four main chapters: 1) an introductory chapter which motivates the research questions and hypotheses of the dissertation project; 2) a methods chapter describing how the hypotheses were operationalized; 3) a results chapter which describes the empirical findings of the studies; and 4) a discussion chapter which details the research contributions and significance of the included studies. Thus, the thesis introduction as a whole will be organized according to the typical structure of a standard journal article. Crucially, the thesis introduction does not include the application of a theoretical framework to a set of empirical data (cf. analysis), which can be the case in monograph dissertations. Instead, such analytical procedures are mainly undertaken within the research papers.[1]

The first introductory chapter of the thesis introduction serves the function of reviewing previous research and theoretical concepts that are relevant to the area of children and online advertising. The fact that the media and communication subject has undergone major changes from being a more positivist and psychology oriented field to being more oriented towards critical and interpretive social theory, motivates dividing the introductory chapter into two parts or "layers" (see **Figure 1.1**). The first part of the introductory chapter discusses the theoretical concepts underlying the present dissertation from the perspective of recent media and communication research. This theoretical section reviews previous research on central concepts such as media effects and children's advertising susceptibility, and uses this research to derive a number of broad theoretical research questions that are addressed and investigated in the current thesis. The second part of the introductory chapter then shifts the focus from media and communication theories towards a media psychology perspective. Previous findings from psychological research are used to motivate a set of hypotheses regarding children and online advertising.

The media and communication perspectives and the media psychology perspectives discussed in the introduction are related to each other such that more abstract and theoretical media and communication research questions are subsequently narrowed down into more concrete and testable media psychology hypotheses. In other words, theoretical research questions are operationalized as empirical hypotheses. These hypotheses are then further operationalized as quantitative research variables following procedures described in the methods chapter of this thesis introduction. After describing the main results from testing these hypotheses, the thesis introduction will be concluded by discussing the outcomes in terms of research contributions and societal significance. The first part of the discussion chapter will address the outcomes of the hypothesis testing and their contribution to media psychological research. In the second part of the discussion chapter, the more theoretical

[1]The concept of analysis seems to take on different meanings depending on the disciplines and research traditions: 1) analysis as the procedure of deriving and testing hypotheses (positivist media psychology), and 2) analysis as the application of theoretical models to empirical data, or interpreting empirical data in the light of theory (interpretive media studies).

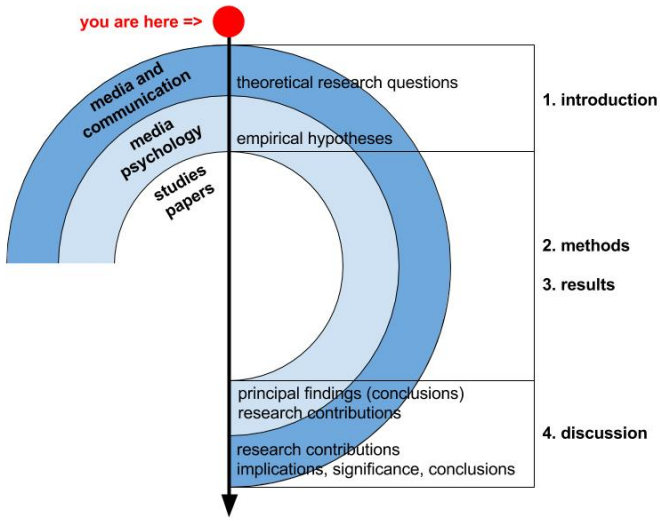

Figure 1.1: Schematic representation of the thesis introduction (or "kappa") preceding the research papers in a Swedish compilation thesis. The "outer layer" of the thesis introduction discusses relevant theoretical concepts from a media and communication perspective. This part leads to a set of theoretical research questions which are later evaluated in discussing how the thesis has contributed to the field of media and communication studies. The "inner layer" of the thesis introduction concretizes the theoretical research questions into testable hypotheses. These hypotheses are motivated by recent research within media psychology, and are later discussed in terms of the dissertation's contribution to media psychology research.

research questions will be addressed in terms of their research contribution to the field of media and communication studies.

The "layered" structure of the thesis introduction outlined and explained in this section is necessitated by the overarching research aim of investigating distraction effects of online advertising on children's visual attention using objective data collections and generalizable research methods. Since the recent development of media and communication studies orients this academic subject so strongly towards qualitative and interpretive methods, the inclusion of media psychology approaches (i.e. hypothesis testing) within a media and communications dissertation project has been challenging. Therefore, the introductory contextualizations of the current research, as well as the concluding discussions concerning the research contributions have been written from both a media and communication perspective, as well as from the perspective of media psychology. An aspiration of this doctoral thesis is to stimulate and revitalize the interdisciplinary exchanges between these two diverging research traditions (**Flyvbjerg**, 2001).

1.3 Media and communication perspectives

This section introduces three main traditional media and communications perspectives on children and advertising. The media effects perspective is essential since it provides the methodological and epistemological foundation for conducting experimental research on causes and effects (RQ 1). Apart from the discussion of media effects, children's susceptibility or vulnerability to advertising (**Calvert**, 2008; **Harrison and Marske**, 2005) constitutes a second well-established media and communication perspective in this thesis (RQ 2). Finally, the perspective of online media as an attention economy (**Chen and Stallaert**, 2014; **Yan et al.**, 2009), and children as digital natives or media multitaskers is discussed (RQ 3). It is argued that these three perspectives in combination encompass the overarching questions surrounding children's advert distraction during their online activities. In the following, we will consider these three media and communication perspectives on children and advertising, and for each such perspective we will introduce a corresponding media and communication research question which the current thesis aims to investigate.

1.3.1 Advertising and media effects

On a general level, advertising is a kind of strategic communication in which an advertiser agent (or sender) attempts to influence the attitudes and behaviors of a set of consumer targets (or receivers) through mediated messages. This means that the practice of advertising is ultimately predicated on producing various media effects in audiences. The most common goal of advertising is to increase product sales by persuading consumers to change their behaviors and buy a certain product, but often the end objective of advertising is also to create more favorable attitudes and increase consumers awareness of specific brands (**Turow**, 2011). Even if advertising agents intend to induce media effects that ultimately change attitudes and behaviors among consumer targets, these effects are dependent on more basic media effects, such as attracting viewers attention and facilitating memory retrieval (**Weinschenk**, 2009). Thus, advertising is conceptualized as influencing consumers through a hierarchy of effects, where basic effects such as visual attention function as preconditions for desired effects such as product purchase.

This is a common trait of most so called hierarchy of effects models within advertising communication research, whether these models are called AIDA (attention, interest, desire, action) or CAB (cognition, affect, behavior) (**Wijaya**, 2015). Within media and communication research, hierarchy of effects models represent a special case of media effects which consists of short-term effects such as attention and recall, feeding into long-term effects such as changes in attitudes and consumption preferences. Furthermore, hierarchy of effects models only consider the intended media effects of advertising. From a media and communication perspective, hierarchy of effects models can be understood within a more

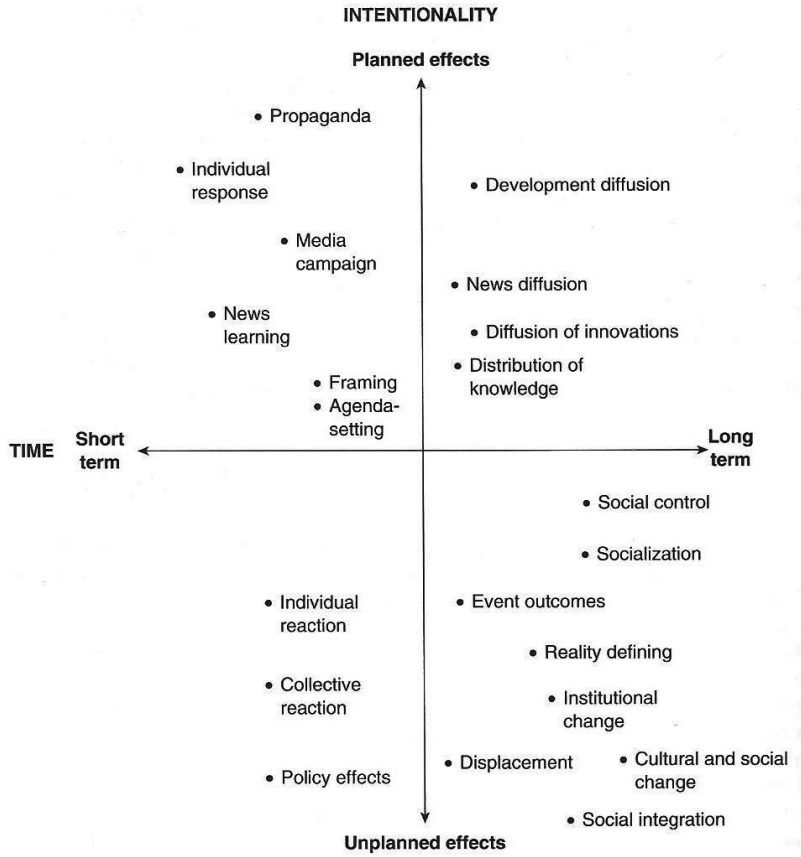

Figure 1.2: Time and intentionality as two major dimensions of media effects, adapted from McQuail (2010). The present thesis deals primarily with short-term effects, and discusses the relationship between intended and unintended short-term effects on the individual and collective levels.

general framework of media effects, which also considers the potentially unintended effects of advertising (**McQuail**, 2010). See **Figure 1.2**. Such unintended effects are especially important to consider when children are involved as advertising targets, and can range from increased commercialization to parent-child conflicts (**Buijzen et al.**, 2003a; **Buijzen and Valkenburg**, 2003b; **Jørgensen et al.**, 1992). An important aspect of this thesis project was to investigate advert distraction as an unintended effect of online advertising directed to children, because unintended effects tend to be neglected in the research literature (**Buijzen and Valkenburg**, 2003b; **Perse**, 2001).

From a media and communication perspective, the advertising media effects predicted by hierarchy of effects models and other media effects models have been highly controversial. Whereas psychologically oriented communication researchers tend to accept some aspects of media effects as a matter of fact (**Desmond and Carveth**, 2007), cultural studies ori-

ented media scholars strongly disprove of any evidence of such effects (**Gauntlett**, 2005). Leaving aside the ideological differences between these vantage points, this disagreement could partly be explained by the fact that psychologists have tended to investigate short-term media effects such as attention and memory, while media scholars have emphasized long-term effects. This difference in the temporal aspect of media effects have significant methodological consequences since short-term effects are easier to investigate using experimental methods which produce more accurate and reliable results. Inquiries of long-term media effects, on the other hand, are often marred by numerous confounding factors and less rigorous research designs.

While short-term media effects are more reliable, it can be argued that long-term effects are more interesting from a theoretical perspective. After all, if a media effect dissipates immediately, can it be considered to have any real impact on audiences? However, in this thesis we will argue that short-term effects of online advertising are highly relevant to investigate, since these commercial messages are often presented on web pages that children use for goal-directed interaction. If online advertising is intended to capture users' visual attention (short-term effect), then we need to investigate whether the same adverts can also produce the unintended effect of advert distraction and decreased online task performance in children. If, for example, salient online advertising have the unwanted effect of negatively affecting children's online reading comprehension (long-term media effect), then this is clearly an online communication problem that should be addressed by media and communication research. Thus, the first research question of this thesis was to investigate how we can establish a causal link between online advertising properties and short-term media effects on children's visual attention during the process of website interaction.

- **RQ 1: How can we study causal media effects of online advertising on children from a media and communication perspective?**

As we mentioned earlier, previous media and communication research on media effects has often been invalidated due to the fact that researchers have tried to investigate long-term effects, which may suffer from a host of confounding factors. A case in point would be the so called "video violence debate" which have tried to assess a proposed positive association between children's engagement with representations of violence (through movies and video games) and children's level of aggression (**Dalquist and Christofferson**, 2011). When level of aggression is viewed as a long-term media effect, this research has at best found a weak association with children's exposure to mediated violence, whereas other factors such as socio-economic status usually plays a more important role (**Ferguson et al.**, 2008). Furthermore, these research designs have failed to elucidate the directionality between video violence and aggression, since it is just as likely that aggressive children prefer to play violent video games. These problems notwithstanding, the greatest obstacle in the "video violence

debate" is probably the difficulties inherent in providing valid operationalizations of the construct of "aggressiveness" (**Anderson and Bushman**, 2002).

By introducing research question 1 above, the intention of this thesis is to contribute to the improvement of media effects studies, such that 1) confounding factors are reduced through experimental control, 2) causal and directional effects are investigated rather than bi-directional associative relationships, and most importantly 3) short-term effects of online advertising on children are given valid operationalizations and measured as accurately as possible. Given that many commercial websites visited by children are shaped by the publicity model of communication, in which audiences attention is paramount (**McQuail**, 2010), the current research project set out to measure children's visual attention by using eye-tracking methodology. To our knowledge, this physiological equipment provides the most precise and valid measurements of children's attentional processes while engaging with online material. The motivation for this research was to uncover whether online advertising produce unintended short-term effects on children's visual attention in the form of advert distraction and lower task performance. In accordance with recent advances in media psychology, the current research acknowledges that such short-term media effects might be dependent on individual and contextual factors. Thus, the current thesis has also investigated some moderating factors that could produce conditional effects of online advertising (**Valkenburg et al.**, 2016; **Potter**, 2011).

1.3.2 Children's susceptibility to advertising

Media and communication research on children's susceptibility to advertising is closely linked to the research on advertising media effects. According to this research, children are regarded as vulnerable to advertising because these commercial messages produce many of the media effects intended by advertiser agents, from attention and recognition to changes in attitudes and behavior (**Nairn and Fine**, 2008; **Kunkel et al.**, 2004). By contrast, adults are more capable of quickly identifying and filtering out commercial content, and critically analyzing the persuasive claims made by advertisers. A related perspective on children's susceptibility to advertising is provided by the Elaboration Likelihood Model, which suggests that children tend to be persuaded by peripheral aspects of advertising, such as vivid colors and commercial spokespersons, whereas adults are more focused on the central argument presented in advertisements (**Petty et al.**, 2005; **Petty and Cacioppo**, 1986). Empirical research based on television advertising have shown that children under the age of 4–5 years are unable to reliably distinguish between commercial content and regular programs. Thus, advertising recognition is regarded as children's first developmental step towards an adult-like understanding of advertising (**Kunkel et al.**, 2004).

However, even if children are able to recognize TV advertising at this age, they still do not fully understand that commercial messages are meant to persuade them to change their

attitudes and product preferences (**Kunkel et al.**, 2004). The second stage, when children start to understand persuasive intent in advertising, is believed to occur at 8–10 years of age, and therefore many countries regard it as unfair commercial practices to direct advertising to children under this age (**Lapierre**, 2013). However, the exact age when children understand persuasive intent in advertising has proved difficult to determine (**Kunkel**, 2010), and consequently some countries have other restrictions. In Sweden, it is not allowed to send television advertising directed to children under 12 years (**Jarlbro**, 2001; **Jørgensen et al.**, 1992), because according to Swedish legislation, children under 12 years of age should be protected (**Sjöberg**, 2013). In the current research project, the main priority was to investigate children's ability to filter out online advertising while engaging in other online tasks. Thus, it was important that the children who participated should be able to recognize and cope with persuasive intent in online advertising, while at the same time they should be able to engage in goal-directed website interaction. For these reasons, children aged 9–12 years were selected for this thesis project.

Media and communication research seems to converge in stating that commercials have a stronger effect on younger children, and that advertising media effects such as purchase requests for advertised products decline as children grow older (**Kunkel et al.**, 2004). This development is generally attributed to increases in children's level of persuasion knowledge. According to the Persuasion Knowledge Model (**Friestad and Wright**, 1994), the key aspect of persuasion knowledge is an individual's ability to represent advertising as consisting of a persuasion agent (the advertiser) and a persuasion target (the consumer), see **Figure 1.3**. In order to cope with advertising persuasion attempts, the persuasion target has to apply previous knowledge about persuasion agents and their tactics, e.g. that advertising agents tend to communicate biased information which is designed to change the mental states of the target (**Campbell and Kirmani**, 2000; **Friestad and Wright**, 1994).

Based on this model, several researchers have suggested that children's persuasion knowledge probably depends on their ability to take other individuals' perspective (theory of mind), which in turn depends on the development of several executive functions that are associated with a growth spurt in children's prefrontal brain regions around the age of 8–10 years (**Moses and Baldwin**, 2005). According to this view, children's persuasion knowledge is not a stable construct, but should rather be regarded as a by-product of children's developing executive functions (**Diamond**, 2013; **Davidson et al.**, 2006), such as the ability to inhibit reflexive responses (inhibitory control), keeping track of multiple agents' objectives (cognitive flexibility, working memory), and ability to evaluate others' mental states (theory of mind). A significant benefit of measuring executive functions would be that children's advertising vulnerability could be assessed on an individual level, rather than according to age groups or developmental stages in the Piagetian sense (**Lapierre**, 2013; **Morra et al.**, 2012). Such research designs have recently been implemented in order to investigate children's advertising susceptibility, and the results showed strong positive associations

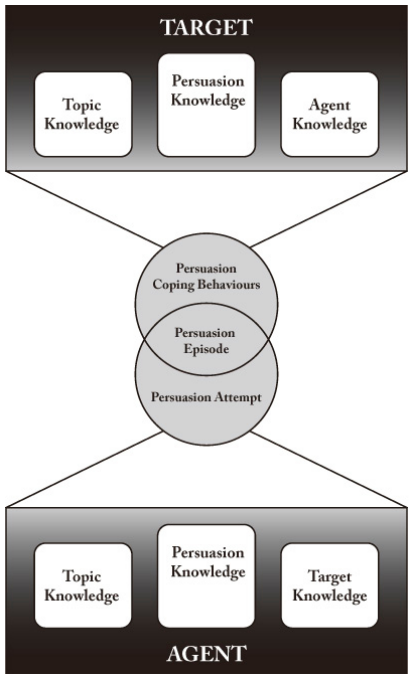

Figure 1.3: The persuasion knowledge model, adapted from **Friestad and Wright** (1994). The target of commercial messages (i.e. consumers, children) needs to develop some key mental representations about the advertising agent in order to be able to cope with persuasion attempts.

between children's executive function and their persuasion knowledge, such that higher levels of theory of mind and executive control in children predicted higher levels of advertising knowledge (**Lapierre**, 2013). In order to further this research, the present thesis introduced research question 2 concerning the relationship between children's executive functions and their perceptual susceptibility to online advertising.

- **RQ 2: How can we develop our understanding of children's individual level of advertising susceptibility on commercial websites?**

Investigating children's persuasion knowledge and advertising susceptibility in terms of executive functions may explain several contradictory findings in previous research on children's advertising susceptibility. When researchers have attempted to measure children's persuasion knowledge directly, the results sometimes indicate that older children fail to apply their persuasion knowledge when being exposed to advertising (**Lapierre**, 2013; **Moses and Baldwin**, 2005). If persuasion knowledge depends on executive functions, such findings could be explained in terms of children having access to advertising knowledge (competence), but have not yet fully automated the application of these schemata to advertising persuasion attempts (performance). Similarly, children's individual level of executive func-

tion may underlie other constructs such as their advertising literacy. However, several media literacy constructs have proved difficult to measure reliably (**Rozendaal et al.**, 2011; **Livingstone and Helsper**, 2006), especially with regard to new marketing techniques utilized in online advertising (**Blumberg et al.**, 2014), and therefore it should be investigated if children's executive function can be measured as a proxy of their advertising literacy.

As has been discussed earlier, online advertising is fundamentally different from television advertising in that internet adverts are predominantly presented spatially adjacent to other types of web content that users interact with in a more or less goal-directed fashion (**Blumberg et al.**, 2014; **Sandberg**, 2014). This raises questions about children's perceptual susceptibility to salient online advertising and their ability to filter out concurrent commercial messages while pursuing goal-directed website interaction. In order to measure children's individual level of advertising susceptibility, both as a filtering function and as an ability to maintain task performance levels, one suitable assessment method was the so-called anti-saccade task. This task measures children's ability to inhibit reflexive eye movements towards a peripheral distractor, and their ability to quickly execute a voluntary eye movement in the opposite direction (**Eenshuistra et al.**, 2004). It has been shown that children's performance in the anti-saccade task correlates well with their overall level of executive functions, and thus we expect this test to also be positively related to children's persuasion knowledge (**Klein and Foerster**, 2001). As children start to use the internet for task-oriented interaction around ages 8–10 years, it is of great importance to investigate their vulnerability to unintended short-term effects of online advertising, such as advert distraction and lower task performance.

1.3.3 Online media and advertising

Media and communication researchers have argued that when there is a surplus of mediated information relative to the amount of human attentional resources, then the basic conditions for an attention economy are met (**Davenport and Beck**, 2013). According to this theory, the attention of audiences takes on value in analogy with monetary systems (and can be exchanged for money). Advertising in general is a good example of an attention economy in the sense that a multitude of commercial messages compete for the scarce resource of audience attention, and money is invested in order to ensure these attentional resources. Putting mediated messages on display in order to maximize human attention corresponds to a publicity model of communication, which is fundamentally different from e.g. a transmission model, in which the transfer of meaningful information is the main purpose (**McQuail**, 2010). Online media have not changed the attention economy (or publicity model) of commercial communication, but dramatically intensified it and generalized it beyond advertising to all areas of mediated communication.

The network model of online media allows every user to communicate with any other user, and since the production costs of digital information are comparatively low, any internet user can generate, distribute, and communicate content. When these factors combine, the scene is set for an explosion of information in which mediated content is generated at an exponential rate. However, since the amount of human attention cannot grow at the same rate, the competition for attention in online media becomes even more drastic. The development of social media and personalized online advertising can be regarded as attempts to channel information that is more relevant for particular users, because this information then has a higher attentional value (**Van Dijck**, 2013). In this attention-seeking online media environment, it becomes a skill of users to filter out irrelevant information and navigate between relevant patches in order to extract meaning.

In the attention economy of online media, attention management becomes a key information processing ability (**Davenport and Beck**, 2013). From a media and communication perspective, some researchers have argued that younger generations that grow up immersed in online media would naturally adapt to the information overflow and develop techniques for managing their attention across a multitude of media outlets. To convey this notion, the concept of children as "digital natives" was formulated in the early 2000s (**Prensky**, 2001). A key aspect of digital natives is that this particular demographic is believed to be more proficient in using digital technology to accomplish various real-world objectives or tasks – such as downloading a movie or chatting online – than adults (**Livingstone**, 2002), who are more familiar with the logic of mass media and formal education (cf. "digital immigrants"). In more recent media and communication research, the concept of children as digital natives have become more questioned (**Danielsson**, 2014), and instead the concept of children as "media multitaskers" have been introduced (**Blades et al.**, 2014; **Rideout et al.**, 2010; **Ali et al.**, 2009). The latter concept focuses on the multiplicity of online media, which allows users to alternate between using media for entertainment, and functional or task-oriented internet use.

Research on digital work environments has observed that IT workers often face the challenge of constant interruptions, e.g. emails that require immediate reply, and that they develop various multitasking strategies in order to handle such workflow interruptions (**Iqbal and Horvitz**, 2007; **Mark et al.**, 2005). An important insight from this research is that human attention is essentially serial in nature, and that multitasking actually consists of rapid task-switching, or shifting attentional resources between several interactive processes (**Gazzaley and Rosen**, 2016; **Ophir et al.**, 2009). Task-switching is a cognitively demanding operation that increases cognitive load and may negatively impact task performance. Frequent workflow interruptions have even been linked to negative health consequences and mental fatigue (**Gulliksen et al.**, 2015; **Becker et al.**, 2013). Commercial websites offer similar possibilities – or risks – for users to switch between multiple sources of information, both commercial and informational, with one single shift in visual attention. While children's

develop the cognitive underpinnings that promote media multitasking at around 8–10 years (executive functions), they do not necessarily have the metacognitive strategies for realizing that such behaviors are associated with a cognitive cost (**Baumgartner et al.**, 2014; **Wallis**, 2010; **Vega**, 2009). Therefore, the present thesis formulated research question 3 with regard to children's attention management and possible advert distraction on commercial websites.

- **RQ 3: How can we understand children's attention management during goal-directed interaction with commercial websites?**

The current thesis specifically investigates aspects of children's attention to online advertising. This advertising medium has profound consequences in terms of how adverts are delivered to consumers. Some of the most important characteristics of online advertising are: 1) adverts can be targeted towards specific individuals based on e.g. search behavior, thus allowing for personally relevant advertising messages, 2) adverts can be visually enhanced (e.g. through animation) and presented alongside other types of content which makes commercial messages more difficult to avoid, and 3) adverts are interactive, allowing for new advertising formats such as advergames, and potentially linking consumers directly to online stores (**Sandberg**, 2014). The blend of commercial and editorial content is common on the internet, and most users have grown accustomed to the human-computer-interaction scenario of e.g. reading a news article in the main column of a web page, while banner advertising is presented in the spatially adjacent right column. Most adults users have the cognitive capacity to focus on the task-relevant information presented on such websites, while filtering out most of the visual "noise" coming from task-irrelevant adverts.

Children's cognitive resources, however, are known to be more limited, and thus the purpose of this study was to investigate how online advertising affected several communication outcome variables in children while they engaged in different types of task-oriented interaction with commercial websites. By using eye-tracking measurements of children's website interaction in combination with task-oriented research designs, this thesis intends to operationalize the concept of advert distraction. Experimental procedures are needed in order to isolate and test individual properties of online advertising, such as perceptual prominence (e.g. animation) and content relevance (e.g. age-relevant content). Task-oriented interaction with websites allows us to define attentional resources directed at task-irrelevant adverts as distractions, while eye-tracking measurements enable us to study how children's visual attention is divided between tasks and adverts with a high degree of detail. By using detailed recordings of eye movements, we can also measure how task types and advert saliency conditions affect children's cognitive load. Such measurements are important in order to understand children's distractibility (**Baumgartner et al.**, 2014; **Wallis**, 2010; **Vega**, 2009).

1.4 Media psychology perspectives

In 1987, the American Psychological Association founded a media psychology division to address the emerging changes in the media landscape, from mass media such as television towards information technologies and computer-mediated communication (CMC). Whereas many definitions of media psychology currently co-exist, a relatively comprehensive definition can be found in the recently issued *Oxford Handbook of Media Psychology*:

> Media psychology concerns applying psychological theories and research (including methods and measurements) to and integrating them with communication and media theories and research, in explaining individual differences and underlying mechanisms in media uses and effects on individuals' cognitions, affect, and behavior. For example, explaining individual differences in susceptibility to specific media content (**Dill**, 2013).

In a similar vein, other researchers have stressed that the media psychology approach answers the call for new research methods as digital media becomes more dynamic, interactive, and individualized (**Valkenburg et al.**, 2016). According to current media psychological theory, effects of online advertising on children are mainly dependent on three factors: 1) the characteristics of the media message, 2) the cognitive development of the child, and 3) the environment and context of internet use (**Valkenburg**, 2004). These three factors have recently been integrated into an investigative framework for children's processing of commercial media content called the PCMC model (**Buijzen et al.**, 2010). In the following, we will explain the methods used to investigate these three factors.

1.4.1 Advert saliency and visual attention

In the context of display advertising, perceptual prominence can be understood as features or properties in the visual domain that cause people to look at the advert (exogenous attentional orienting response). Within cognitive psychology, significant efforts have been made in order to better understand perceptual prominence (as used in online advertising) from a more human-centered and evolutionary perspective. Within this field of research, perceptual prominence is referred to as bottom-up or stimulus-driven visual saliency, and this research tries to explain to what extent visual features in natural scenes can predict eye movements and visual attention. Experiments in this area have shown that there seems to be a significant correlation between points of visual attention and image regions containing high levels of certain features, such as color, intensity (luminance), and spatial density (edges) (**Itti and Koch**, 2001; **Parkhurst et al.**, 2002). However, this research could be criticized for being too laboratory-oriented in using static images and free viewing conditions.

More applied and ecologically valid research on display advertising and task-oriented website interaction has found that animation and abrupt onset in adverts are the strongest predictors of visual attention in adult users (**Ludwig et al.**, 2008; **Simola et al.**, 2011; **Kuisma**, 2015). Based on these findings, the research presented in this dissertation used animation and abrupt onset in display adverts as indicators of perceptual prominence.

Although basic image features such as edges, luminance, and animation (previously referred to as perceptual prominence) seem to reliably explain some portion of the distribution of visual attention, there is compelling evidence to suggest that the perceived relevance of pictorial content have a stronger influence on what internet users actually attend to in terms of eye movements (**Henderson et al.**, 2007). Unlike basic image features, content relevance is more challenging to quantify, since the perceived relevance of visual stimuli vary with specific tasks and specific demographics of the subject. Within cognitive psychology, this dual source of visual attention has been explained by proposing that image features are processed first in a fast, parallel and pre-attentive fashion. The output of this process consists of regions of interest that are then fed into a second attentional process which operates top-down by selecting regions that match the current internal goals/motivations of the subject. The output of these two processes are combined into a so called "attentional priority map", which is based on both bottom-up and top-down information (**Broadbent**, 1958; **Fecteau and Munoz**, 2006). What is crucial in this model of attention is that it takes into account individual and demographic differences in the population, and thus explains why age-relevant advertising content (such as toys and cartoons) is more interesting to children.

Task-oriented website interaction is a special case of general web browsing activities. According to human-computer interaction research (HCI), web browsing tends to fall in one of the following categories: 1) directed, when the target of the information search is sharply defined and the process is very systematic; 2) semidirected, when the target is not clearly defined and the process is less systematic; and 3) undirected (or surfing), when there is no specific goal in the interaction process (**Brajnik and Gabrielli**, 2010; **Bilal and Kirby**, 2002). Using these distinctions, task-oriented website interaction would fall into the category of directed web browsing. Recently conducted surveys of Swedish children's internet use indicate that around the age of 8–10 years children start to use the internet for functional purposes such as information search and school activities (**Findahl and Davidsson**, 2015). This media usage pattern can be explained by research on children's cognitive development, which provides evidence that basic executive functions such as inhibitory control and working memory are almost fully developed in children around 8–10 years, and that higher executive functions such as cognitive flexibility and capacity for task-oriented behavior are undergoing rapid maturation (**Anderson**, 2002; **Klenberg et al.**, 2001). Previous research indicates that an increasingly central component in children's capacity for task-oriented behavior is effortful control which includes individual differences in the ability

to voluntarily sustain focus on a task (**Rothbart and Rueda**, 2005; **Gumora and Arsenio**, 2002). The fact that this capacity is maturing in children aged 8–10 and that it is subject to individual differences underscores the importance of investigating how online advertising affects children's task-oriented website interaction.

An important objective in this project was to operationalize and measure advertising saliency in authentic online advertising that children encounter during undirected website interaction. Measures of visual saliency have been developed previously within cognitive psychology and applied to images of natural objects and scenes, but these saliency measures have not been applied extensively to the field of online advertising (**Itti and Koch**, 2001). Similarly, previous research within media psychology has identified perceptual prominence and content relevance as two types of advertising saliency that are predicted to affect children's advert processing, but these saliency types have not been operationalized as experimental conditions. In this project, we operationalized advert saliency and measured how it affected children's visual attention during undirected and task-oriented interaction with commercial websites. On a general level, we hypothesized that higher levels of visual saliency would increase children's visual interaction with online advertising. By the same token, we expected that salient online adverts would decrease children's task performance.

- H 1A*: Higher levels of visual saliency in online advertising will cause higher levels of advert attention in children.*
- H 1B*: Higher levels of visual saliency in online advertising will cause lower levels of task performance in children.*

Previous research has provided evidence that children frequently visit commercial websites, and that the commercial content displayed on these sites are designed to target children with perceptually prominent and age-relevant advertising messages (**Van Reijmersdal et al.**, 2012; **Harris et al.**, 2012). It is a relevant question to inquire how children interact with these commercial messages, and how they are affected by them. The typical way of investigating such research questions is to ask children about their internet usage habits and how they understand commercial intent in online advertising (**Lapierre**, 2013). Two limitations with this approach is that children have to rely on self-reported outcome measures that are insensitive to the online interaction process and/or that the research situation creates an unnatural focus on a narrow selection of advertising content. The aim of this dissertation was to investigate effects of online advertising on children during realistic interaction with commercial websites. In order to measure the website interaction process as accurately as possible, we registered children's visual attention using eye-tracking measurements. Another motivation was to obtain detailed data on the types of online advertising that children were exposed to under natural conditions, and analyze the saliency levels of these adverts.

1.4.2 Children's cognitive development

Executive functions (also known as cognitive control and supervisory attentional system) are a set of cognitive processes – including attentional control, inhibitory control, working memory, and cognitive flexibility, as well as reasoning, problem solving, and planning – that are necessary for the cognitive control of behavior: selecting and successfully monitoring behaviors that facilitate the attainment of chosen goals. When studying executive functions in children, a developmental framework is helpful because these abilities mature at different rates over time (**Moses and Baldwin**, 2005). The development of executive functioning corresponds to the neurophysiological developments of the growing brain; as the processing capacity of the frontal lobes and other interconnected regions increases, the core executive functions emerge (**Anderson**, 2002). Children's prefrontal cortex undergoes rapid development in two developmental stages (**Lapierre**, 2013). First, between 3–5 years, basic executive functions such as inhibitory control and working memory develop. These functions serve as preconditions for later development. Second, between 8–10 years, more advanced capabilities such as attentional control and cognitive flexibility develop (**Klenberg et al.**, 2001). These latter functions are associated with the maturation of more complex task-oriented behavior, the ability of attentional shifting, and greater capability to accommodate for task interference and distraction.

In media and communication research children tend to be either lumped together under broad demographic categories such as age groups and gender, or they are investigated in-depth as individual cases through self-reported interviews. Neither of these approaches is sufficiently detailed, generalizable, and objective to capture individual differences among children. However, individual differences are significant in children in the same age groups, since we know from developmental psychology that children's prefrontal cortex is growing rapidly (**Unsworth et al.**, 2004; **Carlson and Moses**, 2001; **Cacioppo et al.**, 1986). Due to children's developing cognitive functions, it can be assumed that children between the ages of 8–10 years would have lower inhibitory control towards salient online adverts displayed on the web pages, and lower capacity for cognitive flexibility and task-oriented web surfing. Based on previous research, it can also be expected that there will be substantial individual differences in these capacities. These developmental factors can be assumed to increase children's vulnerability to advert distraction and decrease their task performance.

Therefore, an important objective in this dissertation was to construct a measure of executive function that was sensitive to children's individual level of cognitive development, and that could be used as a predictor of their advert attention and task performance. This construct was referred to as gaze control, and it was operationalized by measuring children's individual success rate in a series of anti-saccade trials. According to cognitive psychology research, the anti-saccade test has been proved to measure children's inhibitory control, and more indirectly, other executive functions such as working memory and attentional

control (**Unsworth et al.**, 2004). Anti-saccade performance has been measured in children around 8–10 years before (**Kramer et al.**, 2005; **Eenshuistra et al.**, 2004; **Klein and Foerster**, 2001), but this measure has not been used as an indicator of children's individual level of gaze control and associated with their advert distraction and task performance while interacting with commercial websites. In this project we hypothesized that children's gaze control would be negatively associated with advert distraction and positively associated with task performance.

- H 2A*: Higher individual level of executive function in children will be associated with lower levels of advert attention.*
- H 2B*: Higher individual level of executive function in children will be associated with higher levels of task performance.*

Inhibitory control is a core executive function that refers to children's ability to inhibit a prepotent or automatic response towards a salient stimulus in order to maintain a more adaptive and goal-directed behavior. This type of executive control can be accurately measured by presenting children with a task in which a salient distractor suddenly appears in the periphery if the visual field. Beforehand, the participants are instructed to avoid (i.e. inhibit) looking at the distractor and instead make a saccade in the opposite direction of the visual field. It is assumed that this anti-saccade task measures participants' ability to first suppress a reflexive saccade towards the distractor, and then generate a voluntary saccade in the opposite direction (**Munoz et al.**, 1998). Children's ability to perform this anti-saccade task has been found to increase with age and the development of prefrontal control and executive functions. In one of the first large-scale developmental investigation of the anti-saccade task, it was found that children's success rate increased sharply between young children up to ca 5 years of age (less than 20% success rate) and ca 15 years of age (more than 80% success rate) (**Munoz et al.**, 1998). Similar findings in later studies have consolidated these results, which indicates that the anti-saccade task is a sensitive measure of children's developmental level of inhibitory control, but also to some extent of complex executive functions (**Fukushima et al.**, 2000; **Bucci and Seassau**, 2012). An indication that the anti-saccade task is used extensively as a behavioral measure of executive function is that protocols for designing and administering the test has recently been standardized (**Antoniades et al.**, 2013). See **Figure 1.4**.

The anti-saccade task merits special interest in the context of children's advert distraction and online task performance. First of all, the anti-saccade task consists of a situation where children are required to focus on a primary task while suppressing the urge to look at suddenly appearing salient stimuli in the periphery. This situation maps nicely to children's task-oriented interaction with commercial websites, where it is common that the main task-relevant content is presented centrally, while salient task-irrelevant advertising content may

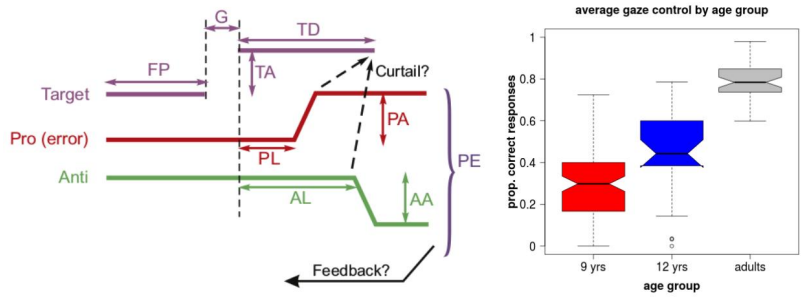

Figure 1.4: The left figure shows a schematic representation of a generic anti-saccade trial, adapted from (**Antoniades et al.**, 2013). Stepwise movement of the target from its initial fixational position (purple). A correct anti-saccade (green) and an incorrect pro-saccade (red). The right figure shows average proportions of correct anti-saccade trials found in two age groups investigated in the current thesis (**Holmberg et al.**, 2015, 2014; **Holmberg**, 2016a submitted). Simulated data for adults, based on results presented in **Eenshuistra et al.** (2004).

appear on the sides. Therefore, it should be investigated to what extent children's success rate in the anti-saccade task predicts their distractibility with regard to online advertising. It seems reasonable to assume that higher anti-saccade success rates would be associated with fewer fixations on (and saccades to) online adverts. Second, evidence suggests that outcome measures from the anti-saccade task provide a developmentally sensitive measure of children's individual level of inhibitory control. This ability to capture individual differences in children is important since children's rapidly developing executive functions entails that large individual differences can be expected in terms of advertising distractibility. These individual differences are not accurately captured by broad demographics such as age group or gender. Finally, some research has suggested a positive link between anti-saccade performance in children and higher executive functions such as working memory, planning, and cognitive flexibility (**Davidson et al.**, 2006; **Carlson**, 2005; **Zelazo et al.**, 2003). If this is the case, we might expect that children's performance level in the anti-saccade task might to some extent predict their task performance during task-oriented website interaction.

1.4.3 Task-orientation and advert distraction

Although the current dissertation subscribes to the developmental perspective on children's advertising processing described by the media psychology approach, there are also some noticeable shortcomings that need to be addressed. The first and foremost problem is that this research field does not take into account the emergence of task-oriented internet use among 8–10 year-old children (**Findahl and Davidsson**, 2015). Thus, it is not clear how children's advertising processing may be differentiated depending on whether their internet activity is entertainment-based or goal-directed. According to the PCMC model (**Buijzen et al.**, 2010), task-orientation could be included in the third of the factors that are assumed to determine children's exposure to online advertising (context of internet use). However,

the research literature on children and online advertising does not provide any investigations within task-oriented research designs. Beside the fact that children start to use the internet in a goal-directed manner, task-orientation is also necessary in order for media psychology to describe and understand the concept of advert distraction. Without a specified online task, it is difficult to assess the effects that online advertising might have on task performance, and by extension, advert distraction. Investigating advert distraction is particularly important among children, since their cognitive development suggests that they lack fully developed abilities for inhibitory control and cognitive flexibility. In effect, this means that children may find it more difficult to cope with advert distraction during task-oriented website interaction.

Based on previous research on task-oriented website interaction, we suggest that common task types such as information search and reading-for-comprehension should be standardized and associated with clear performance measures. The absence of such research designs and measures makes it more difficult to evaluate unintended and potentially negative effects of online advertising on children's interaction with commercial websites. Recently, some media psychological research has emerged in which effects of salient online advertising has been tested on adults' online reading (**Kuisma**, 2015; **Pasqualotti and Baccino**, 2014; **Simola et al.**, 2011). Since reading-for-comprehension is of high importance for children, this dissertation argues that similar research procedures should be applied to this age group. Similarly, the effects of online advertising should be investigated on children's information search, visual search and advergame activity. Another possibility would be to investigate how different types of task-oriented website interaction affects children's advertising exposure compared to free or undirected interaction. In this case, previous research has shown that tasks involving high cognitive load (as opposed to perceptual load) can potentially suffer more from salient distractors (**Lavie**, 2005; **de Fockert et al.**, 2001). Finally, since task performance in children around 8–10 years can be expected to be linked to their development of executive functions, measures of such capacities (e.g. anti-saccade tasks) need to be included when analyzing children's advert distraction.

Media psychological research emphasizes the need to take into account so-called conditional media effects (**Valkenburg and Peter**, 2013b). Conditional media effects can been described as follows: "some children may be more susceptible to some advertising properties in some internet usage situations or task types". Investigations of conditional media effects thus stress the importance of taking individual differences among children into account. Translated into the context of online advertising, conditional media effects would provide a framework for investigating if, for example, children with less developed executive function are more disadvantaged by salient online advertising during task-oriented internet use. Another example of conditional online advertising effects has to do with context of internet use and the particular task type that children engage in on commercial websites. Recent neuroscientific research has been able to shed light on the relationship between

distracting visual stimuli (such as prominent adverts) and task types with varying levels of cognitive load (**de Fockert et al.**, 2001). First, tasks with higher cognitive load were associated with increased prefrontal activity. But more interestingly, this research seems to indicate that negative effects of visually prominent distractors are larger in task types that involve high levels of cognitive load (i.e. taxing on working memory, task-switching, cognitive flexibility). Based on the research cited in this section, we hypothesized two conditional media effects that would moderate the distraction effects of online advertising on children's task-oriented internet use: 1) we hypothesized that children's individual level of gaze control would moderate advert distraction in terms of lower task performance, and 2) we hypothesized that the level of cognitive load associated with task types would moderate children's advert distraction in terms of visual attention to adverts.

- H 3A*: Individual level of executive function will have a moderating effect on children's level of advert distraction.*
- H 3B*: Task type during website interaction will have a moderating effect on children's level of advert distraction.*

Current research on children's task-oriented website interaction suffer from two problems. First, the task-oriented research design has not been extensively applied within previous media psychology research on children and online advertising. Second, there seems to be little consensus in reliable measures of task performance, and in the advergame research area, children's task performance is seldom reported (**Van Reijmersdal et al.**, 2012; **Mallinckrodt and Mizerski**, 2007). In the case of online reading comprehension on commercial websites, a small body of research literature exists, which can be utilized in order to investigate this type of interaction in children as well (**Kuisma**, 2015; **Pasqualotti and Baccino**, 2014; **Simola et al.**, 2011). One study is particularly interesting in the current context, since it investigated the effects of salient online advertising on adults' visual attention during online reading-for-comprehension tasks (**Simola et al.**, 2011). In this study, users were presented with 32 web pages containing a short text and an adjacent display advert. Display adverts were presented in more or less perceptually prominent conditions (animation and abrupt onset). After reading each text, the participants answered a related comprehension question. The researchers found that perceptually prominent adverts did attract more fixations and saccades, but that several eye movement measures associated with text processing were unaffected. Neither did this study find any significant effects of advert saliency on adults' reading comprehension (i.e. task performance). When it comes to investigating the effects of task types on children's advert distraction, previous research on task-evoked pupillary responses suggested that pupil dilation was likely the most suitable eye movement measure for investigating cognitive load caused by the task (intrinsic load) and by advert distractions (extraneous load) (**Johnson et al.**, 2014; **Paas et al.**, 2003; **Beatty**, 1982).

Table 1.1: Media and communication research questions (bold) and associated media psychology hypotheses (italic).

RQ 1: How can we study causal media effects of online advertising on children from a media and communication perspective?
H 1A*: Higher levels of visual saliency in online advertising will cause higher levels of advert attention in children.*
H 1B*: Higher levels of visual saliency in online advertising will cause lower levels of task performance in children.*
RQ 2: How can we develop our understanding of children's individual level of advertising susceptibility on commercial websites?
H 2A*: Higher individual level of executive function in children will be associated with lower levels of advert attention.*
H 2B*: Higher individual level of executive function in children will be associated with higher levels of task performance.*
RQ 3: How can we understand children's attention management during goal-directed interaction with commercial websites?
H 3A*: Individual level of executive function will have a moderating effect on children's level of advert distraction.*
H 3B*: Task type during website interaction will have a moderating effect on children's level of advert distraction.*

1.5 Research questions and hypotheses

In this introductory chapter, we have discussed three main research questions that have guided the current thesis. Each such research question addresses a specific media and communication studies perspective on children and online advertising. All the empirical studies undertaken in this dissertation project have been intended to inform the media and communication research field by providing some answers to these research questions. However, research questions are quite general and open-ended by nature, and therefore, each research question has also been operationalized as testable and verifiable hypotheses. While these hypotheses extend their corresponding media and communication research question, they are formulated and motivated based on previous media psychology research. See **Table 1.1** for an overview of general research questions and specific hypotheses.

Given the long-standing debate about the status of media effects within media and communication studies, the first research question simply asks whether it is possible to investigate effects of online advertising on children, and how such effects can be accurately defined. In attempting to provide an answer to this research question, the present thesis introduced two related hypotheses. By using eye movement measurements of children while they performed goal-directed interaction with commercial websites, we intended to investigate if saliency properties of online advertising had an effect on children's visual attention and/or on their task performance. Positive effects on visual attention were defined as short-term in-

tended effects of online advertising, while negative effects on task performance were defined as short-term unintended effects (with regard to advertising agents).

The second research question also addresses a discussion withing media and communication studies regarding children's susceptibility to advertising effects. While some previous research based on television advertising tended to emphasize that children before a certain age do not have the level of persuasion knowledge necessary to cope with commercial messages, more recent research has focused on individual differences in children's cognitive development as a predictor of their advertising susceptibility. The present thesis follows the latter track, but shifts the focus towards using gaze control as a measure of executive function, and investigates how this individual measure predicts children's advert attention and task performance during goal-directed website interaction. We hypothesized that higher levels of gaze control would have a negative impact on children's advert attention, and a positive effect on their task performance.

The third media and communication research question focuses on online advertising as a part of the attention economy of online media. According to this view, due to the information overload inherent in online media, users are forced to adopt various strategies of attention management in order to navigate to information that is meaningful to them. Previous media and communication research has observerd that children adopt a media multitasking strategy, which is cognitively demanding. The present thesis intends to investigate how children deal with visual information overload on commercial websites, and whether visual media multitasking can cause advert distraction effects. In order to operationalize this research question, two hypotheses were formulated suggesting that the context of internet use (task type) and individual level of gaze control will interact with advert saliency in determining children's advert distraction.

Chapter 2

Methods

This section describes the methods used in four studies undertaken within this dissertation project. Although the studies differ in terms of research questions, there are also similarities that are common for all studies. An important similarity is that all four studies consisted of an initial anti-saccade experiment in order to measure children's individual level of inhibitory control, and a subsequent experiment that investigated the effects of online advertising on children's visual attention and website interaction. Another similarity is that all data recordings and experimental procedures were undertaken in the children's own school environment in order to provide a high degree of ecological validity to the research. All studies were ended with a short questionnaire used to collect basic demographic data about the children, such as age, gender, and internet usage habits. In some studies, the experimental procedures for investigating children's website interaction were combined with qualitative interviews. In those cases, qualitative interviews were always conducted after the web experiments in order to exclude the possibility of any carry-over effects or priming on the experiment. Data recording in the experimental procedures were always undertaken using website stimuli and eye-tracking equipment. See **Table 2.1** for an overview.

2.1 Participants and data collections

All child participants were recruited from two elementary schools in the south of Sweden (N = 137). The recruitment phase was initiated around 3 months before the data collection, and was handled in cooperation with headmasters and class teachers of the respective schools. The main selection criterion was that the schools should be representative of the population in terms of demographics. The children had mixed ethnic backgrounds, but were all sufficiently fluent in Swedish to participate in regular teaching. The children were

presented with a cover story about participating in a study on internet surfing, and our research questions about online advertising was not mentioned beforehand. Parental consent forms were distributed in the school classes, and we received written consent from all caretakers of the children that participated in the study. Before starting the experimental procedures, each child was also asked verbally for individual consent. Participant ages varied between 9 and 12 years. The gender distribution was fairly equal between girls (N = 71) and boys (N = 66). In some cases, participants were excluded from the data analysis phase due to insufficient data quality during eye movement recordings, or due to technical problems while running the experimental procedures. These children are also included in the counts. All participants had normal or corrected-to-normal vision. Participants in Study 3 and 4 consisted of the same individuals.

Eye movement data of participants' anti-saccades tasks and website interaction were recorded in all studies 1 through 4. Similarly, survey data of participants' basic demographics were registered in all studies. In addition, screen recordings of all presented web page stimuli were recorded in Study 1. These data recording instruments are specified below.

2.1.1 Researching children

As we conducted research on children in this project, it was a first priority that the children who participated should feel comfortable and relaxed during data collections. An important step towards this end was the decision to move the eye-tracking equipment to the children's school environment, rather than performing the observations in a lab environment that was unfamiliar to the children. An added benefit of this approach is that all studies should have a fairly high level of ecological validity. Each study began with a short presentation of the research with all children gathered in their classroom. At this point, no mention was made about the focus on online advertising, but rather a cover story was given in which the research was presented as an effort to better understand children's internet usage on a general level. It was emphasized that participation in the study was optional, and that the internet surfing sessions did not constitute any kind of test to measure performance levels across children (due to the repeated measures designs of the experiment, each child was only compared against him- or herself). The children were predominantly very excited about participating in the data collections, and they were interested in web surfing activities, and spontaneously talked a lot about their experiences with online media. The web-based experiments were carefully planned in order to not be exceedingly lengthy or monotonous, and extra thought was given to making the experiments a fun and challenging experience. The children participated in the experiments individually in a secluded room close their classroom. After participating, each child was offered some refreshments and was given a movie ticket. A few weeks after the data collections were finalized, we returned to the

schools and informed all participants about the true purpose of the studies and the research focus on online advertising.

From a scientific perspective, this research raises some interesting questions about involving children as participants. In this paragraph, two of these questions will be discussed briefly: 1) to what extent are children regarded as independent subjects as opposed to developing subjects, and 2) what are the ontological and epistemological implications of the present research. In addressing the first issue, it seems clear that this questions maps quite nicely to a suggested opposition between children as beings (independent subjects) and becoming (developing subjects) (**Prout**, 2002; **Buckingham**, 2013). If children are regarded as beings, research on their media use tends to focus on their subjective experiences of various phenomena, e.g. disturbing online advertising, while if children are regarded as becomings, more objective aspects of their media use tends to be emphasized and compared to adults or more "typical" users. The present research project has tried to balance this opposition by focusing on objective aspects of children's website interaction and advert distraction (e.g. eye movements), while at the same time studying these objective aspects without comparing children to adults, or viewing children as subordinate. As for the second question about the ontological and epistemological aspects of this research, this issue connects to an ongoing discussion about whether social phenomena can be studied using objective methods used in the natural sciences (**Flyvbjerg**, 2006). From the perspective of social constructivist epistemology, it is often argued that the social context of most types of media interaction precludes objective study, since such interactions are socially constructed. Although this perspective is relevant to some areas in social science, the present research has attempted to minimize the social context while investigating the effects of mediated commercial communications on children's website interaction and advert distraction.

Ethical considerations

According to Swedish legislation, research projects needs to apply for ethical approval if the methods used meet any of the following criteria: (1) they constitute a physical intervention on a living (or deceased) person; (2) they aim to affect the research subject physically or mentally; and (3) they entail an obvious risk of harming the research subject physically or mentally; (4) the research concern biological material taken from a living (or deceased) person which is traceable to that individual; (5) the research entails handling of sensitive personal data (race or ethnic origin, political views, religious or philosophical convictions, trade union membership, health or sex life, legal offenses and convictions).

Since none of the criteria above are applicable to the eye-tracking equipment used in the research studies undertaken in this dissertation project, ethical approval was not applied for. The recoding equipment utilized operates remotely at a distance of approximately 70 cm during ca 45 minutes of eye movement data recordings. The remote eye-tracking device

(RED) illuminates the participant's eyes with infrared light (IR) while it simultaneously records a video of the eyes. The IR emitted by the RED lies within the same spectrum as ordinary sunlight, and IR exposure at the duration and distance used in the current study has been shown to be harmless to humans (**Mulvey et al.**, 2011, 2008). In the case of RED equipment, all registrations are made remotely, which means that no part of the equipment is in direct contact with the participant. Since the RED does not restrict physical movement and allows the children the same freedom of movement as when seated in front of an ordinary computer screen, the RED method is to be regarded as completely non-invasive.

The legal criteria for ethical vetting listed above is not applicable to the stimulus programs that participants interacted with in any of the studies presented here. The anti-saccade tasks consisted of a total of 32 trials that presented an alternating fixation cross and target dot on the stimulus screen. The internet interaction sessions consisted of web pages featuring a mix of non-commercial content and online advertisements. Crucially, the stimulus programs were conducted in order to examine if the experimental procedures would affect the participants' visual attention and cognitive processes. Consequently, the stimulus programs were not administered in order to affect the research subjects physically or mentally.

Finally, the legal criteria above are not applicable to the survey data or eye movement data recorded in presented studies. The RED records a video of the participant's eyes during human-computer interaction. This video is used to extract the pupil position and the corneal reflex of the IR light source as numerical values. After this image processing stage, the eye images are deleted by the RED recording software. Thus, the RED recordings do not constitute registration of any biometric information. Similarly, the survey data collected about the participant's age, sex and internet habits does not constitute sensitive personal data. The records linking participants names and codes were later destroyed. All research procedures were undertaken in accordance with the guidelines for good research practice issued by the Swedish Research Council (**Hermerén**, 2011), which is the funding agency for this research project.

2.1.2 Eye-tracking recordings

Two different remote eye-tracking systems were used in the four studies supporting the present research (see **Figure 2.1**). In each study, the same eye-tracking device was used in the initial anti-saccade tasks as well as in the subsequent website interaction tasks. As mentioned earlier, the benefit of using remote eye-trackers is that these systems can be regarded as non-invasive in that they allow natural head movements in front of the stimulus monitor. These properties are especially valuable when investigating child samples, since children can be more easily disturbed and fatigued by invasive equipment than adults (e.g. chinrest). In order to elicit natural eye movement behavior from children, the data collection system

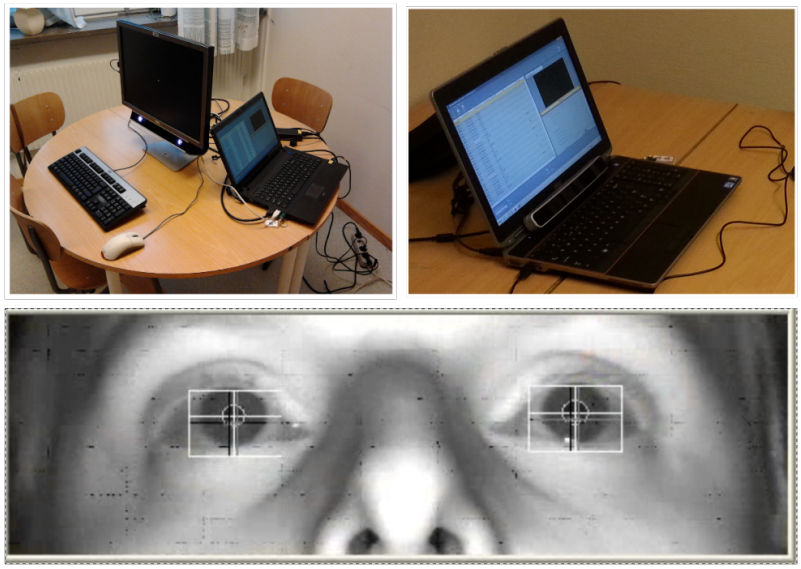

Figure 2.1: Two remote eye-tracking devices used for investigating children's interaction with commercial websites. An SMI RED 250 Hz system is shown top left, and an SMI REDm 120 Hz is shown top right. Both systems illuminate the participant's eyes with infrared light (IR). The bottom image shows a single video frame from an eye-tracking camera, which records the participants eyes in the infrared spectrum. The frame shows how the image processing software has successfully detected the pupil (white crosshair) and IR corneal reflex (black crosshair) needed to calculate the point of regard (POR) on-screen.

should be as unobtrusive as possible, and this is the case with remote eye-trackers. However, a trade-off with remote systems is that they can be associated with poorer accuracy and precision compared to systems that utilize chinrests to stabilize head movements. Poor accuracy and precision, in turn, can affect event detection and advert distraction measures, and such issues should be addressed in the data analysis phase.

This non-invasive measurement technique in combination with performing data recordings in children's natural school environment is expected to produce more ecologically valid results compared to using a laboratory environment. All studies consisted of two eye movement data recordings that were identical for each participant: 1) an anti-saccade test, and 2) a website interaction session. Before each data recording, a calibration protocol was followed, in order to adjust the eye-tracking system to the participant.

Calibration and validation

Calibrations were conducted such that it was first ensured that each participant was seated comfortably in front of the stimulus monitor. Second, an animated 2-point or 5-point calibration procedure was displayed on the stimulus monitor, in which the participants were instructed to gaze directly at each calibration point until it changed position. Directly

after the calibration, a 4-point validation was recorded to measure the deviation between gaze positions and validation targets. Calibrations were repeated until the deviation was below 1 deg of visual angle (corresponding to ca 10 mm on the stimulus screen). The accuracy level and calibration protocol were designed to minimize stress and fatigue in the children before each data recording.

In Study 1 and 2, an SMI RED 250 Hz system was used (cf. **Figure 2.1** top left). The overall quality of the eye-tracking data was calculated as the average deviation between the calibrated point of regard (POR) and four validation points. The average horizontal and vertical deviation was 0.75 deg and 0.92 deg respectively. The amount of missing samples (including blinks) in the anti-saccade data was 12.6%. These quality measures were only calculated for the anti-saccade dataset, but they should generalize to the web surfing dataset as well, since the exact same calibration procedure was applied in both cases. One participant in Study 1 had to be excluded due to technical problems and poor data quality.

In Study 3 and 4, an SMI REDm 120 Hz system was used (cf. **Figure 2.1** top right). The overall quality of the eye-tracking data was calculated as the average deviation between the calibrated point of regard (POR) and four validation points. The average horizontal and vertical deviation was 0.66 deg and 0.80 deg of visual angle respectively. The average amount of null data in the eye movement samples was 4.75% (including blinks). No participants in Study 3 and 4 were excluded due to poor data quality.

Event detection

Study 1 extracted eye movements from screen recordings (see next section). In Study 2, eye movement data were recorded with a 250 Hz sampling rate. Because of this relatively high sampling rate, eye movement events such as fixations, saccades and blinks were detected using the default settings for "High Speed Event Detection" in SMI BeGaze (v. 3.2). This type of event detection basically uses saccades to identify eye movements by means of an identification by velocity algorithm (I-VT) (**Salvucci and Goldberg**, 2000). The default values of 40 deg per second peak velocity and 50 ms minimum fixation duration (minimum saccade duration was set automatically by the software) were used for detecting eye movement events in this dataset (**Holmqvist et al.**, 2011).

In Study 3 and 4, eye movement data from each trial were first imported into the SMI BeGaze 3.5 software. Due to the 120 Hz sampling rate, the raw gaze data was analyzed using an identification by dispersion algorithm (I-DT) (**Salvucci and Goldberg**, 2000). This type of "low-speed" event detection basically identifies uses fixations to identify eye movements. The default values of 80 ms min. duration and 100 px max. dispersion were used for detecting eye movement events in these datasets (**Holmqvist et al.**, 2011).

2.1.3 Screen recordings

Study 1 utilized screen recordings to capture all dynamic web page stimuli that the children interacted with during their free or undirected web surfing sessions. The screen recordings were captured using the SMI ExperimentCenter 3.1 software, which allowed synchronized gaze point data to be superimposed on the screen videos. These video recordings also captured user events such as mouse clicks. Screen recordings of the stimulus monitor with superimposed gaze point were captured at 10 Hz. By using computer vision software these videos were subsequently analyzed in terms of online advertising content, and the same video data were also used to determine which online adverts that the children had looked at (**Bradski**, 2000). These recordings proved to be a useful method for capturing rich website interaction since they register all visual information rendered on the stimulus monitor in real-time. The method of screen recordings represents a new and useful tool for media and communication research that wishes to study internet users' interaction with social media websites.

Advertising saliency measures

In Study 1, a saliency analysis of the online adverts was performed on the screen-recordings obtained from the children's free surfing sessions. Each advert in the video data was defined in terms of its spatial and temporal location, and by using the OpenCV 2.3.1 software (**Bradski**, 2000), the regions corresponding to adverts were processed to extract three basic saliency measures. The saliency features extracted in this study were based on the number of pixels associated with 1) flicker/motion, 2) luminance, and 3) edges within the advert regions in each video frame (**Parkhurst and Niebur**, 2004). Flicker/motion was quantified by measuring the absolute difference in pixels between pairs of successive video frames (i.e. image subtraction). Speed of motion was not considered in this study. Luminance was calculated by thresholding each frame and measuring the remaining luminance pixels. Edge information were measured in each frame by using the OpenCV Canny function, which returned the number of edge pixels in advert regions (cf. **Figure 2.3** A on page 39 below). These measures were also calculated for the surrounding web page in which an advert appeared (the entire video frame containing the advert), in order to calculate the relative saliency values for each advert frame.

2.2 Gaze control measures

In order to measure each participants' individual level of gaze control, a pre-test experiment was administered in the form of an anti-saccade task. In each trial, a central fixation cross was replaced by a peripheral target, and participants were instructed to look in the

opposite direction relative to the target location. After four practice trials with verbal instructions, a series of 32 anti-saccade trials were presented to each participant. The stimulus parameters of the anti-saccade test were chosen in accordance with recently suggested standards (**Antoniades et al.**, 2013). Thus, the test was designed with no temporal gap between central fixation offset and target onset. The central fixation foreperiod was set to a duration of 1500-2000 ms, and the target duration was set to 1000 ms. After target offset, a blank screen was presented for 500 ms (cf. **Figure 1.4** on page 23 above). Targets were presented in four randomized locations (top, bottom, left, and right) at an eccentricity of ca 10° from the central fixation cross. To reduce visual fatigue in the children, the stimuli were constructed with dark background.

After a preliminary calibration, participants were introduced to the anti-saccade task. Verbal instructions were given to the children to envision the task as "a game played with the eyes", where each trial would consist of the appearance of a peripheral target dot in a random location, while the objective was to avoid looking at the target and instead look as quickly as possible in the opposite direction on the screen. When the participants had understood the task, a 4-trial practice session was conducted. After these practice trials, a new two-point calibration was initiated and repeated until the horizontal and vertical deviation was below 1° of visual angle. When sufficient calibration accuracy had been achieved, 32 actual anti-saccade trials were presented in two blocks of 16 trials each, with a short pause in-between.

2.2.1 Anti-saccade tasks

Across all Studies 1-4, eye movement data from the anti-saccade task were analyzed by using the Engbert and Kliegel algorithm in order to detect the first saccade in each trial (**Engbert and Kliegl**, 2003). A minimum saccade duration of 32 ms was provided as a parameter for the detection algorithm. The first saccades were then analyzed for latency, peak velocity and direction relative to target position using a second algorithm (**Ahlström et al.**, 2013). Saccade latency was calculated using a minimum latency parameter of 0.08 ms, peak velocity was calculated using a maximum saccade velocity parameter of 1000 deg/s. Anti-saccades were categorized binomially as correct if they were terminated within a 45 deg angle in the opposite direction of the target location (see **Figure 2.2**). Only the total proportion of correct anti-saccades for each participant was used for further analysis, as this construct was considered to be the most valid measure of gaze control. Crucially, the same event detection algorithm was used for all anti-saccade datasets in Study 1-4. The reason for this approach was to achieve maximum continuity in terms of the gaze control measure across all four studies (**Holmberg et al.**, 2015, 2014; **Holmberg**, 2016a submitted).

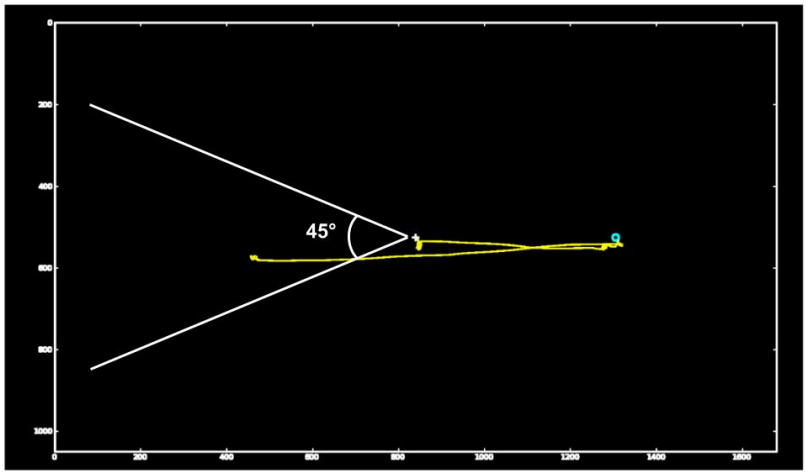

Figure 2.2: Eye movement data from one child have been superimposed on the anti-saccade stimuli from one single trial (yellow). Each trial started with a central fixation cross, and after a short delay a distractor dot appeared in the periphery of the screen (blue circle). Children were instructed to avoid looking at the dot, and immediately look in the opposite direction. The figure shows an incorrect anti-saccade trial in which the participant has first made a saccade towards the distractor, and then made a second saccade towards the correct location opposite to the distractor. The 45 deg angle indicates the region in which the first saccade should have landed in order for the trial to be analyzed as correct (not shown on actual stimuli during the task).

2.3 Free internet usage

This research design was developed in order to elicit natural website interaction in children, as well as naturally occurring online advertising exposure. Although this study design provided valuable insights into children's dynamic interaction with commercial websites, it failed to take into account the wide between-subjects variations in website interaction patterns (some children visited a high number of web pages whereas others only visited a few), and the wide between-websites variations in advertising occurrences (some websites contained a high number of adverts and others none). As a consequence, the outcome measures provided by this research design were characterized by high levels of variability, and due to the lack of experimental control over the web page stimuli, the analysis proved to be cumbersome. Furthermore, as no uniform task was associated with this undirected website interaction, we could not measure children's task performance, which in turn meant that visual attention to online adverts during these web surfing sessions could not be meaningfully associated with (task-irrelevant) advert distraction. However, the first study on free internet usage proved valuable as an explorative investigation into children's unconstrained web surfing behavior, since this study provided us with a basis for controlled studies that we undertook later on.

2.3.1 Study 1: Undirected website interaction

After the anti-saccade pre-test, the children continued with free web surfing sessions. These sessions were implemented as follows: 1) A Microsoft Internet Explorer 8 window launched in full screen mode, and loaded a local HTML file containing a list of links to 47 websites; 2) The participants could select any link they preferred from the list and browse freely on the corresponding target website; 3) The participants could return to the initial link list at any time by hitting the browser's "home button", and select another website to browse. In addition, participants could search or enter any URL in the browser window, in case they wanted to browse websites not present in the link list. The link list was based on results from an internet usage survey, in which the children were encouraged to list all the websites they typically visited when going online. We assumed that this approach would facilitate natural web surfing while minimizing browser interaction difficulties (i.e. typing in URLs on the keyboard). The free surfing sessions were limited to 7 minutes. This time period was estimated to elicit a sufficient sample of advert exposures to gauge the effect of the selected saliency features on visual attention. From a methodological point of view, it should be noted that allowing keyboard interaction often causes participants to reposition their eyes relative to the calibrated position, which may cause eye-tracking data loss (eyes occluded while looking at keyboard).

2.4 Task-oriented web experiments

In Study 1, the online advertising stimuli consisted of authentic adverts that children naturally encountered during undirected internet use (see **Figure 2.3** A on page 39 below). Although this approach provided ecologically valid online adverts, this approach proved to introduce excessive variability in advert properties and children's advert attention. In order to simplify the data analysis and improve the reliability of children's advert distraction measures, the following three studies were designed to be progressively more controlled and simpler in terms of research designs. Even more importantly, the task-oriented nature of these studies contributed to the conceptual clarity surrounding the issues of operationalizing and measuring children's advert distraction.

In Study 2, online advert stimuli were prepared in accordance with two types of visual saliency conditions, namely perceptual prominence (or bottom-up saliency) and content relevance (or top-down saliency). Content relevance was operationalized as three levels of task-relevance in online adverts: 1) low task relevance, which meant that the advert content was relevant for other computer interaction tasks, e.g. login pages for social websites; 2) high task relevance, which meant that the advert content was similar to the target pictures that children were looking for in the advergame tasks; and 3) a control condition, which was implemented as advertising content that was judged to be highly irrelevant to children

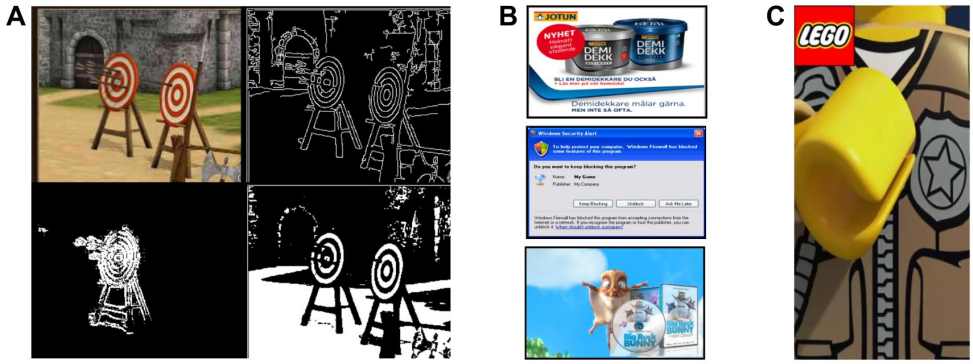

Figure 2.3: **A.** Authentic online advertising were used as stimuli in Study 1. The figure shows the saliency analysis of one single frame from an animated advert: original advert (top-left), edge pixels (top-right), motion pixels (bottom-left), and luminance pixels (bottom-right). The number of white pixels in each sub-image constitutes the respective values for the saliency measures on this frame.
B. Online advertising conditions used in Study 2. In the task relevance conditions, the pictorial content of the adverts was manipulated to different degrees of task relevance. Irrelevant advert in the control condition (top). Low task relevance (middle). In the high task relevance condition, the advert content was based on the target image of the task (bottom).
C. Online advertising conditions used in Study 3 and 4. While content relevance was present in both conditions (LEGO toys), the perceptual prominence of adverts was varied according to two levels: static (control) and animated.

in this age group, see **Figure 2.3** B on page 39 below. Perceptual prominence, on the other hand, was operationalized as advert onset speed. This saliency factor was given three levels: 1) slow onset speed, which meant that the adverts faded in slowly on the web pages; 2) fast onset speed, which meant that the advert popped up abruptly on the web pages; and 3) a control condition, which meant that the adverts loaded simultaneously with the rest of the web page content. These two types of visual saliency were combined in a 3×3 factorial design.

In Study 3 and 4, the advert saliency conditions were even further simplified in order to increase the reliability of the experimental results. In these studies, the online adverts were only presented in a static control condition and an animated experimental condition. In Study 3, there was only one reading task combined with these two advert saliency conditions (1×2 study design), and in Study 4, two task types were combined with the same two advert conditions (2×2 study design). Both advert saliency conditions were generated by recording authentic movie commercials from the LEGO™ YouTube™ channel, which was regarded as highly relevant commercial content for young children (see **Figure 2.3** C below). Besides the increased simplicity in terms of advert saliency conditions in Study 3 and 4 (static vs animated), the online task types were also shifted from a more entertainment-based task in Study 2 (advergame) to more functional tasks, such as reading comprehension and information search. Thus, there is a methodological progression across all four studies presented in this thesis, such that experimental complexity was decreased and societal relevance of the tasks studied was increased.

2.4.1 Study 2: Advergame interaction

This experimental design was developed in order to elicit natural website interaction in children, while at the same time providing experimental control over all web page stimuli presented on-screen, including online adverts. The web pages were designed as a mock-up advergame called *Big Buck Bunny* (**Wikipedia**, 2016a), and this particular theme was selected since recent internet usage research has found that children around 9–12 years of age frequently (and even predominantly) engage in such online activities (**Medierådet**, 2013; **Dahl et al.**, 2009). Thus, the design of Study 2 was significantly different from Study 1 in that children in two age groups (9 and 12 years) were instructed to solve a number of in-game tasks while they were simultaneously exposed to online advertising in controlled saliency conditions. By developing this design, our intention was to investigate to what extent online advertising would distract children in terms of task performance and visual attention on adverts.

Children in both age groups performed the exact same experiment, which consisted of 36 trials. Each trial consisted of a web-based visual search task, in which participants were instructed to memorize a single image presented on an initial web page, and then proceed to a second web page to select the the most similar image in an array of 12 images. On the second page, 3 similar but unique target images were presented, along with 9 unique distractor images with lower similarity (see **Figure 2.4** on page 41). An implication of this image similarity approach was that target images were never identical to the initial image, which added a cognitive component due to the fact that finding an optimal solution encouraged the participants to perform an image similarity judgment. The initial image memorization phase was self-paced, while the second image selection phase introduced a 7000 ms delay before the web page allowed the participant to select an image and thus move to the next web task.

On the second image selection web page, an online advert was presented according to 9 saliency conditions. Apart from perceptual prominence, these advert conditions also tested advert saliency in terms of content relevance (task relevance), which is more demanding to implement within an experimental setting. The task relevance factor included a control condition depicting irrelevant inanimate objects. All adverts except those in the high task relevance condition were based on naturally occurring adverts found on websites frequently used by children in the current sample.

2.4.2 Study 3: Reading comprehension

This experimental design was adapted from **Simola et al.** (2011), and was used in order to investigate the effects of perceptually prominent display advertising on children's online reading comprehension. Web pages containing short factual texts were designed as a mock-

Figure 2.4: The advergame mock-up website consisted of two types of web pages. On the first web page, a target image was presented, and children were instructed to search for the most similar picture on the next page. The figure shows the layout of the image selection web page used to solve the online tasks. The image array contains 3 target images and 9 distractor images in randomized positions. An experimental advert in the high task relevance condition is presented in the top-right corner. The banner advert to the far right was added to make the web pages more realistic, and was kept constant in all trials. The participant's eye movements during the trial are superimposed on the web page image.

up version of a Swedish news website for children called *8 sidor* (**Wikipedia**, 2016b). This mock-up version contained top links and search bar from the original site, but interaction such as top link navigation was disabled (cf. **Figure 2.5**). Instead, the web pages were linked such that participants first navigated to a web page with instructions to read the following text carefully (for a maximum duration of 90 seconds) in order to answer some comprehension questions as correctly as possible. After the instruction page, the participants clicked a link to navigate to the factual text. When they had finished reading the text, they could click on a link that would take them to the comprehension questions, otherwise the web page automatically ended the reading trial after 90 seconds and redirected them to the comprehension questions. This procedure was repeated six times for each factual text.

In the reading-for-comprehension tasks, web pages were constructed that simultaneously presented a short factual text in the main column, along with an online advert in the right column (cf. **Figure 2.5**). Six texts were selected from the Swedish translation of The New International Reading Speed Texts (**Trauzettel-Klosinski and Dietz**, 2012). The texts had an equal length of 146 words, and several text properties were controlled for (such as word length and lexical difficulty). The online adverts were presented in a static control condition and an animated experimental condition. These conditions were generated by recording authentic movie commercials from the LEGO™ YouTube™channel. Combinations of text instance and advert condition were randomized. After reading each text, the children nav-

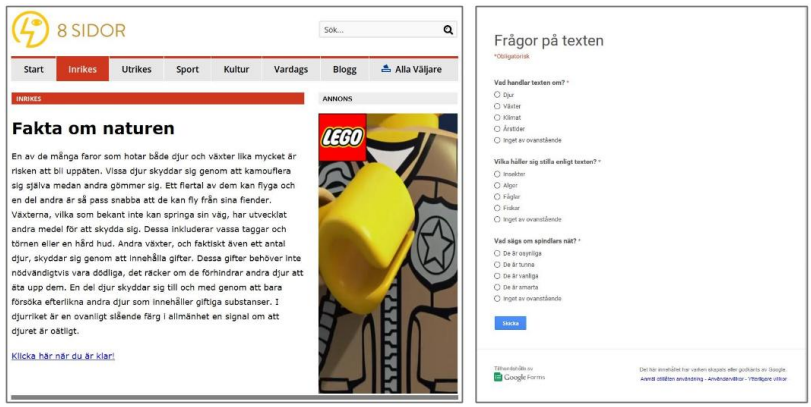

Figure 2.5: The figure shows a web page from the mock-up of a commercial news website. These web pages consisted of a short factual text presented in the main column, and a banner display advert presented in the right column (left). After reading each text, the participants navigated to a web page containing three comprehension questions with five multiple choice alternatives each. The mock-up website consisted of six web pages of this type, with a different text on each page. Adverts presented in the right column were randomized and controlled according to experimental conditions.

igated to a web form containing three comprehension questions with five multiple choice alternatives for each question.

2.4.3 Study 4: Information search

Although this study did investigate effects of online advertising on children's information search, the main purpose was to compare advert distraction measures across two task types: reading comprehension and information search. Thus, Study 3 (the previous study) investigated reading comprehension, and Study 4 extended this study using the same web page stimuli, but with a novel task condition. Both studies were performed in one single data collection and the same children participated in them. The web pages were linked such that participants read each of six factual texts twice under two successive task conditions: 1) in the reading-for-comprehension tasks children were instructed to read the text carefully (for a maximum duration of 90 seconds) in order to answer three multiple-choice comprehension questions presented on a subsequent web page; and 2) in the subsequent information search tasks, participants were presented with a single word from the previously read text, and instructed to search for this word and click on it within 30 seconds (see **Figure 2.6**).

In the information search tasks, the children first navigated to a web page containing three instructions: 1) to search for a single word occurring in a text presented on the following web page; 2) to click on the target word when they found it; and 3) to try to complete the search task within 30 seconds. After reading the instruction and clicking on a link, the children arrived on the next web page, which simultaneously presented a short factual text in the

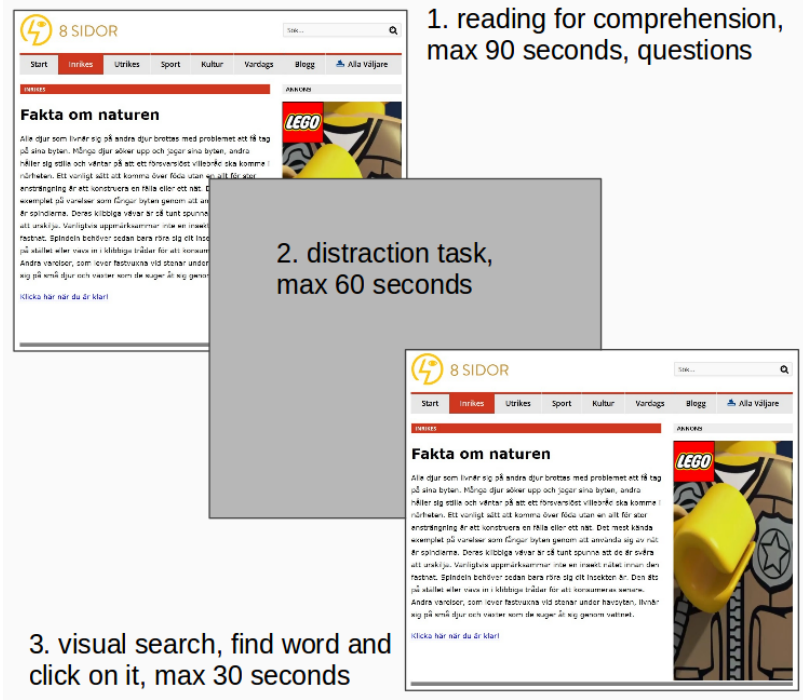

Figure 2.6: The figure shows a web page from the mock-up of a commercial news website. The web page consists of a short factual text presented in the main column, and a banner display advert presented in the right column. This web page was used both for the reading-for-comprehension task type as well as the information search task type. The mock-up website consisted of six web pages of this type, with a different text on each page. Adverts presented in the right column were randomized and controlled according to experimental conditions.

main column, along with an online advert in the right column. The advert conditions were the same as in the reading-for-comprehension tasks, and were presented in a static control condition and an animated experimental condition. However, advert conditions were randomized between task types (i.e. the advert condition presented during reading was not necessarily presented during information search). If the information search task had not been completed within 30 seconds, the trial was ended, and the web page automatically redirected to another web page (see **Figure 2.6**).

2.5 Task performance measures

In Study 2, two task performance measures were analyzed. Trial accuracy was determined by analyzing mouse click responses recorded by SMI Experiment Center 3.2 and encoding these responses as a binomial variable depending on whether the tasks had been solved correctly by clicking on one of the three target images. The second performance measure, trial duration, was also analyzed in this step, by recording the time difference in milliseconds

between trial onset (when the task web pages were loaded) and the participants' response (when the mouse click was used to solve the task). There was no upper limit on trial duration, but the variability in this measure was quite low.

In Study 3, the main task performance measure was reading comprehension. Each text was associated with three comprehension questions, with five multiple choice alternatives for each question. Reading comprehension was measured for each question as a binomial variable depending on whether the correct alternative was selected (**Simola et al.**, 2011). In Study 4, reading comprehension performance (Study 3) was extended and compared with information search performance. Two performance measures were used in the information search tasks: task accuracy was encoded as a binomial variable depending on whether the target word was found and clicked on within the 30 second time limit, and trial duration measured the time from trial onset until the target word was clicked or the trial ended.

Task processing measures

In Study 3, three widely-used text processing measures were calculated for each reading trial. These measures are often referred to as global reading measures (**Rayner**, 1998). First, average fixation duration was calculated, since longer fixation durations are often assumed to be positively correlated with cognitive load and increased processing difficulty during reading. Second, the number of words per minute was also calculated since lower reading rate is assumed to be indicative of text processing difficulties. Third, the total number of regressive saccades were calculated since such regressions indicate problems with understanding the meaning of the text (possibly caused by advert distraction). Saccades inside the text region were classified as regressive if their end point coordinate was both to the left and above the starting point coordinate. The reason for this implementation was that the spatial resolution of the eye movement data was not sufficient to separate individual lines of the text. These text processing measures were similar to measures used in previous research on adult internet users (**Kuisma**, 2015; **Simola et al.**, 2011).

In Study 4, the focus was shifted from text processing measures towards more general task processing in order to compare cognitive load across reading tasks and information search tasks. Previous research on task-evoked pupillary responses suggested that pupil dilation was the most suitable eye movement measure for investigating cognitive load caused by the task (intrinsic load) and by advert distractions (extraneous load) (**Johnson et al.**, 2014; **Paas et al.**, 2003; **Beatty**, 1982).

2.6 Advert distraction measures

In Study 2, event detected eye movement data were used to calculate two advert distraction measures in relation to the area of interest (or AOI) corresponding to adverts (see **Figure 2.7**). The first measure was constructed by adding all fixation durations on the advert in each trial. This AOI measure is better known as total dwell time in the eye-tracking literature (**Holmqvist et al.**, 2011). The function of this measure is often to provide a close approximation of the total amount of visual attention devoted to a specific region of the visual field. The second distraction measure was constructed by counting the number of saccades that originated outside the pixel coordinates of the advert AOIs, and was terminated inside the same region (a variation of the more common number of saccades and number of transitions measures) (**Holmqvist et al.**, 2011). The terminology of these distraction measures was chosen in order to clearly contrast the functional difference between fixations and saccades. Thus, saccades to adverts were assumed to measure their attention attracting power, while dwell time on adverts was assumed to measure their attention retaining power (**Born and Kerzel**, 2008).

In Study 3, two common advert distraction measures were calculated in each reading trial. The first measure was calculated as the number of fixations on advert areas of interest (AOIs). Fixations approximates the amount of foveal visual intake dedicated to adverts during reading (**Holmqvist et al.**, 2011), interest towards pictorial content, and the attention retaining power of the visual design of adverts (**Holmberg et al.**, 2014). The second measure was calculated as the number of saccades into the advert AOI. This measure was used to approximate the attention attracting power of adverts **Holmberg et al.** (2014).

In Study 4, we used an advert distraction measure that was similar to the number of fixations on adverts utilized in Study 3. However, since an important aspect of Study 4 was to compare advert distraction across two task types with different durations (reading tasks with max duration 90 seconds, and search tasks with max duration 30 seconds), it was necessary to calculate this distraction measure as relative to trial duration. Therefore, this advert distraction measure is referred to as number of fixations on adverts per minute.

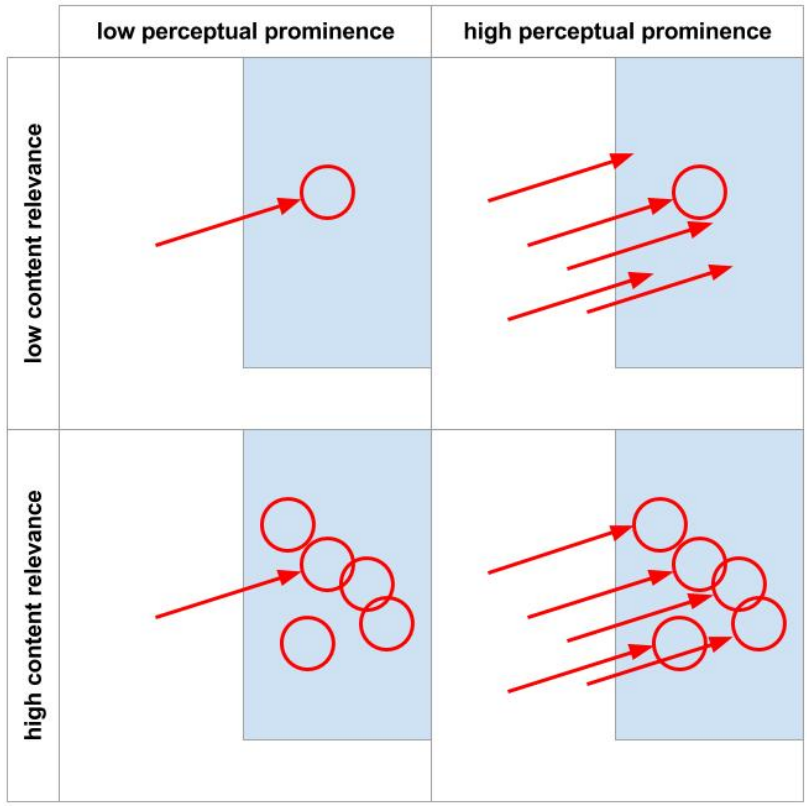

Figure 2.7: Online adverts are represented by blue boxes, and eye movements are represented by red figures. Distraction measures were expected to depend on the perceptual prominence (e.g. animation, abrupt onset) and content relevance (e.g. toys, cartoons) of online adverts. When perceptual prominence was increased, the amount of attentional shifts towards adverts was expected to increase (red arrows). This attention attracting property was analyzed as the number of saccades from task-relevant web content towards the advert area. By contrast, when content relevance was increased, the amount of visual attention was expected to increase (red circles). This attention holding capacity was analyzed as the number of fixations on task-irrelevant adverts. Adverts combining high levels of perceptual prominence and content relevance were expected to cause the highest levels of advert distraction measures.

Table 2.1: Overview of project study designs.

Study	Time	Participants	Research designs	Data collection
1	Nov 2011–Jan 2012	N=26, 3rd grade	Anti-saccades, Undirected interaction	Eye-tracking (SMI RED 250Hz), Screen recording
2	Nov 2012–May 2013	(N=9, 3rd grade[1]), N=19, 3rd grade, N=26, 6th grade	Anti-saccades, Task-oriented, Advergame	Eye-tracking (SMI REDm 120Hz[1], SMI RED 250Hz)
3	Nov 2014–Jan 2015	N=57, 3rd grade[2]	Anti-saccades, Task-oriented, Reading comprehension	Eye-tracking (SMI REDm 120Hz)
4	Nov 2014–Jan 2015	N=57, 3rd grade[2]	Anti-saccades, Task-oriented, Information search	Eye-tracking (SMI REDm 120Hz)
All	Nov 2011-Jan 2015	N=137 children	Anti-saccades	Demographics, Eye-tracking

Notes:
1. A smaller sample participated in a pilot study in order to test web-based experiments.
2. The same individuals participated in both Study 3 and 4.

Chapter 3

Results

The studies performed within this dissertation project have one thing in common: The dependent measures in all studies have been related to children's visual attention to online advertising (response measures), and the independent variables in all studies have consisted of content properties of online advertising (stimuli measures). This research framework was designed in order to investigate and understand how perceptually prominent (or salient) advert properties predict children's advert distraction during various types of undirected and task-oriented website interaction. By applying task-oriented research designs when studying children's interaction with commercial websites, and measuring effects of adverts properties on children's visual attention and task performance, the overall aim of the studies was to estimate children's advert distraction. A summary of these dependent and independent variables used across all studies is presented in **Table 3.1**.

As various parts of children's cognition and executive function reach maturation, they naturally start to explore the internet and use this medium for increasingly task-oriented purposes, such as information search and school-related activities. This cognitive maturation occurs in children around the age of 8–10 years, and due to the ubiquitous access to internet-enabled devices in Sweden, this is also the age when Swedish children start using the internet in a goal-directed manner. However, since cognitive functions develop rapidly in children around age 8–10 due to a developmental spurt in prefrontal growth, a great deal of individual variation can be expected in this age group, both in terms of distractibility and in capacity for task-oriented internet use. For these developmental reasons, we thought that it was motivated to investigate task-oriented internet use in children aged 9 and 12 years, and to measure their advert distraction on commercial websites. In order to take into account children's varying cognitive maturation at these ages, we also measured their gaze control across all studies, and used this measure as a predictor of online task performance and advert distraction.

Table 3.1: Overview of dependent variables and predictors used in each study.

Study	Dependent variables	Predictors
1	Advert attention (binomial)	Advert saliency (continuous), gaze control (continuous)
2	Advert distraction, task performance	Perceptual prominence (3 levels), content relevance (3 levels), gaze control (continuous)
3	Advert distraction, task performance	Perceptual prominence (2 levels), gaze control (continuous)
4	Cognitive load, advert distraction	Task type (2 levels), Advert saliency (2 levels), gaze control (continuous)

Note: Dependent variables are related to children's advert exposure and task performance. Predictors are generally advert properties and measures of individual differences, such as age, gender and gaze control.

In the following sections, an overview of the four research studies underlying the present dissertation will be presented to indicate how each study was situated into the overarching research framework. In so doing, I will start out by first summarizing the hypotheses in each research study according to the dependent and independent variables listed in **Table 3.1** above, and then continue to describe the results in testing these hypotheses. When discussing the results, I will define the measures used, and the significance level of the measure associations tested. A general discussions of the results and their potential implications will be postponed until the next chapter.

3.1 Study 1 (Paper 1)

The main objective in the first study was to undertake an explorative investigation of children's online activities under conditions that were as natural as possible. The motivation for this was to obtain unprejudiced information about how children aged 9 interacted with the internet during unconstrained web surfing on websites that they preferred to visit in their leisure time. Another motivation was to obtain detailed data on the types of online advertising that children were exposed to under natural conditions, and quantify the saliency level of these adverts. Finally, we wanted to measure individual differences in inhibitory control in this age group, and examine if this developmental factor could explain differences in children's visual attention to naturally occurring online advertising. In order to investigate these research questions we hypothesized that higher levels of visual saliency in online adverts would generally be associated with higher levels of visual attention to adverts in children. To test this hypothesis, we used image processing software to analyze and quantify three dimensions of visual saliency in the screen recordings containing children's

free website interaction. The saliency dimension selected were based on previous psychological and perceptual research, and consisted of: 1) the level of motion in adverts, 2) the level of edge information present, and 3) the level of luminance in the adverts. These three saliency measures were computed for each occurring online advert, and a binomial regression analysis was performed in order to examine how saliency levels could predict children's advert attention. Regarding the effect of children's developmental level of inhibitory control, we hypothesized that lower success rate in the anti-saccade task would be associated with higher levels of visual attention to online advertising. Thus, children's individual proportion of correct anti-saccades were entered into the regression analysis as a predictor of advert attention.

The results of the saliency analysis of online adverts were based on a total of 396 adverts that were identified in screen recordings containing 7 minutes of undirected web surfing behavior from 25 children aged 9 (third grade). The screen recordings sampled all web page stimuli that the children interacted with at 10 Hz (10 fps video), and image processing software was used to extract three continuous saliency measures from each advert video frame. These advert saliency measures were computed as relative to the entire screen in which the advert occurred. Relative saliency measures were then averaged over each online advert. Thus, each online advert was associated with an average relative saliency measure which was later used as a predictor of children's advert attention. In addition, each adverts relative size and total duration of presentation were also included as saliency measures. Thus, the saliency figures given in **Figure 3.1** below should be interpreted such that the average relative size of online adverts was about 7.5% of the entire screen area (1680×1050 pixels), i.e. about 360×360 pixels. Similarly, the average relative amount of motion pixels in adverts was nearly 20% of the total screen area, which indicates that online adverts accounted for an average of $\frac{1}{5}$ of all the motion occurring on the screen at any given moment while children were surfing. Since children in this age group preferentially engaged in online gaming and online video which contains a lot of motion, it can be expected online adverts might account for a larger proportion of the total number of motion pixels other types of websites. On such websites, the impact of one animated online advert might have much greater impact since it stands out from a relatively static surrounding.

The results of the anti-saccade task showed that 9-year-olds in our sample had a considerably lower success rate than would have been expected in adults. Healthy adults normally achieve success rates of about 80% correct anti-saccades in standardized versions of this test. In our sample, 9-year-olds had an average proportion of about 20% correct anti-saccade trials out of a total of 32 trials per child. This figure is similar to what has been found in previous psychological research, and confirms our assumption that children around age 8-10 have a relatively less developed capacity for inhibitory control. However, the most interesting result was that there was a great deal of individual variation in gaze control among the children in our sample. Such variability might also be expected since rapid pre-

Descriptive statistics of advert saliency measures.

Saliency measure	Mean	SD
Duration (sec)[1]	20.47	45.45
Rel. Size[2]	0.072	0.056
Rel. Motion[3]	0.180	0.220
Rel. Edges[3]	0.085	0.052
Rel. Luminance[3]	0.068	0.065

1. Durations were added when adverts were visible on the web page. Time when adverts were completely invisible due to page scrolling is not included.
2. Size values were calculated for each video frame and averaged over each unique advert. Average size presented as a proportion relative to the display size at a resolution of 1680 × 1050 pixels.
3. Saliency values were calculated for each video frame as a proportion of pixels relative to the saliency value of the entire web page. Relative saliency values were then averaged over each unique advert.

Effects of advert saliency and individual factors on visual attention.

	Coeff.	Std. Error	z value	P= r(>|z|)
(Intercept)	4.04	1.02	3.95	0.0001
Adv. Dur.	0.86	0.13	6.50	0.0000
Adv. Motion	1.01	0.13	7.46	0.0000
Adv. Edges	0.68	0.29	2.34	0.0191
Adv. Lum.	-0.61	0.23	-2.72	0.0066
Adv. Size	0.00	0.00	0.98	0.3249
Sub. Int.Use	-0.07	0.17	-0.43	0.6695
Sub. Gen. (m)	-1.18	0.77	-1.53	0.1256
Sub. Gaze	-4.47	1.63	-2.74	0.0061
Gen. × Gaze	3.48	2.73	1.27	0.2035

Predictors of children's visual attention to internet adverts. Advert saliency measures (Adv.) were log-transformed before entered into the regression model. Measures of individual differences (Sub.) include internet use (Int.Use), gender (Gen.), and gaze control (Gaze). Interaction between gender and gaze control is given last.

Figure 3.1: Advert salience measures are presented in the left hand table. Regression table including advert saliency measures, demographic variables (age and level of weekly internet use), and individual level of gaze control as predictors of advert attention is presented in the right hand table.

frontal development it this age group entails potentially large individual differences. When analyzing the anti-saccade data, we also found near-significant differences depending on children's gender. Although popular belief holds that girls develop earlier in terms of cognitive functions, we found that boys' average proportion of correct anti-saccades (27%) was considerably higher than in girls (16%). Due to this gender difference, we decided to include an interaction analysis of gaze control and gender when adding these variables to the regression analysis in order to evaluate predictors of children's online advert attention. A table for this regression analysis is shown in **Figure 3.1**.

Finally we used the recorded eye movement data from the children's undirected website interaction in order to examine when children had been looking at online adverts. This was achieved by extracting the real-time gaze point location of each individual child on the web page stimuli they had interacted with. Using image processing software, the gaze point location was extracted for each individual frame of the screen recordings, and if the gaze point coordinates were within the rectangular area of an online advert during two successive frames (i.e. 200 ms given a frame rate of 10 fps), the advert were coded binomially as having been attended. This advert attention measure was then entered as the dependent variable of a mixed-effects logistic regression analysis (with participant as random factor), and the associations to previously mentioned predictor variables were evaluated. Some advert saliency measures were log-transformed in order to achieve better normal distributions for these measures. The regression analysis revealed that among the advert saliency measures calculated, advert presentation time and advert motion were the strongest predictors of children's advert attention. After these measures came advert luminance (the negative coefficient means that darker adverts on bright web pages were associated with increased

probability of visual attention), and advert edge density. Interestingly, advert size did not have a significant effect, which might indicate that this property does not attract visual attention in itself, when other properties have been controlled for. Among the variables referring to individual differences among children, neither level of internet use nor gender had any significant effects on advert attention. However, in support of our hypotheses, children's individual level of gaze control proved to be a strong negative predictor of advert attention. This result means that higher score on the anti-saccade task, and better gaze control in an individual, was associated with less advert attention.

3.2 Study 2 (Paper II)

In order to achieve better causal explanations of the effect of online advertising saliency on children's task performance and advert distraction, the second study introduced an experimental and task-oriented research design. The experimental design was built into an authentic looking advergame in which the task was to search for similar images. Children participating in this study performed a number of trials on this task, while their eye movements and web page interactions were recorded. In this study the main objective was to operationalize two types of visual saliency in online advertising frequently mentioned in the research literature, namely perceptual prominence (or bottom-up saliency) and relevant content (or top-down saliency). Perceptual prominence was operationalized as advert onset speed. This saliency factor were given three levels: 1) slow onset speed, which meant that the adverts faded in slowly on the web pages, 2) fast onset speed, which meant that the advert popped up abruptly on the web pages, and 3) a control condition, which meant that the adverts loaded simultaneously with the rest of the web page content.

We hypothesized that higher levels of perceptual prominence (abrupt advert onset) would cause higher levels of advert distraction and lower levels of task performance when playing the advergame. The other type of visual saliency was operationalized as three levels of task-relevance in online adverts: 1) low task relevance, which meant that the advert content was relevant for other computer interaction tasks (e.g. login to social website), 2) high task relevance, which meant that the advert content was similar to the target pictures that children were looking for in the advergame trials, and 3) a control condition, which was implemented as advertising content that was judged to be completely irrelevant to children in this age group. Concerning advert relevance, we hypothesized that high levels of relevant content in online adverts would cause more advert distraction in children and lower task performance. These two types of visual saliency were combined in a 3×3 design, which allowed us to evaluate the relative effects of perceptual prominence and relevant content in online adverts in two age groups: 9 years old and 12 years old. Concerning the age groups, we hypothesized that older children would have a higher level of cognitive maturation, and that they would be less distracted by online advertising, see **Figure 3.2**.

Table 1 | Effects of independent variables on task performance measures (trial accuracy and trial duration).

	Trial accuracy (binomial)				Trial duration (ms)			
	Estimate	**Std. error**	***z* value**	***Pr*(>|*z*|)**	**Estimate**	**Std. error**	***t* value**	***Pr*(>|*t*|)**
(Intercept)	2.8843	0.6755	4.2700	0.0000	10926.6540	520.9880	20.9730	0.0000
Advert onset speed (smooth)	0.3231	0.6324	0.5110	0.6094	8.3820	472.3650	0.0180	0.9858
Advert onset speed (abrupt)	−0.5470	0.5884	−0.9300	0.3525	435.4470	472.3400	0.9220	0.3567
Advert task relevance (low)	0.0166	0.5757	0.0290	0.9770	160.2250	472.2880	0.3390	0.7345
Advert task relevance (high)	0.8351	0.6290	1.3280	0.1843	−215.8810	472.2690	−0.4570	0.6477
Advert position (bottom-right)	**0.0108**	**0.0050**	**2.1380**	**0.0325**	−2.6040	3.2140	−0.8100	0.4179
Child age (12 years)	**0.9242**	**0.3275**	**2.8220**	**0.0048**	123.7080	215.0440	0.5750	0.5652
Child gender (male)	**−0.8124**	**0.2901**	**−2.8000**	**0.0051**	**653.6960**	**185.1890**	**3.5300**	**0.0004**
Child gaze control	**2.2361**	**0.7643**	**2.9260**	**0.0034**	−44.9860	471.4690	−0.0950	0.9240

Significant effects are emphasized with bold face. Child gaze control values have been centered.

Table 2 | Effects of independent variables on task distraction measures (dwell time on ads and saccades to ads).

	Dwell time on ads (ms)				Saccades to ads (count)			
	Estimate	**Std. error**	***t* value**	***Pr*(>|*z*|)**	**Estimate**	**Std. error**	***t* value**	***Pr*(>|*z*|)**
(Intercept)	485.9071	68.1109	7.1340	0.0000	0.8091	0.1543	6.7270	0.0000
Advert onset speed (smooth)	−78.8628	52.8385	−1.4930	0.1358	**−0.3115**	**0.1195**	**−2.3970**	**0.0166**
Advert onset speed (abrupt)	**125.8762**	**52.8353**	**2.3820**	**0.0173**	**0.2992**	**0.1194**	**3.0960**	**0.0020**
Advert task relevance (low)	**185.6223**	**52.4182**	**3.5410**	**0.0004**	**0.2047**	**0.1195**	**2.1060**	**0.0353**
Advert task relevance (high)	**412.5676**	**52.8994**	**7.7990**	**0.0000**	**0.8984**	**0.1194**	**8.4320**	**0.0000**
Advert position (bottom-right)	**−3.4347**	**0.5302**	**−6.4780**	**0.0000**	−0.0016	0.0012	−1.3800	0.1677
Child age (12 years)	**92.3068**	**35.5833**	**2.5940**	**0.0096**	−0.0267	0.0805	−0.1530	0.8786
Child gender (male)	−14.0102	30.5717	−0.4580	0.6468	0.1700	0.0692	1.6180	0.1058
Child gaze control	**−265.1405**	**77.8884**	**−3.4040**	**0.0007**	**−0.3102**	**0.1764**	**−2.4340**	**0.0151**

Significant effects are emphasized with bold face. Child gaze control values have been centered.

Figure 3.2: Effects of advert saliency types (perceptual prominence and content relevance) and individual variables on advert distraction measures (cf. Table 1) and task performance measures (cf. Table 2).

The results showed that none of the advert saliency conditions had significant effects on any of the task performance measures (task accuracy and trial duration) while playing the advergame. Thus, if participants were distracted by the online adverts, they managed to compensate for it in terms of maintaining high levels of task performance. However, trial accuracy was significantly impacted by the individual variables age, gender, and gaze control. Older age group (12 years), female gender, and higher level of gaze control was associated with significantly better task performance. Shifting focus to the advert distraction measures, the situation is more or less reversed. Higher levels of advert saliency (both perceptual prominence and content relevance) were associated with higher levels of fixations on adverts as well as more saccades to adverts. Interestingly, comparing the relative impact of both advert saliency dimensions, the evidence suggests that content relevance (top-down saliency) had a stronger effect on advert distraction than perceptual prominence. A bit surprisingly, older age group (12 years) was associated with higher levels of advert distraction. However, as hypothesized, gaze control was consistently associated with lower advert distraction.

3.3 Study 3 (Paper III)

The main objective in the third study was to investigate how online advertising affected children when they utilized a commercial website in a reading-for-comprehension task. We reasoned that reading and understanding texts online is a functional task that many children frequently encounter in real-life situations, e.g. when performing school-related activities, and that successful outcomes in this task has a high value for children. For this reason, it is important that online advertising does not cause so high levels of distraction that children's task performance is significantly impaired. We also reasoned that children aged 9 are undergoing rapid cognitive development, and that children with less developed executive functions may be more negatively impacted by salient online adverts while performing web-based reading-for-comprehension tasks. In order to examine the effect of children's individual level of inhibitory control, each child underwent an anti-saccade pre-test before performing the reading tasks. Based on our previous studies, we had found evidence that suggested that high levels of animation in online adverts were associated with high levels of advert attention and distraction, and in some cases, lower levels of task performance. Since animation is also frequently used in authentic online advertising in order to increase advert saliency and thus increase the probability of attention in users, we decided to compare the effects of static adverts (low saliency level) with animated versions of the same advert (high saliency level).

In order to ensure that the adverts also had a high level of age-relevant content (which simulates online behavioral tracking), the display adverts used in this experiment were based on authentic LEGO™ video commercials. These experimental online adverts were presented on web pages that also contained a short factual text, which the children were instructed to read in order to be able to answer some comprehension questions afterwards. We hypothesized that animated adverts (high saliency level) would cause more advert distraction in children, and lower reading comprehension. We also hypothesized that children's level of cognitive development would have an effect, such that higher proportions of correct anti-saccade trials would be associated with less advert distraction and better task performance. Finally, the last aim with this study was to investigate if level of advert saliency interacted with children's individual level of gaze control, such that children with lower scores on the anti-saccade task were relatively more disadvantaged by high-saliency animated adverts during online reading-for-comprehension, see **Figure 3.3**.

Reading comprehension was registered as a binomial variable for each comprehension question. The results revealed that even if advert animation had a general negative effect on reading comprehension compared to static adverts, this negative effect was much more pronounced among children with lower levels of gaze control. Among children with high levels of gaze control, there was not much difference in reading comprehension depending advert saliency level. Interestingly, in the reading-for-comprehension task, children's in-

Table 1. Predictors of children's reading comprehension. Modeling the effects of advert animation, advert distraction, and voluntary gaze control.

Predictors	Model 1		Model 2		Model 3	
Level 1	z value	p value	z value	p value	z value	p value
(Intercept)	0.412	0.6807	-0.589	0.5556	0.621	0.53434
Adv. condition (animated)	-1.808	0.0705	-1.828	0.0676	-2.684	**0.00727**
Adv. number of fixations	-2.320	0.0204	-2.171	0.0300	-2.068	**0.03865**
Adv. number saccades into	1.259	0.2079	1.199	0.2304	1.083	0.27883
Level 2						
Subj. gaze control			0.951	0.3417	-0.500	0.61673
Cross level						
Adv. condition (animated) × Subj. gaze control					2.107	**0.03516**
Model deviance	1398.2, p = 0.02		1397.3, p = 0.35		1393.0, p = 0.04	

Model 1-3 include random effects of participant and trial. In logistic regression, z-values are given to indicate the direction of linear effects (instead of t-values), and coefficients are given on the logistic scale, and have therefore been excluded.

Figure 3.3: Predictors of children's reading comprehension investigated in Study 3.

dividual level of gaze control did not in itself predict higher task performance. The effect of gaze control only became apparent when analyzing the interaction with advert saliency. This results suggests that the reading-for-comprehension task impacts other cognitive functions than the other tasks investigated in this project. One interpretation of this result is that higher levels of gaze control is primarily beneficial in tasks that involve high perceptual load, such as advergames or some types of visual search. Further investigations into this area are needed. The results also showed that higher levels of advert distraction (fixations on advert) had an independent negative effect on task performance in the case of reading comprehension.

3.4 Study 4 (Paper IV)

This study extended Study 3 such that the same mock-up website and the same web page stimuli was used (including advert conditions), but the a new task type called information search was introduced and compared to the reading comprehension tasks type investigated previously. The information search tasks were constructed such that a single word was showed on a web page, and then children were instructed to search for that word in a text, and click on it when they had found it. Maximum trial duration in this task was 30 seconds. In addition, a new measure of cognitive load was introduced by measuring children's average pupil dilation while interacting with both task types. Thus, the main objective in this study was to investigate the independent and combined effects of task type and advert prominence on children's cognitive load and advert distraction. The same static and animated advert conditions as used in the reading comprehension tasks were also used across in the new information search task types.

We hypothesized that the task type conditions and advert prominence conditions would affect children's cognitive load and advert distraction. We expected reading comprehension

Table 1. Effects of task type and advert prominence on task-related cognitive load (mean pupil dilation).

Predictors	Estimate	Std. Error	t value	p value
(Intercept)	14.678	0.525	27.939	0.000
Task type (visual search)	1.149	0.090	12.835	0.000
Advert prominence (animation)	0.181	0.072	2.520	0.012
Gaze control (anti-saccades)	-2.222	1.334	-1.665	0.096
Interaction				
Task type × Advert prominence	-0.119	0.099	-1.199	0.231

Table 2. Effects of task type and advert prominence on advert-related distraction (fixations per minute).

Predictors	Estimate	Std. Error	t value	p value
(Intercept)	2.177	0.690	3.154	0.002
Task type (visual search)	-1.311	0.395	-3.320	0.001
Advert prominence (animation)	1.861	0.527	3.533	0.000
Gaze control (anti-saccades)	-1.335	1.572	-0.849	0.396
Interaction				
Task type × Advert prominence	-0.902	0.585	-1.542	0.123

Figure 3.4: Results from Study 4 revealed that task type had a significant effect on mean pupil dilation during task processing, such that information search tasks were associated with significantly larger pupil size compared to reading comprehension tasks (cf. Table 1). This result indicates that information search tasks were more demanding in terms of cognitive load. Study 4 also revealed that task types with high cognitive load caused lower levels of advert processing, measured as number of fixations per minute on adverts (cf. Table 2).

tasks to generate more cognitive load and less advert distraction (according to the theory of limited cognitive capacity) than visual search tasks (**Lang**, 2000). We also expected animated adverts to generate higher levels of extraneous cognitive load, and higher levels of advert distraction. These hypotheses were derived from previous research on task-evoked pupillary responses and cognitive load theory. Evidence that supported these hypotheses would indicate that children could benefit from lower advertising saliency on websites used to solve cognitively demanding tasks, see **Figure 3.4**. The results of this research is presented in Paper IV (Holmberg, 2016).

The results supported our hypotheses concerning the effects of advert prominence on cognitive load and advert distraction measures. Thus, animated adverts caused higher levels of cognitive load and advert distraction in children across task types. However, contrary to our hypotheses concerning the effects of task types, the empirical results suggested that information search tasks were more demanding in terms of cognitive load than reading comprehension tasks. Furthermore, the evidence supported our hypotheses based on the theory of limited cognitive capacity, such that information search trials (high cognitive load) were associated with lower levels of advert distraction measures, while reading comprehension

trials (low cognitive load) were associated with more advert distraction, measured as number of fixations per minute on task-irrelevant adverts. These results suggests that children might be more susceptible to advert distraction when using web pages that are cognitively less demanding.

Chapter 4

General discussion

In discussing the outcomes of this dissertation project, it is necessary to return to the structure of the thesis presented in **Figure 1.1** on page 8. As described in this figure, the general discussion (chapter 4) will begin with a summary of principal findings from a media psychology perspective. The purpose of this organization is to enable the reader to evaluate the result of each study in relation to the hypotheses presented in the introduction (chapter 1). After summarizing the principal findings and discussing the contribution of the results with regard to the media psychology research field, the thesis will continue to discuss the results of thesis in relation to the more theoretically oriented media and communication research questions presented in the introductory chapter. In order to discuss this theoretical aspect of the thesis, the results from the hypothesis testing need to have been evaluated first. The discussion concerning how this dissertation project have informed the media and communication research questions shows its contribution to this field of research. When the contributions to media and communication studies have been elucidated, the general discussion will be concluded with a discussion of the societal implications of this research in terms of advertising policy. Finally, some directions for future research will be suggested.

4.1 Summary of principal findings

In the first study of this project, the effects of advert saliency and individual level of gaze control on 9-year-old children's visual attention were analyzed in an explorative eye-tracking study on children's free (or undirected) website interaction. Within this study, a method for sampling, analyzing and quantifying visual saliency in authentic online advertising was developed, and these saliency measures were later used as predictors of children's visual attention during website interaction. In order to determine children's level of inhibitory

control over their visual attention, this study also introduced an anti-saccade test for children, and this test was used to measure and quantify children's level of gaze control. In line with our expectations, we found that 9-year-olds as a group had significantly lower success rates on the anti-saccade task compared to adults (about 60 percentage points lower), and that there was large individual differences on this measure within the group. By measuring visual saliency in online adverts and children's individual level of inhibitory control, this study revealed how these two factors affects children's visual attention to online adverts during undirected internet interaction. By using regression analyses, the strongest predictors of children's attention to adverts were found to be higher levels of motion in online adverts and lower levels of gaze control in children. Children's gender or level of internet use were not identified as contributing factors.

In order to investigate children's advert distraction, the subsequent studies utilized web-based experiments in which children could solve online tasks in a number of similar trials while being exposed to concurrent online adverts in two types of saliency conditions: level of perceptual prominence and level of task-relevant content. The second study revealed that higher levels of both saliency types were associated with higher number of fixations and saccades to adverts, and importantly, that adverts in the task-relevant content conditions attracted more visual attention than perceptual prominence. This effect conforms with a line of previous psychological research on saliency and visual attention (**Henderson et al.**, 2007; **Wolfe and Horowitz**, 2004). Interestingly, in line with the first study, it was also found that children's individual level of gaze control was negatively associated with their level of advert distraction, while age had a similar but weaker effect. An important result of this study was that advert saliency levels did not significantly affect children's task performance while playing the advergame, and thus high online task performance was maintained in both age groups even in conditions were visual attention to adverts was significantly higher. In terms of task performance, individual factors seem to have a stronger impact than advert saliency factors, with girls and older children (12 years) out-performing boys and younger children (9 years).

The third study investigated online reading and text comprehension on commercial websites. In contrast to previous studies, high perceptual prominence in online adverts was associated with a general decrease in task performance (reading comprehension scores). In order to further clarify the relation between gaze control, advert saliency, and reading comprehension, a hypothesis was formulated such that high levels of gaze control in children would moderate negative effects of advert saliency on their reading comprehension. To test this hypothesis, an interaction analysis was performed on advert saliency and individual level of gaze control with regard to children's reading comprehension. This analysis revealed a significant interaction effect, such that children that were lower in gaze control had significantly lower reading comprehension when exposed to animated adverts with high perceptual prominence. Thus, this result identifies a possibly vulnerable group of children

with less developed inhibitory control that might experience lower task performance on commercial websites with high saliency online adverts, which is referred to as differential susceptibility (**Valkenburg and Peter**, 2013b). This can be regarded as a conditional media effect in that negative effects of salient online adverts on reading comprehension seem to be conditional on children's level of gaze control (**Valkenburg et al.**, 2016).

In Study 4, a new task type called information search was introduced and compared to the reading comprehension tasks type investigated previously. In addition, a new measure of cognitive load was introduced by measuring children's average pupil dilation while interacting with both task types. The main objective in this study was to investigate the independent and combined effects of task type and advert prominence on children's cognitive load and advert distraction. We expected reading comprehension tasks to generate more cognitive load and less advert distraction (according to the theory of limited cognitive capacity) than visual search tasks (**Lang**, 2000). contrary to our hypotheses concerning the effects of task types, the empirical results suggested that information search tasks were more demanding in terms of cognitive load than reading comprehension tasks. Furthermore, the evidence supported our hypotheses based on the theory of limited cognitive capacity, such that information search trials (high cognitive load) were associated with lower levels of advert distraction measures, while reading comprehension trials (low cognitive load) were associated with more advert distraction, measured as number of fixations per minute on task-irrelevant adverts. These results suggests that children might be more susceptible to advert distraction when using web pages that are cognitively less demanding.

4.2 Contributions to media psychology research

The empirical studies undertaken in this thesis project have been guided by a media psychological framework for investigating children's processing of commercial media content, thus referred to as the PCMC model (**Buijzen et al.**, 2010). This investigative framework can be described as a synthesization of several theories within psychology and communication research, which have been adapted in order to make well-founded predictions about children's processing of commercial media content. The PCMC model predicts that children's advert processing depends on 1) the resources required by the persuasive message, and 2) the resources required by the context of media use. In this thesis, the amount of resources required by the persuasive message has been operationalized as saliency properties of online adverts, while the amount of resources required by the context has been operationalized as different types of free and task-oriented internet use. Based on these operationalizations, three general hypotheses were formulated in the introductory chapter of this thesis. By evaluating these hypotheses against the empirical studies undertaken, we can explain the contribution of the current thesis to media psychology.

4.2.1 Effects of advert saliency on attention

A central assumption within media psychological research is that physical and semantic properties (e.g. visual saliency and pictorial content) of mediated messages are partly responsible for causing cognitive and behavioral effects in media audiences. Some of these effects are more general, such as the effects of saliency on attention, and some effects are more individual, such as content corresponding to personal interests (**Valkenburg**, 2004). This assumption is also echoed in media psychological research on children and advertising (**Buijzen et al.**, 2010; **Van Reijmersdal et al.**, 2012). In this thesis we wanted to test this assumption in the context of online advertising and children's visual attention, and thus we hypothesized that higher levels of visual saliency in online advertising (e.g. animation) would cause more visual attention to adverts (H 1A) and lower task performance (H 1B) in participants. These hypotheses were operationalized such that children were exposed to salient online advertising while performing task-oriented interaction on commercial websites. During this interactive process we measured children's eye movements on the web pages.

As expected, the results of the studies underlying this thesis strongly suggests that visual saliency in online advertising indeed captures and increases children's visual attention to these media messages in a causal relationship. The effects of perceptual prominence in online advertising, such as animation, luminance, edge density and abrupt onset, show consistent positive effects on children's visual attention across all the studies undertaken in this dissertation project. The effects of content relevance in online advertising show similar or even stronger effects. This evidence strongly supports H 1A. The independent effect advert saliency on children's task performance was considerably lower or non-existent. In Study 2, we found no significant effects of advert saliency on children's task accuracy during advergame interaction. However, in Study 3, we found a small but significant negative effect of advert animation on children's online reading comprehension. Thus, there is mixed support for H 1B, and further analyses indicated that the effects of advert saliency on task performance interacts with other factors such as children's executive control (cf. conditional effects).

These results contributes to media psychology in providing ample evidence that perceptual prominence in online advertising directly impacts children's attentional resources in the visual domain. On a methodological level, the present thesis contributes to media psychological research in two important areas: 1) by suggesting how visual saliency in online adverts can be measured quantitatively in authentic web page material, and varied according to experimental conditions using HTML technology, and 2) by introducing eye movement measurements as an accurate method of observing children's visual attention online. Future research should further investigate the effects of content relevance in personalized online advertising on children's visual attention, since behavioral targeting technologies are based

on presenting adverts with high relevance to users. New online advertising formats such as social media and native advertising should be investigated in the same respect. Furthermore, the relationship between visual attention to online advertising and higher cognitive processes such as memory and attitudes also needs more attention.

4.2.2 Effects of individual gaze control

Apart from the message properties discussed in the previous section, media psychology also theorizes that individual characteristics of media users play a crucial role in determining their overall susceptibility or vulnerability to media effects. Thus, media psychological models of advertising effects on children predict that developmental level and age are key factors that influence how children will process persuasive messages in terms of allocation of cognitive resources (**Valkenburg and Peter**, 2013b). Some of these predictions have been confirmed by previous research, such that children's individual level of executive function were found to be positively associated with their understanding of persuasive intent in advertising (**Lapierre**, 2013). In order to extend this research to include children's attentional sensitivity to salient online advertising during task-oriented website interaction, the present thesis hypothesized that higher individual level of executive function in children would be associated with lower levels of advert attention (H 2A) and better task performance (H 2B). Children's executive function and inhibitory control were measured as their individual success rate in an anti-saccade task, and this construct was referred to as gaze control.

Individual level of gaze control was measured in children aged 9 and 12 years through an anti-saccade pre-test. Children in the older age group performed significantly better on this test. After this test, the children were instructed to perform either free interaction with commercial websites (Study 1) or task-oriented interaction (Study 2–4). Interestingly, across all studies, gaze control was found to be negatively associated with children's visual attention to online adverts, meaning that children with high levels of gaze control consistently interacted less with commercial web content (only a non-significant trend in Study 4). This finding strongly supports hypothesis H 2A. In studies that measured children's task performance, it was found that gaze control was positively correlated with trial accuracy in Study 2 (advergame), but no such independent effect was found in Study 3 (reading comprehension). Thus, the evidence regarding H 2B was mixed. Since gaze control was found to be negatively correlated with visual attention to online advertising in all studies, but only correlated positively with task performance in one study, it seems reasonable to suggest that gaze control is a better indicator of children's inhibitory control, than their general executive functioning.

These results contribute to media psychology in suggesting gaze control as a physiological measure of children's visual susceptibility to online advertising. This measure is based on the standardized anti-saccade task, which has been used as a reliable indicator of executive

function (**Eenshuistra et al.**, 2004). The studies conducted in this dissertation project show that the gaze control construct is sensitive to both individual differences among children within the same age group, as well as differences between age groups. Since the gaze control measure was more strongly associated with lower levels of advert attention than with higher task performance, we suggest that this construct may primarily measure children's inhibitory control in the visual domain, rather than general level of executive functioning. Providing an individual-level measure of children's visual susceptibility to salient online advertising is an important contribution to future research on children and advertising, and it would be relevant to compare the gaze control measure to methods measuring similar constructs, e.g. go-no-go tasks (inhibitory control), flanker tests (coping with interference), and digit span tasks (working memory) (**Johnson et al.**, 2014; **Lapierre**, 2013; **Simonds et al.**, 2007; **Bunge et al.**, 2002). Potentially, the gaze control measure could also be used to investigate advert distraction in children with ADHD (**Kaufmann et al.**, 2010).

4.2.3 Effects on advert distraction

Media psychological models of children's processing of commercial media content (PCMC) suggest that not only does message attributes and individual variables determine advertising effects in children, but also a third type of variable referred to as the context of media use is important to incorporate. Context of internet use is a broad concept, but has been exemplified with activites such as watching a program, using a website, or playing a game (**Buijzen et al.**, 2010). In order to test this assumption, we operationalized a hypothesis stating that task types that demanded more of children's attentional resources would cause lower advert distraction (H 3A). Media psychology models in general also theorizes that individual characteristics of the media user play a crucial role in determining the media effects or communication outcomes in a specific situation. The idea that children's advert attention varies with dispositional (e.g. temperament) and developmental (e.g. prefrontal control) susceptibility variables that are specific for each child is referred to as conditional media effects (**Valkenburg et al.**, 2016). In order to investigate this assumption, we hypothesized that higher levels of gaze control in children would moderate their susceptibility to salient online advertising (H 3B). Both these hypotheses were tested using task-oriented research designs, which allow us to define visual attention directed at task-irrelevant adverts and decreased task performance as potential advert distraction effects.

Advert distraction is challenging to measure, because unlike e.g. pupil position, cognitive states are more difficult to observe directly. In this thesis project, we used two eye movement measures to indirectly infer children's level of advert distraction while they were engaged in task-oriented interaction: 1) cognitive load while focusing on task-relevant information (measured as pupil size), and 2) visual attention on task-irrelevant adverts (measured as number of fixations) (Study 4). Furthermore, we introduced two task types in order to sys-

tematically vary the context of internet use (reading-for-comprehension and information search). In support of hypothesis H 3A, the evidence showed that context of internet use, defined as task type, had significant effects on both eye movement measures used to indicate advert distraction, such that task types that produced higher cognitive load in children were associated with less advert distraction. Another important measure of children's advert distraction is task performance. In order to investigate conditional effects of salient online advertising on children's task performance (reading comprehension), we analyzed the interaction between saliency level (animation) and individual level of gaze control (Study 3). In support of H 3B, the results showed that high levels of gaze control in children moderated negative effects of advert saliency on their task performance.

An important research contribution to media psychology is represented by the combination of methodological approaches utilized in order to infer the cognitive state of advertising distraction from eye movement data collected during the process of website interaction. A key component is the task-oriented web experiments developed within this project, that allows for the functional distinction between task-relevant web page objects and task-irrelevant online advertising. Not only did these methods enable us to successfully describe advert distraction on a physiological level, but it also allowed us to operationalize and test theoretical concepts developed within media psychology, such as the concept of varying contexts of media use (task-orientation, task type, etc.) and the concept of conditional effects (e.g. differential-susceptibility to advert saliency based on executive functions). These insights could be applied in other research areas and populations, e.g. adults distraction and information overload in digital work environment, or children's distraction by media multitasking (e.g. engagement with social media while pursuing school work). Although the current thesis did find evidence of a direct link between attentional advert distraction measures and task performance in one study (Study 3), this area also merits closer investigation.

4.3 Contributions to media and communication studies

Media and communication studies have a rich tradition of theory-driven research on the relationship between children and advertising. By applying theoretical models, this tradition seeks to understand how and why online advertising impacts children. This research has generated several fields of investigation which focus on different aspects on children and advertising, ranging from power relations between advertising agents and young audiences, to children's media literacy and advertising vulnerability. In some instances, the effects of commercial media on children have been thought to be so complex and multifaceted that theoretical approaches are more feasible than empirical investigations. However, as methods for experimental research and detailed physiological measurements have improved in recent years, it is becoming increasingly possible to investigate complex media interactions. The aim of the current thesis is to use detailed measurements of children's website inter-

action and visual attention in order to further three specific media and communication research questions on children and online advertising: 1) the possibility of studying media effects, 2) children's vulnerability to advertising, and 3) online advertising as an attention economy. By discussing these research questions in the context of the empirical studies undertaken, we can explain the contribution of the current thesis to the field media and communication studies.

4.3.1 New media effects research

In recent decades, media and communication studies has been characterized by divided opinions regarding the epistemological and ontological status of media effects. On the one hand, psychology and communication researchers coming from a realist standpoint have tended to take such media effects for granted. On the other hand, media scholars with a social constructivist outlook have questioned the possibility of measuring how the form and content of media messages produce generalizable effects on behaviors and mental states in audience members on two grounds: 1) the difficulty of controlling for the social context of media use (**Flyvbjerg**, 2001), and 2) the difficulty of presenting media stimuli under experimental control while performing ecologically valid measurements of causal media effects (**Gauntlett**, 2005). In order to approach the lack of consensus regarding media effects, the present thesis formulated a research question concerning how we can study causal media effects of online advertising on children from a media and communication perspective (RQ 1). Media effects were defined using the conceptual framework presented in **McQuail** (2010).

The results presented in this thesis show that the social constructivist arguments against the possibility of reliably measuring valid media effects can be mitigated to a large extent. Firstly, the problem of controlling for varying contexts of children's media use (**Flyvbjerg**, 2001) was approached by contrasting free or undirected internet interaction (Study 1) with task-oriented or directed interaction (Study 2–4). Furthermore, children performed the website interaction one by one. Based on these studies, the current thesis argues that variations in the social context of internet use can be significantly reduced by constraining website interaction sessions to one child at a time, and that variations in the context of media use can be reduced by introducing all participants to the same web-based tasks rather than using free interaction. Secondly, the problem of handling the huge natural variation in online advertising while measuring valid attentional responses in children (**Gauntlett**, 2005) was approached by contrasting authentic commercial website stimuli (Study 1) with web-based experiments in the form of mock-up websites featuring realistic online tasks (Study 2–4). Results from these studies showed that controlled web-experiments allow us to investigate causal effects of single advert attributes (e.g. animation) on children's visual

attention, and that unobtrusive remote eye-tracking measurements of children's website interaction and advert distraction provides a high degree of (ecological) validity.

These results contributes to media and communication studies by providing answers to a research question concerning the feasibility of investigating causal media effects of online advertising on children's visual attention (RQ 1). On a theoretical level, the present thesis shows that social constructivist objections against realist research approaches can to a large extent be mitigated. On a methodological level, the studies performed within this dissertation project provides detailed descriptions of how to combine realistic goal-directed media interaction with experimental control, and reliable and valid measurements of visual attention. With all these research methods in place, the current investigation of children and online advertisements could potentially be extended to other areas within media and communication studies, such as adults' interaction with a number of visual media, including social websites, printed newspapers, television viewing behaviors and more. However, while flexible, this set of methods also have several limitations. Most notably, short-term physiological media effects (intended/unintended) are selected instead of long-term effects.

4.3.2 Children as individual media users

Starting with television, media and communication studies have discussed children's vulnerability to advertising. From a television perspective, it was concluded that children up to around 8 years tended to be vulnerable to advertising because they had not developed the mental coping strategies necessary to critically evaluate persuasive intent in advertising. With the advent of online media in the early 2000s, the media and communication studies perspective on children as media users shifted gradually from being vulnerable towards being competent digital natives. However, as online advertising technologies evolved towards higher sophistication, and as studies showed that children start to use the internet for task-oriented purposes around ages 8–10 (**Findahl and Davidsson**, 2015), some media scholars voiced concern about children and online advertising risks (**Livingstone**, 2009). Against the background of these ambivalent views on children's potential vulnerability to online advertising, the present thesis formulated a research question concerning how we can develop our understanding of children's individual level of advertising susceptibility during interaction with online websites (RQ 2), especially during task-oriented interaction.

The results from the present research shows that children are vulnerable to online advertising distraction in the visual domain during task-oriented interaction with commercial websites. By measuring children's gaze control, the studies performed in this thesis shows that children's cognitive development varies on an individual level, and that younger children (9 yrs) have less developed executive function that older (12 yrs). More importantly, the results from this research shows that children's gaze control is a strong predictor of their individual susceptibility to visual saliency in online advertising in terms of eye movements

towards adverts (Study 1–3). This shows that all children does not have equal opportunities when it comes to their ability to cope with online advertising, and that lower levels of cognitive development predicts higher levels of visual interaction with, and attention to, commercial content. Furthermore, in one of the studies included in this thesis (Study 3), it was found that children with the lowest levels of gaze control were at the highest risk of experiencing a significant decrease in task performance (reading comprehension) when they were exposed to concurrent salient online adverts (animation).

The results regarding children's susceptibility to online advertising presented in this thesis contribute to media and communication studies such that they shift the focus away from advertising persuasion susceptibility towards visual susceptibility during goal-directed internet use (RQ 2). Although advertising persuasion remains an important form of commercial vulnerability in children, this thesis contributes to a more detailed investigation of the actual process of free and goal-directed interaction with commercial websites, and how children's cognitive development (level of gaze control) can render them individually susceptible to salient online advertising during this interactive process. In a societal perspective, this research could be applied in order to refine our understanding of children's media and information literacy on commercial websites on a more fine-grained scale. Potentially, eye movement measurements could be used in a classroom context in order to increase children's awareness of the effects of online advertising on the website interaction process.

4.3.3 Experiences of online distraction

As online media are becoming increasingly pervasive in people's everyday lives, concerns are being voiced that information overflow may give rise to cognitive load, stress and distraction (**Gazzaley and Rosen**, 2016). Such concerns have been directed towards digital work environments, where it has been observed that increased task-switching and stress on working memory can be a contributing factor of mental fatigue in adult populations (**Becker et al.**, 2013). Similar concerns have been raised about children as "digital natives", who attempts to handle the information overflow inherent in online media through adaptive strategies such as media multitasking (**?**). Since such multitasking strategies essentially consist in rapid task-switching at a substantial cognitive cost (**Gazzaley and Rosen**, 2016; **Baumgartner et al.**, 2014; **Ophir et al.**, 2009), such behaviors could potentially explain some part of the negative correlation between internet use and academic achievements found in many western societies (**OECD**, 2015). The risk of unintended experiences of distraction seems particularly relevant in the context of children's confrontation with the attention economy of online advertising, and therefore this thesis formulated a research question focusing on how we can understand children's attention management during goal-directed interaction with commercial websites (RQ 3).

In order to tackle this research question in a concrete way, we used eye-tracking equipment that provided detailed accounts of children's attentional processes while solving online tasks on commercial websites that simultaneously presented task-relevant information and task-irrelevant salient online advertising. The research studies conducted within this thesis project provide empirical evidence that children aged 9 find it difficult to manage their attentional resources in order to filter out advertising and focus on relevant content (Study 2–4). This is shown by the amount of eye movements these children made towards salient and relevant online adverts. Around 12 years of age, children seem to find this attention management significantly less effortful and show lower levels of advertising distraction (Study 2). The results indicate an unintended effect of the attention economy dominating online advertising that impacts children in the younger age groups that are beginning to use the internet for goal-directed purposes. Other studies in this thesis show that these unintended attentional effects may also negatively impact children's task performance (Study 3).

The present research contributes to media and communication studies by providing an empirical and physiological correlate to theoretical concepts such as children's media multitasking and attention management (RQ 3). Several studies undertaken within this project have successfully quantified children's online advert distraction as attentional measures which in turn allow us to show how advertising distraction increase in children when an animated advert is presented instead of a static one. These distraction measures are also useful in order to compare online advert distraction in child and adult populations, and between different contexts of internet use (task type). Taken together, these results could be used to regulate online advertising saliency on websites that combine conflicting communication models, such as editorial content and salient advertising (**McQuail**, 2010). Such restrictions of advertising saliency could be implemented on the browser level, such that high saliency adverts are filtered out while low saliency adverts are allowed. On a more societal and educational level, the results in this thesis could be used in order to help children and adults to make more informed decisions about their attention management and media multitasking capabilities. This might help reduce experiences of online distractions, both at home and in the working environment.

4.4 Societal implications and significance

The main contribution of this research project is that we have successfully combined methods and theories from media and communication research and developmental psychology in order to improve our understanding of how children are distracted by online advertising when they engage in task-oriented interaction with commercial websites. In effect, this research project have developed a media psychological framework for measuring how salient online advertising affects children's visual attention, and this framework allows us

to test predictions made by theoretical models such as the processing model of commercial media content (PCMC) (**Buijzen et al.**, 2010). Thus, the empirical evidence produced in the research studies presented in this dissertation supports the hypotheses that perceptual prominence and content relevance are advertising saliency dimensions that attract children's attentional resources, and diminishes attentional resources available for goal-directed website interaction. In task types involving high cognitive load, such as reading-for-comprehension, more attentional resources directed towards adverts (i.e. more advert distraction) were associated with lower task performance.

The present dissertation project also extends existing media psychological approaches in three crucial respects: 1) children's interaction with commercial websites was investigated in task-oriented research designs by developing experimental mock-up websites, 2) children's individual level of inhibitory control (gaze control) was measured and included as a predictor of advert distraction and task performance, 3) children's task processing and advert distraction was measured by means of eye-tracking, which provides detailed, generalizable, and objective measures as compared to self-reported measures. In all studies included in the present dissertation, children's individual level of gaze control was shown to be negatively associated with advert distraction measures. In effect, this developmental measure seems to provide an indicator of children's individual level of online advertising distractibility. Furthermore, existing media psychological theories such as the PCMC model was extended by using cognitive load theory in order to explain how different task types are associated with different levels of advert attention (**Johnson et al.**, 2014; **Buijzen et al.**, 2010; **Lavie**, 2005). Task types involving high cognitive load were associated with less advert distraction.

From a societal perspective, the outcomes of this research may be utilized in several ways. First of all, the research conducted within this dissertation project converge in showing that commercial websites often contain highly salient online advertising, and that children aged around 8–10 years are not always endowed with sufficient levels of inhibitory control and cognitive flexibility in order to avoid advert distractions and maintain online task performance. Thus, the current research indicates that in educational or pedagogical situations that involve task-oriented website interaction, it might be well-advised to avoid commercial websites featuring highly salient online advertising, in order to provide children with equal learning opportunities. Second, from a parental perspective, the same argument could be a motivation for considering adblock software on children's web browsers, and to enable do-not-track features in order to minimize advertising based on behavioral tracking of children. However, behavioral tracking could also be used for the benefit of children, by providing the advertising industry with incentives for serving personalized non-salient adverts when predictive algorithms indicate that a specific user may be a child under 10 years of age. Also, the current research could be used as an empirical knowledge base when designing pedagogical material within the field of media and information literacy (MIL).

4.5 Suggestions for future research

Having answered some of the questions that initially motivated this dissertation project, it may also be interesting to consider some of the new questions that these answers give rise to. The advert distraction study design used in the present project has been applied to two strategically selected age groups, and the results suggests that the younger of these age groups (9-year-olds) actually are distracted by online advertising. This raises the question about internet use and distractibility in younger children, e.g. 6-year-olds. Based on the findings of the current project, it would be feasible to investigate this age group using similar research methods. We could probably expect to find stronger effects of advert distraction and performance losses in 6-year-olds due less developed executive function and inhibitory control. The relationship uncovered between task types, advert prominence, and cognitive load should also be further investigated.

Advertising content analysis

A challenge in the current project has been to obtain authentic online advertising directed to children. Because of this obstacle, the present studies have not really been able to determine what kind of advertising content that children encounter online. However, in order to make correct inferences about children's online advertising exposure we would need to overcome the problem with collecting authentic advertising content directed to children, and enable large scale content analyses of this material. There is a possibility that the advertising dimensions of perceptual prominence and content relevance are not the best or most valid dimensions. This is an empirical question.

Future research should address the challenge of accurately sampling online advertising as it is presented to children. This problem is partly inherent in the dynamic, personalized advertising environment that the internet is designed to be. This means that genuine advertising contents and formats that children encounter "in the wild" are underrepresented in this research. As a consequence, the current research studies have chosen to focus only on display advertising (i.e. banner adverts). However, according to recent advertising research, display advertising is the most common advertising format online, and is predicted to remain so in the foreseeable future.

Media and information literacy

A research area that is closely connected to the current project involves children's media and information literacy (MIL). Although, some efforts were made to operationalize this concept, it remains under-researched. However, it seems intuitive that MIL could be an

important source of individual differences among young internet users, and thus it could have profound explanatory power when it comes to defining which factors that determine children's visual attention to adverts, their decoding of commercial intent, and their advert distraction. One method that would be suited in order to investigate children's media and information literacy could be think-aloud protocols, potentially incorporating retrospective interviews based on children's visual interaction with websites.

Theory of mind and persuasion knowledge

Children's first abilities for theory of mind starts at around 4 years of age and continue to develop into more advanced forms throughout childhood (**Moses and Baldwin**, 2005). Recent research on children's susceptibility and understanding of advertising has suggested that theory of mind constitutes an executive function that is closely related to children's processing of persuasive messages (**Lapierre**, 2013). Future research on children and online advertising could investigate potential connections between children's persuasion knowledge and physiological measurements of how children use their visual attention to decode online advertising messages.

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Original papers

Paper 1

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Children's attention to online adverts is related to low-level saliency factors and individual level of gaze control

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Twenty-six children in 3rd grade were observed while surfing freely on their favourite websites. Eye movement data were recorded, as well as synchronized screen recordings. Each online advert was analyzed in order to quantify low-level saliency features, such as motion, luminance and edge density. The eye movement data were used to register if the children had attended to the online adverts. A mixed-effects multiple regression analysis was performed in order to test the relationship between visual attention on adverts and advert saliency features. The regression model also included individual level of gaze control and level of internet use as predictors. The results show that all measures of visual saliency had effects on children's visual attention, but these effects were modulated by children's individual level of gaze control.

Keywords: children, online advertising, visual attention, visual saliency, internet use

Introduction

Current media research indicates that Swedish 9-year-old children spend about one hour online every day (Medierådet, 2013; Nordicom, 2013). Although this average statistic is likely to be representative of this particular population, research also shows that there is quite a lot of variability around this central tendency. Thus, there is a fairly large group of heavy internet users among Swedish 9-year-olds, but also large groups of children that have very little contact with the internet (Medierådet, 2013; Holmberg, Sandberg, & Holmqvist, 2014). In this research, heavy internet usage is defined as more than 3 hours of daily internet use. To some extent these differences in internet use can be explained by demographic factors such as gender and social class (e.g. boys are usually over-represented among heavy internet users) (Medierådet, 2013). Looking at the media development over the last couple of years, there is a clear trend that daily internet use among children is increasing in younger age groups (Medierådet, 2013; Nordicom, 2013). Typical online activities among 9-year-olds are playing games and watching video clips (Carlsson, 2012). As children grow older, online gaming activities are gradually replaced by activities on social networking websites (Carlsson, 2012). Similar internet usage patterns are found in all Nordic countries.

In parallel to this general increase in children's online activity, the internet is also growing rapidly as a commercial advertising channel. In Sweden, between 2005 and 2010, investments in internet advertising increased more than any other type of advertising, both in absolute and relative measures (Sundin, 2013). The popularity of the internet as an advertising channel can be explained to some extent by the new and unique affordances that this medium provides in terms of advertising formats and strategies. An important new advertising technology on the internet has been labeled "behavioral targeting", and allows advertisers to track users' online behavior in order to infer their individual characteristics and interests (Singer & Singer, 2011). Based on such user profiles, advertisers are able to serve up more relevant and better targeted adverts to website users (Goldfarb & Tucker, 2011). On the other hand, the digital medium also allows for manipulations of basic visual features of online adverts in order to attract users' visual attention. Flashing banners, animations and pop-up ads are examples of how salient visual features such as motion and abrupt onset are incorporated into internet adverts to increase attentional capture (Ludwig, Ranson, & Gilchrist, 2008; Parkhurst & Niebur, 2004).

Since children's internet use is rising at the same time as this media environment is becoming more commercialized, we think it is important to measure the level of visual saliency in adverts found on children's websites, and investigate how these visual features affect children's exposure to adverts during ordinary internet use. At 9 years of age, children are undergoing rapid development in terms of voluntary attention, executive control, and decision-making, which poten-

tially makes them more sensitive to salient adverts than adults (Bucci & Seassau, 2012; Davidson, Amso, Anderson, & Diamond, 2006). Interview studies with children concerning their experiences of online advertising suggest that children tend to find adverts irritating and intrusive, and they express a feeling of being "followed" by adverts while surfing across their favourite websites (Martinez, Sandberg, & Jarlbro, 2013). While internet usage statistics can provide a general outline of children's online activities, interviews studies can capture childrens experiences of online adverts. However, none of these methods are suited to give detailed information about children's actual visual exposure to online advertising as it occurs in real-time. In this exploratory study, we use eye-tracking to measure childrens visual attention, and we formulate several hypotheses concerning how individual factors and advert properties impact children's exposure to online adverts.

Advert saliency and visual attention

Visual saliency refers to the fact that certain visual features can make objects "pop out" from the surround and impinge on viewers' visual attention. Many such saliency features (e.g. motion, contrast, color, and luminance) can be extracted from a visual scene by using computer algorithms to produce so-called "saliency maps" (Itti & Koch, 2000). Eye-tracking studies have shown that such saliency maps to some extent can predict where viewers will fixate (Foulsham & Underwood, 2008). Although visual features in internet adverts can be analyzed in order to quantify their visual saliency, the media research in this area is scarce. Furthermore, there is little research concerning child audiences' actual visual exposure to internet adverts. It is possible to theorize that children's visual exposure to online adverts is low, based on the assumption that children engage in task-oriented behavior while surfing on the internet, which enables them to ignore visual stimuli from task-irrelevant adverts (Malcolm & Henderson, 2010). Another possibility is that children actually do look at online adverts, but only when the advert content is relevant to their personal interests, and not depending on basic visual features. Currently, there is a fairly strong consensus that, while low-level visual features such as abrupt onset can account for some portion of people's eye movement behavior, relevant content is more powerful in explaining visual attention allocation (Tatler, Hayhoe, Land, & Ballard, 2011; Foulsham & Underwood, 2008). In order to further this debate, we measure visual saliency in internet adverts and hypothesize how these visual features affect children's visual attention (**H1**).

- **H1:** Higher levels of saliency will be associated with more visual attention to online ads.

Children's gaze control

When visual attention is driven by salient features, it is referred to as exogeneous or stimulus-driven attention. Several studies have shown that the capacity to inhibit stimulus-driven, reflexive eye movements undergoes significant development throughout childhood, which is linked to ongoing development of the frontal lobe (Klein & Foerster, 2001; Eenshuistra, Ridderinkhof, & Molen, 2004). This research on stimulus-driven attention is relevant when investigating children's exposure to online advertising for two reasons: 1) younger children as a group could be more sensitive to visual saliency in online ads than adolescents and adults, and 2) younger children's individual level of gaze control could vary substantially due to rapid physiological and cognitive development, thereby predisposing some children for advertising exposure. In this study we operationalized the concept of gaze control by using an anti-saccade task to determine children's individual level of oculomotor control. This paradigm directly measures participants' voluntary control of their eye movements, and has been shown to correlate with cognitive functions such as executive control, working memory capacity and visual distractibility (Kramer, Gonzalez de Sather, & Cassavaugh, 2005; Munoz & Everling, 2004; Hutton & Ettinger, 2006; Zanelli et al., 2005). To our knowledge, there have been no attempts to measure children's visual distractibility in relation to their advertising exposure. In the present study, we measure the gaze control of 9-year-old children, and hypothesize how their individual ability for gaze control affects their advertising exposure (**H2**).

- **H2:** Lower levels of gaze control will be associated with more visual attention to online ads.

Internet use and advertising exposure

Demographic factors can predict some aspects of children's internet use. Survey data from current media research in Sweden show that children in the tween age group (9-12 years) spend about 1-2 hours online each day. Boys and younger children are more likely to use the internet for playing online games, while girls and older children are more likely to spend their online time on social networking websites (Carlsson, 2012). Boys are also more likely to belong to the category of heavy internet users, that have 2-3 times higher internet usage compared to their peer average (Carlsson, 2012). However, these media usage surveys do not reveal if there is any relationship between childrens internet usage patterns and their online advertising exposure. While it is likely that the more time children spend online, the more they become subject to advertising messages, it is also necessary to take into account the type of web pages that different groups of children prefer to visit. E.g. websites containing online games

could display more advert content than social networking sites. These arguments suggest that 9-year-old boys could have a higher potential for advertising exposure than girls in the same age, which we hypothesize in this study (**H3**).

Previous research have also investigated adolescents' online gaze behavior, and found large individual differences between potential exposure (the number of adverts on web pages) and actual exposure (visual attention to adverts) (Gidlöf, Holmberg, & Sandberg, 2012; Sandberg, Gidlöf, & Holmberg, 2011). A possible explanation for these observed differences is that some individuals have more experience of using the internet for task-oriented purposes, and therefore have developed skills in avoiding online advertising. We know from other domains of research that gaze behavior differ significantly between experts and novices (Jarodzka, Scheiter, Gerjets, & van Gog, 2010). Using weekly internet usage time as an indicator of internet literacy, we hypothesize that this measure impacts childrens visual attention to online ads (**H4**).

- **H3:** Male gender in children will be associated with more visual attention to online ads.
- **H4:** Less internet use will be associated with more visual attention to online ads.

In order to test the aforementioned hypotheses, we designed a quasi-experiment in which 9-year-old children were allowed to surf freely on their favourite websites. During these free web surfing session we recorded the children's eye movements as an indicator of their visual attention. We also recorded the dynamic web page stimuli that the children interacted with as real-time screen recordings. These screen recordings allowed us to extract the level of visual saliency in authentic online adverts and measure the effects of several saliency features on children's visual attention. In order to factor in the children's individual level of gaze control, an anti-saccade task was performed on all participants in the study.

Methods

Given the young age of the participants in this study, we assumed that undertaking the study in a familiar school environment would elicit the most natural web surfing behavior in the children. In addition, the eye-tracking apparatus selected for this study was the least invasive. Taken together, these features increase the ecological validity of the current study design, compared to performing the study in a more controlled laboratory environment.

Participants and apparatus

An elementary school in the south of Sweden was selected for the study. The main selection criterion was that the school should be representative of the population in terms of demographics. 40 children in two Swedish 3rd grade classes were given forms for parental consent. 26 children were given parental consent and opted to partake in the study. Before partaking in the study, all children were given an internet usage questionnaire. Ages ranged from 9 years (n=23) to 10 years (n=3). The children had mixed ethnic backgrounds, but were all fluent in spoken Swedish. The gender distribution was fairly equal between girls (n=14) and boys (n=12). All children had normal or corrected-to-normal vision. One participant had to be excluded due to technical problems during the web browsing session.

The recording equipment consisted of a SMI RED 250 laptop system that was used for web surfing and eye movement recordings respectively (a single-computer setup). The laptop (Intel Core i7 2.67GHz CPU, 2.98 GB RAM) was connected to the internet through a wireless 3G USB modem with a bandwidth of approximately 1Mb/s (Huawei Mobile Broadband). The web page stimuli were presented on a 1680×1050 LCD monitor with a SMI remote eye-tracking device attached to the lower side. The children interacted with the web pages through an optic mouse and a USB keyboard, both of which were connected to the recording / stimulus presentation laptop. Audio playback was handled with desktop speakers connected with 15mm TRS plug. Eye-tracking data were recorded at 250Hz with SMI iViewX 2.7 software during all tasks, and concurrent screen recordings from the stimulus monitor were captured at 10Hz. All calibrations, validations, stimulus presentations, and screen recordings were handled using SMI ExperimentCenter 3.1 software.

Study design and materials

Before the internet surfing session, an anti-saccade test was presented on the stimulus monitor in order to test each participants' individual level of gaze control. Each trial in the anti-saccade test consisted of two stimulus events. First, a fixation cross was presented in the center of the screen with a duration of 1500-2000 ms. Second, the fixation cross was replaced by a peripheral target, presented ca 10 deg off-center on the screen. As the target appeared, participants were instructed to saccade in the opposite direction. Targets were randomly presented horizontally (left or right of the fixation cross) or vertically (top or bottom), with a duration of 1000 ms. After target offset, a blank screen was presented with a duration of 500 ms. The anti-saccade test consisted of 32 such trials. The stimulus parameters of the anti-saccade test were chosen in accordance with recently suggested standards for this paradigm (Antoniades et al., 2013). To reduce eye fatigue, all stimulus slides in the anti-saccade test were constructed with black background and white fixation

cross and targets.

After the anti-saccade pre-test, the children continued with free web surfing sessions. These sessions were implemented as follows: 1) A Microsoft Internet Explorer 8 window launched in full screen mode, and loaded a local HTML file containing a list of links to 47 websites; 2) The participants could select any link they preferred from the list and browse freely on the corresponding target website; 3) The participants could return to the initial link list at any time by hitting the browser's "home button", and select another website to browse. In addition, participants could search or enter any URL in the browser window, in case they wanted to browse websites not present in the link list. The link list was based on results from the internet usage survey, in which the children were encouraged to list all the websites they typically visited when going online. We assumed that this approach would facilitate natural web surfing while minimizing browser interaction difficulties (i.e. typing in URLs on the keyboard). The free surfing sessions were limited to 7 minutes. This time period was estimated to elicit a sufficient sample of advert exposures to gauge the effect of the selected saliency features on visual attention.

Procedure

Before each data recording, a general calibration protocol was followed, in order to calibrate the eye-tracking system. An animated 2-point calibration procedure was displayed on the stimulus monitor, in which the participants were instructed to gaze directly at each calibration point until it changed position. Directly after the calibration, a 4-point validation was recorded to measure the deviation between gaze positions and validation targets. Calibrations were repeated until the deviation was below 1 deg of visual angle (corresponding to ca 10 mm on the stimulus screen). The accuracy level and calibration protocol were designed to minimize the children's cognitive load before each data recording.

When the participant was sitting comfortably in front of the stimulus monitor, the calibration protocol described in the previous section was carried out, and then the anti-saccade test began. Verbal instructions were given to the children to think of the anti-saccade test as a game, in which the objective was to first keep the gaze directly at the fixation cross, and then avoid looking at the target dot presented peripherally, and instead look in the opposite direction. When we had ensured that the participants had understood the task, 4 training trials were initiated. After that, 32 actual trials were presented in 2 blocks of 16 trials each. Between the blocks there was a short intermission in order to debrief the participants.

After the anti-saccade test was completed, the participants proceeded directly to the free web surfing task. A 2-point re-calibration was made according to the general calibration protocol. Before the web surfing session started, the participants were instructed that a list of links to websites would appear in an ordinary browser window, and that the only task was to explore the list and navigate to any site they preferred to visit. The participants were also informed that the surfing session would be terminated automatically after a couple of minutes. The exact number of minutes was not mentioned in order not to confuse or stress the partcipants.

Data analysis

The overall quality of the eye-tracking data was calculated as the average deviation between the calibrated point of regard (POR) and 4 validation points. The average horizontal and vertical deviation was 0.75 deg and 0.92 deg respectively. The amount of missing samples (including blinks) in the anti-saccade data was 12.6%. These quality measures were only calculated for the anti-saccade dataset, but they should generalize to the surfing dataset as well, since the exact same calibration procedure was applied in both cases. No participants had to be excluded due to poor data quality.

Eye movement data from the anti-saccade test were analyzed by using the Engbert and Kliegel algorithm in order to detect the first saccade in each trial (Engbert & Kliegl, 2003). A minimum saccade duration of 32 ms was provided as a parameter for the detection algorithm. The first saccades were then analyzed for latency, peak velocity and direction relative to target position using a second algorithm (Ahlström et al., 2013). Saccade latency was calculated using a minimum latency parameter of 0.08 ms, peak velocity was calculated using a maximum saccade velocity parameter of 1000 deg/s. Anti-saccades were categorized binomially as correct if they were terminated within a 45 deg angle in the opposite direction of the target location. Only the total proportion of correct anti-saccades for each participant was used for further analysis, as this construct was considered to be the most valid measure of gaze control.

Saliency analysis of the online adverts was achieved by using the screen-recordings obtained from the children's free surfing sessions. Each advert in this video data was defined in terms of its spatial and temporal location, and by using the OpenCV 2.3.1 software (Bradski, 2000), the regions corresponding to adverts were processed to extract three basic saliency measures. The saliency features extracted in this study was the amount of motion, luminance, and edges (Parkhurst & Niebur, 2004). Motion was quantified by measuring the absolute difference in pixels between pairs of successive frames. Speed of motion was not considered in this study. Luminance was calculated by thresholding each frame and measuring the remaining luminance pixels. Edges were measured in each frame by using the OpenCV Canny function, returning

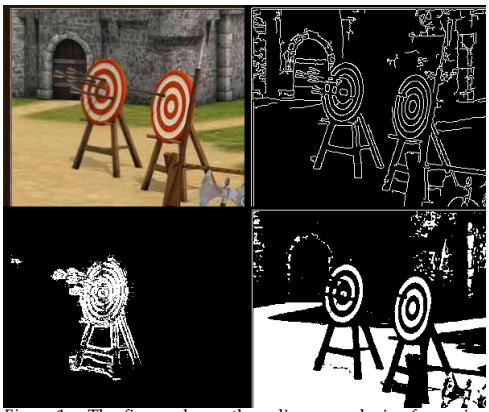

Figure 1. The figure shows the saliency analysis of one single frame from an animated advert: original advert (top-left), edge pixels (top-right), motion pixels (bottom-left), and luminance pixels (bottom-right). The number of white pixels in each sub-image constitutes the respective values for the saliency measures on this frame.

the number of edge pixels. These measures were also calculated for the entire frame in which the ad appeared, in order to calculate the relative saliency values for each advert (**Figure 1**).

Participants' eye movements during the free web surfing session were analyzed using the same screen recording videos that was used for the advert saliency analysis. These videos contained a circle indicating the subjects' gaze position that had been superimposed on the web page stimuli. By using the OpenCV MatchTemplate function, this circle was used to extract the pixel coordinates of the gaze point on the stimulus monitor. These pixel coordinates were then used to determine if the gaze point was within the rectangle of an advert on each video frame or sample. This sample-based variable was then aggregated to the advert level, which allowed for the construction of a binomial dependent variable that indicated if an advert had been looked at or not.

The video-based analysis employed in this study prohibited utilization of other typical gaze measures, such as dwell time and fixation durations on adverts. However, the reason for using the eye movement data as recorded in the screen recordings, was that these videos contained a time-locked representation of the participants' gaze position relative to dynamic visual events in the web page stimuli. In addition, we reasoned that a dependent measure that registered *if* an advert was looked at, rather than *how much* adverts were attended, would be more sensitive to the low-level saliency features investigated in this study.

Results

Children's internet usage

The internet usage survey generated 26 responses. The results from the survey show that most of the children in this study use their own computer (50%) or a parent's computer (69%) when accessing the internet at home. None of the children stated that they did not use the internet at all during an average week. The most common activity when spending time online was playing online games (96%), closely followed by watching video clips (88%) and listening to music (81%). On average, the children spent ca 60 minutes on web browsing per day. This is very close to the current national average, which indicates that the sample in this study is representative of the larger population (Council, 2010). There are also some interesting differences in average internet usage time depending on gender, with boys spending more than double daily time on the internet compared to girls (92 vs 36 minutes). However, these results on internet usage times include two male outlier cases that had great impact on the averages. A two-tailed heteroscedastic t-test revealed no significant difference in internet usage time between genders ($p=0.10$).

Children's gaze control

The proportion of valid anti-saccade trials that was kept for analysis was fairly high (ca 82%). However, the proportion of correct responses was low, indicating that the children had difficulties inhibiting saccades towards the distractor, and saccading in the opposite direction at target onset. The proportion of correct saccades was 21%, which is consistent with other research findings on saccadic eye movements in children (Bucci & Seassau, 2012; Fukushima, Hatta, & Fukushima, 2000). In the correct anti-saccade trials, saccade latencies were 474 ms on average, and 377 ms in incorrect trials. There were no differences in saccade latency depending on gender.

The overall results on anti-saccade accuracy and anti-saccade latency were expected, but a more interesting result of the anti-saccade test appeared when we looked at correct responses by gender. These results revealed that, in the current sample, boys seem to have a significantly higher success rate than girls. The average proportion of correct responses in girls was 0.16, and 0.27 in boys (see **Figure 2**). This difference was significant ($p \leq 0.05$). This result is somewhat surprising since girls are generally assumed to have an earlier cognitive development at this age, which would supposedly facilitate correct responses in the anti-saccade test compared to boys (Patterson, 2008). Because of this difference, we decided to add an interaction between

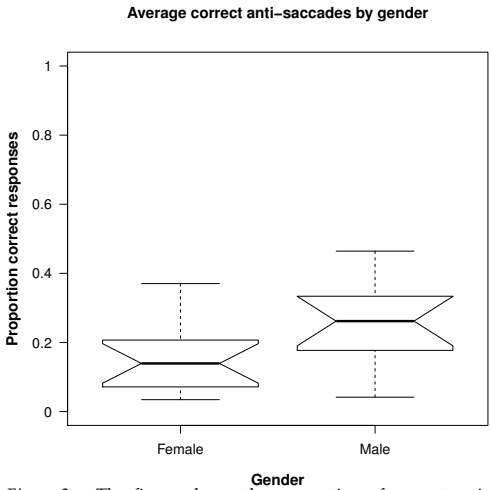

Figure 2. The figure shows the proportion of correct anti-saccades by gender.

gender and oculomotor control to the regression model (see further discussion below).

Saliency features in online adverts

The results reported in this section contain some descriptive statistics of levels of visual saliency found in online adverts. These saliency levels were computed from the web page screen recordings, and are shown in **Table 1** below. The total number of unique ads found in the screen recordings were 396, which means that each child was "potentially exposed" to about 15 ads on average during the course of the 7 minute surfing sessions (Gidlöf et al., 2012). The average presentation time of adverts was 20 seconds, and the average size of an advert was around 350x350 pixels (ca 7% of the screen size).

Visual attention to online adverts

We hypothesized that children's visual attention to internet adverts could be described as a function of saliency variables (presentation time, motion, luminance, edges, and size of adverts), combined with individual factors (gender, oculomotor control, and internet use). Since we found significant differences between boys and girls on the anti-saccade test, we also thought that including an interaction between gender and oculomotor control would contribute to the explanatory power of the model. To test this hypothesis, a mixed-effects multiple regression analysis was performed, in which participants were treated as a random factor. Tests for multicollinearity indicated a low level

Table 1
Descriptive statistics of advert saliency measures.

Saliency measure	Mean	SD
Duration (sec)[1]	20.47	45.45
Rel. Size[2]	0.072	0.056
Rel. Motion[3]	0.180	0.220
Rel. Edges[3]	0.085	0.052
Rel. Luminance[3]	0.068	0.065

1. Durations were added when adverts were visible on the web page. Time when adverts were completely invisible due to page scrolling is not included.
2. Size values were calculated for each video frame and averaged over each unique advert. Average size presented as a proportion relative to the display size at a resolution of 1680 $\times$ 1050 pixels.
3. Saliency values were calculated for each video frame as a proportion of pixels relative to the saliency value of the entire web page. Relative saliency values were then averaged over each unique advert.

interdependence between predictors (VIF=1.63 for gender, 1.16 for oculomotor control, 1.47 for internet usage time, 1.29 for ad presentation time, 2.23 for ad edges, 2.64 for ad luminance, 1.91 for ad motion, and 2.69 for ad size). Also, multiple tests for outlier cases were performed. Results of the regression analysis provided partial confirmation for the research hypotheses. The order, coefficients and p-values for the predictors are given in **Table 2** below.

Table 2
Effects of advert saliency and individual factors on visual attention.

	Coeff.	Std. Error	z value	P= r(>|z|)
(Intercept)	4.04	1.02	3.95	0.0001
Adv. Dur.	0.86	0.13	6.50	0.0000
Adv. Motion	1.01	0.13	7.46	0.0000
Adv. Edges	0.68	0.29	2.34	0.0191
Adv. Lum.	-0.61	0.23	-2.72	0.0066
Adv. Size	0.00	0.00	0.98	0.3249
Sub. Int.Use	-0.07	0.17	-0.43	0.6695
Sub. Gen. (m)	-1.18	0.77	-1.53	0.1256
Sub. Gaze	-4.47	1.63	-2.74	0.0061
Gen. $\times$ Gaze	3.48	2.73	1.27	0.2035

Predictors of children's visual attention to internet adverts. Advert saliency measures (Adv.) were log-transformed before entered into the regression model. Measures of individual differences (Sub.) include internet use (Int.Use), gender (Gen.), and gaze control (Gaze). Interaction between gender and gaze control is given last.

The deviance of the described regression model was 371.28 (df=386), which proved to be considerably lower than the deviance of the corresponding unconditional null model in which all predictors were discarded (deviance=542.12, df=395). A chi-square test showed that the difference in deviance between these models was significant at the highest level ($p \leq 0.001$), providing evidence that the selected group of predictors contributed significantly to explaining the observed variance in the dependent variable. Excluding the non-significant variables, thus providing a reduced model, did not significantly improve the deviance, and therefore a reduced model was rejected. Based on this evidence, we conclude that the best fitting model for predicting children's visual attention to internet adverts is a linear combination of the variable set given in **Table 2** above.

Discussion

In relation to the hypotheses presented at the outset of this study, the main findings are as follows: (**H1**) low-level visual saliency features of internet adverts have a strong influence in determining children's visual attention; (**H2**) children's individual level of oculomotor control seems to modulate the effect of visual saliency features in internet ads, and thus oculomotor control impacts on children's visual exposure to advertising; (**H3**) gender does not seem to directly influence children's attention to internet adverts; (**H4**) children's individual level of weekly internet usage time does not influence their attention to adverts. Before discussing these findings separately below, it is also useful to recapitulate the measure of visual attention utilized in this study. Visual attention has been operationalized as binary variable expressing if children looked at an internet ad (as measured by eye-tracking equipment). Thus, this dependent measure only takes into account *if* an advert was looked at, and not *how much* adverts were attended. The reason behind this operationalization was our assumption that this dependent measure is more sensitive to the low-level saliency features investigated in this study.

Advert saliency and visual attention

Several of the measures of visual saliency employed in this study proved to have a significant effect on children's visual attention to internet adverts. As predictors, these saliency features typically have positive relations to the participants' visual attention to ads, meaning that the higher saliency value, the more visual attention. The only temporal measure included in the analysis was advert presentation time, which had a high positive coefficient. Arguably, this effect is not due to visual saliency so much as to the increased probability of a participant looking at an ad the longer it is presented. In the spatial domain, motion turned out to be the saliency feature with the strongest impact on visual attention. Motion was defined as the sum of different pixels between two successive frame pairs, averaged for each advertisement. This definition captures several types of motion, e.g. abrupt onset, flicker, and object motion (Franconeri & Simons, 2003). It does not, however, take into account the speed of motion, which might also be and important aspect of motion saliency.

Similar to motion, edge information also had a positive coefficient in the regression analysis, meaning that more edges in an online advert (i.e. more spatial clutter) increased the probability of children fixating this advert. The effect of edge information was considerably weaker than that of motion. Advert luminance had a significantly negative regression line, implying that as relative luminance values decreased, visual attention increased. A reasonable interpretation of this negative association would be that when ads consisted of dark patches on a light web page (low relative luminance), this drew more attention than when adverts consisted of light patches on a dark web page (high relative luminance). As a bottom-up saliency feature, relative luminance in internet adverts ranked in between motion (high impact) and edges (low impact).

Interestingly, advert size was the only saliency feature in the analysis that did not have a detectable effect on the participants' vision. This runs counter to many previous studies, which often report a positive association between more visual attention and larger ads (Gidlöf et al., 2012). The exact reason for this deviating result is difficult to state, but in the case of online advertising, it is possible that some previous studies may have confounded the advert size factor with for example motion and/or luminance, by not using real-time screen recordings of participants' web interaction, but rather use static screen dumps of each web page. If this is the case, it points to the benefits of using the methodology utilized in this study when analyzing web stimuli. Looking at all the saliency measures together, they appear to represent a "hierarchy of saliency effects", with motion at the strong end of the spectrum and edge information at the weak end.

A different type of advert saliency which was not addressed in the current study concerns audio in online advertising. On many video websites, e.g. youtube.com (which proved to be very popular among participants in this study), virtually all advertising is presented as videos with integrated audio. This audio signal ranges from speech, which could conceivably guide allocation of visual attention *within* the advertising video, to music, which could engage the viewer emotionally. Although the effects of audio on visual attention have been studied under the audio-visual integration paradigm (Koelewijn, Bronkhorst, & Theeuwes, 2010), it is unlikely that audio as a separate factor would contribute to explaining which adverts were visually attended in the current study.

Gaze control and advert attention

Among the individual factors investigated in this study, oculomotor control emerged as one measure that actually impacts children's visual attention to adverts. The regression analysis suggested a strong negative coefficient for this predictor, meaning that better success rates in the anti-saccade test were associated with significantly fewer gazes to internet adverts. Or, the more voluntary control children had to inhibit their reflexive eye movements, the less they tended to look at advertising. Interestingly, the very fact that oculomotor control had an effect on these children's visual behavior suggests that the online adverts they encountered actually contained a considerable amount of low-level visual saliency. If the online adverts on these websites had not impinged on the children's visual system, high or low gaze control would probably not have been associated with the amount of visual attention to the adverts.

The results on the anti-saccade test showed that the average success rate was around 21% in the sample as a whole, which is considerably lower than what has been observed in adult populations. Success rates around 80% have been reported for adults in recent large-scale studies (Hutton & Ettinger, 2006). Conversely, saccade latencies in the child sample were higher than what would typically be expected in an adult population. On the other hand, our results on gaze control were very similar to other research findings on saccadic eye movements in children (Bucci & Seassau, 2012; Fukushima et al., 2000). However, there are studies reporting a somewhat higher success rate for 9–10 year old children in the anti-saccade paradigm (Kramer et al., 2005; Munoz & Everling, 2004). These differences could simply reflect that the anti-saccade stimuli material have been constructed differently across studies. One question these previous studies do not address is whether there are differences in success rate between boys and girls. In the current study, the difference in oculomotor control depending on gender turned out to be statistically significant, which calls for further investigation. One possibility is that the boys' higher success rate is linked to their engagement in particular types of extracurricular activities that require high levels of visual focus, e.g. video gaming and/or sports. The interaction between gender and oculomotor control did not contribute significantly to the regression model.

Individual factors and advert attention

Gender did not prove to have a reliable effect on visual attention to internet adverts in this study. This result probably reflects a general lack of evidence for strong gender effects in the larger field of vision/cognitive research. A large meta-study concluded that supposedly "well-established" gender differences were actually rather weak across a number of cognitive domains and processes (Hyde, 1981). Also, large survey studies on children's internet usage patterns such as (NORDICOM-Sweden, 2011), indicate that boys tend to visit online gaming sites whereas girls are more likely to engage in social media sites. This pattern was not replicated in the current sample, in which both boys and girls listed online gaming sites as their most preferred internet content. This might explain the similarities in advertising exposure between genders. Furthermore, gender differences in attention to internet adverts might not be that pronounced within the particular age group investigated in this study.

Perhaps more surprisingly, weekly internet usage time also did not contribute to predicting children's visual attention to internet adverts. We reasoned that the amount of time a child spends on using internet daily/weekly would roughly approximate the concept of internet "expertise" (or internet literacy). Such expertise is known to have a powerful altering effect on visual behavior in many professional areas, effectively distinguishing experts and novices (Jarodzka et al., 2010). Based on this research, we expected that children who spent more time on the internet would exhibit a different visual behavior towards internet ads as compared to their peers, e.g. avoiding more ads. The reason internet usage time did not contribute as a predictor of advertising exposure in this study might have to do with the free, unconstrained nature of the web browsing task. Since expertise is generally directed towards solving a specific task, the effect of internet usage time could have been more pronounced if we had given the children e.g. an information search task, in which visual attention to internet adverts would conflict with effectively solving the specified task.

Conclusions

The results of this study provide a chain of evidence and explanations as to why some children report that they experience internet advertising as disturbing and sometimes even coercing in its calls for visual attention (Martinez, Sandberg, & Jarlbro, 2012). An initial anti-saccade test showed that children in 3rd grade (aged 9–10 years) generally have difficulties to inhibit reflexive eye movements towards abrupt onset of peripheral distractors. Saliency analyses of the web pages that children typically visit, revealed that the adverts children are exposed to during free internet surfing contain substantial amounts of motion relative to the surrounding web page. These results were then fed into a multiple regression analysis that showed clear evidence that motion and luminance in internet adverts indeed are powerful predictors of attracting children's visual attention to ads. But perhaps more importantly, the regression analysis showed that children's individual scores on the anti-saccade task modulates their sensitivity to low-level saliency in internet adverts. Although children in this age group are sensitive to low-level saliency, some children may be more at risk of

having their goal-directed surfing activities disrupted by adverts. This raises questions about how advertising on children's websites could be redesigned in order to give children equal opportunities on the web (Livingstone & Haddon, 2009).

A wider objective of the current study is to give publicly funded research a possibility to catch up with the commercially restricted knowledge about saliency factors that drive visual attention that is already generated within advertising companies. Given the the business model of the internet, it seems unlikely that online advertising content could be effectively regulated, but knowledge about the relationship between visual saliency and attention could help researchers and developers to build better browsers that can filter out distracting advertising content. This knowledge can also be used by teachers in order to educate children about visual saliency in online advertising and how it affects visual attention, and thus raise children's awareness concerning attentional effects of commercial content.

Intriguing questions that remain to be answered concerns the effect of higher-level content categories in internet adverts, for example celebrities, animated cartoons and animals. It seems likely that there could be an interaction between low-level saliency features and high-level saliency, so that e.g. a combination of motion and celebrities would cause even more visual attention in children. Additionally, it is urgent to find out what kind of visual and semantic information children encode while attending to internet advertising. This could be tested with a recognition and recall test on internet adverts immediately after the surfing session. The focus on free internet browsing and the effects of low-level saliency features in current study should be understood as part of a larger project that also intends to investigate task-oriented browsing and the effects of behaviorally targeted and relevant online advertising.

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Paper II

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Advert saliency distracts children's visual attention during task-oriented internet use

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The general research question of the present study was to assess the impact of visually salient online adverts on children's task-oriented internet use. In order to answer this question, an experimental study was constructed in which 9- and 12-year-old Swedish children were asked to solve a number of tasks while interacting with a mockup website. In each trial, web adverts in several saliency conditions were presented. By both measuring children's task accuracy, as well as the visual processing involved in solving these tasks, this study allows us to infer how two types of visual saliency affect children's attentional behavior, and whether such behavioral effects also impacts their task performance. Analyses show that low-level visual features and task relevance in online adverts have different effects on performance measures and process measures respectively. Whereas task performance is stable with regard to several advert saliency conditions, a marked effect is seen on children's gaze behavior. On the other hand, task performance is shown to be more sensitive to individual differences such as age, gender and level of gaze control. The results provide evidence about cognitive and behavioral distraction effects in children's task-oriented internet use caused by visual saliency in online adverts. The experiment suggests that children to some extent are able to compensate for behavioral effects caused by distracting visual stimuli when solving prospective memory tasks. Suggestions are given for further research into the interdiciplinary area between media research and cognitive science.

Keywords: online advertising, children, internet use, distraction, visual saliency, visual attention

1. INTRODUCTION

Children's internet use is known to vary a lot between countries (Holloway et al., 2013). In Sweden, children attending primary school and middle school come into contact with the internet in a wide variety of everyday situations, ranging from information search in connection to school projects, to instant messaging on mobile phones during leisure activities. Current media research indicates that children spend an increasing amount of time connected to the internet, and that "tweens" aged between 9 and 12 spend about 1–2 h online a day on average. Notably, there is a steep increase in online activities between these two age groups, and time spent online per day is more than doubled over this age interval (Nordicom, 2013). Typical online activities among 9-year-old children are playing games and watching video clips. These activities are also found among 12-year-olds, but in addition there is a pronounced increase in time spent on social networking websites (Findahl, 2012).

Online advertising seems to quickly become a natural and persistent part of children's overall online experience. Interview studies of 9-year-old children show that, while online advertising is generally perceived as disturbing and confusing, these adverts are also largely tolerated and even sometimes consumed as entertainment (Martinez et al., 2013). However, at the same time these children often show a naive conception about the commercial and persuasive intent of online advertising, as well as a limited understanding of how online advertising use visual cues to capture attention (Buijzen et al., 2010). Whereas older children naturally start to develop the necessary attentional mechanisms needed to shield off impinging visual stimuli from online adverts, these neural structures are still developing in younger children, causing them to react to salient adverts on an involuntary level (Kramer et al., 2005). Involuntary exposure to online advertising might be a problem during free entertainment-based web surfing (depending on whether adverts are age-appropriate, distinct, recognizable etc.), but such "forced exposure" could become much more problematic in the case of task-oriented internet use. In the latter scenario, online adverts could introduce a disruptive element in situations where children are trying to pursue goal-directed activities online. Should this be the case, it becomes urgent to safeguard young children's rights to equal opportunities online (Holloway et al., 2013).

In order to investigate younger children's cognitive sensitivity to online advertising, we believe it is crucial to take into account both individual factors such as age, gender and cognitive development, as well as the visual properties of online adverts. In this study we used the anti-saccade task to determine children's individual level of oculomotor control. This paradigm directly measures participants' voluntary control of their eye movements, and has been shown to correlate with cognitive functions such as executive control, working memory

capacity and visual distractibility (Munoz and Everling, 2004, Kramer et al., 2005, Zanelli et al., 2005, Hutton and Ettinger, 2006). Several studies have also shown that this capacity to inhibit stimulus-driven, reflexive eye movements undergoes significant development throughout childhood, which is linked to increased development of the frontal lobe (Klein and Foerster, 2001, Eenshuistra et al., 2004). To our knowledge, there have been no attempts to measure childrens' visual distractibility in relation to their advertising exposure. In the present study, the motivation for measuring oculomotor control in two age-groups was that we intended to differentiate the effects of prefrontal control from other age-related effects, and that we wanted to find out if better gaze control is related to less advert distraction. The motivation for selecting age groups at 9 and 12 years was that previous research has shown that these ages respresent clear developmental and cognitive stages in children's understanding of persuasive advertising content (Buijzen et al., 2010).

In a recent study, we analyzed low-level saliency features in internet adverts with regard to children's visual attention (Holmberg et al., 2013). In this study, a group of 9-year-old children were allowed to surf freely on their favorite websites, while eye movement data were collected along with real-time screen recordings of the web page stimuli. These screen recordings were used to quantify low-level saliency aspects in all adverts that the children encountered. Key findings of this exploratory study were: (1) that low-level saliency features such as motion (pixel change), luminance and edge density in online adverts had a positive correlation with children's visual attention, and (2) that children with low individual level of gaze control had an increased sensitivity to these saliency features. Other studies have focused on stimulus onset as a key component in low-level visual saliency. This research has shown that abrupt onset of visual stimuli has a powerful effect on attentional capture (Ludwig et al., 2008), and that such low-level factors can impair task performance by distracting attention and increasing cognitive load (Lavie, 2005). There is also some evidence of "high-level saliency features" and their effects on attention (Findlay and Walker, 1999). High-level saliency refer to visual features that become relevant depending on the subject's particular cognitive task (Malcolm and Henderson, 2010), and in order to avoid confusion we will refer to this kind of saliency as "task relevance." Currently, there is a fairly strong consensus that, while low-level visual features such as abrupt onset can account for a some portion of people's eye movement behavior, task relevance is more powerful in explaining visual attention allocation (Foulsham and Underwood, 2008, Tatler et al., 2011).

The general research question of the present study was to assess the impact of internet adverts on children's internet use. Since internet use is a fairly broad concept including several types of interaction, we decided to focus further on one particular type of use case in which children interact with web pages in order to solve a predefined task involving memory and judgement. This type of web interaction should have a high intrinsic value to children, and should consequently be facilitated rather than hindered by the commercial online environments that children encounter. We reasoned that distraction caused by internet adverts would affect both the gaze behavior involved in the process of solving the tasks, as well as the task performance. In order to create experimental manipulations of the internet adverts, we utilized two aspects of visual saliency that are well-known in vision research: low-level visual features (Itti and Koch, 2000; Peters et al., 2005) and content relevance (Henderson, 2003). Low-level visual features were manipulated by varying the advert onset speed, and this feature was expected to distract the visual processing by attracting visual attention to the adverts (measured as saccades to ads). Advert relevance was manipulated by varying the level of task relevance in the advert content, and was expected to cause visual distraction by retaining attention on the adverts (measured as dwell time on ads).

Users' visual interaction with web pages and other interfaces will differ widely depending on the particular task that the interaction process is intended to solve (e.g., Yarbus, 1967; Cowen et al., 2002). The more viewers are allowed to decide their own subjective goals during visual interaction, the more these viewing patterns will vary between individuals (so-called free viewing conditions, e.g., Jansen et al., 2009). By contrast, if viewers are presented with a distinct and uniform task, viewing patterns will generally show much more similarities. In behavioral and psychological research the latter case usually means that it becomes easier to detect weak behavioral signals among random noise. It has been shown that in the absence of a task, viewing patterns become more influenced by low-level saliency features, and conversely, if a task is present, viewing patterns become more concentrated to task-relevant visual features (Hooge et al., 2005). An additional benefit from using a task-oriented experimental paradigm is that the visual interaction process can be evaluated in terms of performance, where some interaction strategies can be linked to better outcomes. In a free viewing task such evaluation of the interaction process is much more difficult. Finally, a task-oriented paradigm is also sensitive to the subjects individual level of expertise, and thus it is possible to isolate and estimate the positive effect of task expertise on solving a particular task (Jarodzka et al., 2010).

By constructing an experimental website that repeatedly presented children with a series of similar tasks, the present study has sought to benefit from all the positive aspects of task-oriented study designs previously mentioned. Thus we expected to find a high overall attentional focus on task relevant elements on the web pages, as well as a difference between younger and older children (caused by a higher level of internet expertise in the latter group). But more importantly, by using a task-oriented paradigm we expect to find differences in task performance depending on the advert saliency manipulations presented in each trial. Task performance is both measured through *performance measures* involving the accuracy and duration of each task response, but also as several *distraction measures* describing the children's visual interaction with the web pages. Thus, our experiment allowed us to test the effects of advert saliency conditions on performance measures and on distraction measures respectively, and it also allowed us to explore possible links between these two kinds of measures. This is crucial since advert saliency might affect these measures differently, and in that case it is important to be able to capture these differential effects to get a correct understanding of the effects of advertising saliency on children's task-oriented internet use.

Two types of performance measures were assumed to be sensitive to advert saliency manipulations: *trial accuracy* and *trial duration*. We reasoned that the advert saliency conditions would distract the children and cause a lower ability to solve the tasks correctly (trial accuracy) and efficiently (trial duration). For the sake of simplicity, high trial accuracy and low trial duration are grouped together as high task performance in the hypotheses. We hypothesized directional effects on task performance caused by the following experimental factors:

- H1a: Higher age and gaze control in children will be related to higher task performance.
- H1b: Higher onset speed in adverts will cause lower task performance.
- H1c: Higher task relevance in adverts will cause lower task performance.

Two types of distraction measures were constructed in order to capture effects of the advert saliency manipulations: *saccades to ads* and *dwell time on ads*. Saccades to ads measure the number of times visual attention has been shifted toward experimental adverts instead of objects relevant for solving the tasks. We reasoned that this measure would capture one important aspect of distraction: (1) the attention attracting power of ads. Dwell time on ads measure the actual amount of time spent on experimental adverts instead of other objects that are critical for solving the tasks, and we reasoned that this measure would capture a second crucial aspect of distraction: (2) the attention retaining power of ads. For simplicity, these two aspects of distraction are grouped together in the hypotheses. We hypothesized directional effects on distraction measures caused by the following experimental factors:

- H2a: Higher age and gaze control in children will be related to less task distraction.
- H2b: Higher onset speed in adverts will cause more task distraction.
- H2c: Higher task relevance in adverts will cause more task distraction.

As can be deduced from the hypotheses listed above, the current study contains both correlational hypotheses (H1a and H2a) as well as more causal hypotheses associated with experimental manipulations (H1b, H1c, H2b, and H2c). This structure will also be reflected when presenting and discussing the results of the study.

2. MATERIALS AND METHODS

2.1. PARTICIPANTS AND APPARATUS

The participants were selected from two age groups, 9-year-olds ($n = 19$) and 12-year-olds ($n = 26$), and were recruited from an elementary school in the south of Sweden. The distribution was fairly equal between girls ($n = 23$) and boys ($n = 22$). Only children that were given parental consent participated in the study ($n = 45$). The data recording equipment consisted of an SMI RED 250 eye-tracking camera and a laptop computer (Intel Core i7 2.67 GHz CPU, 2.98 GB RAM). The laptop was used both for stimulus presentation and eye movement recordings, and was connected to the Internet through a wireless 4 G router. Visual stimuli were presented on a 1680 × 1050 LCD monitor. The interactive web tasks were presented using the standard Internet Explorer 8 web browser. Eye-tracking data were recorded at 250 Hz using the SMI iViewX 2.7 software during all experimental modules.

2.2. EXPERIMENTAL DESIGN AND MATERIALS

A pre-test was administered to all children in the form of an anti-saccade test. After 4 practice trials, a series of 32 anti-saccade trials were presented to each participant. In each trial, a central fixation cross was replaced by a peripheral target, and participants were instructed to look in the opposite direction relative to the target location. The stimulus parameters of the anti-saccade test were chosen in accordance with recently suggested standards (Antoniades et al., 2013). Thus, the test was designed with no temporal gap between central fixation offset and target onset. The central fixation foreperiod was set to a duration of 1500–2000 ms, and the target duration was set to 1000 ms. After target offset, a blank screen was presented for 500 ms. Targets were presented in four randomized locations (top, bottom, left, and right) with an amplitude of ca 10° from the central fixation cross. To reduce fatigue in the children, the stimuli were constructed with a dark background.

Children in both age groups performed the exact same experiment, which consisted of 36 trials. Each trial consisted of a web-based visual search task, in which the participant was instructed to memorize a single image presented on an initial web page, and then proceed to a second web page to select the the most similar image in an array of 12 images. On the second page, 3 similar but unique target images were presented, along with 9 unique distractor images with lower similarity (**Figure 1**). The experimental images were created by splitting an animated open source movie (Big Buck Bunny, © 2008, Blender Foundation) into separate frames, and image similarities were determined using the OpenCV histogram comparison algorithm (Bradski, 2000). Target images were selected from a high correlation coefficient interval ($0.95 \geq r \geq 0.65$), while distractor images were selected using a lower threshold ($r \leq 0.10$). An important implication of this image similarity approach was that target images were never identical to the initial image, which added a cognitive component due to the fact that finding an optimal solution encouraged the participants to perform an image similarity judgement. The initial image memorization phase was self-paced, while the second image selection phase introduced a 7000 ms delay before the web page allowed the participant to select an image and thus move to the next web task.

On the second image selection web page, an online advert was presented according to 9 saliency conditions. The low-level saliency conditions were operationalized as two levels of advert onset speed, which were implemented as animated GIF images. Each GIF animation consisted of a number of transitional frames between the advert image and a blank white image, and was presented at a frame rate of 10 fps. Smooth advert onset was created using 50 transitional frames and a 1000 ms pause, while abrupt onset speed was created using 2 transitional frames and a 3000 ms

FIGURE 1 | Layout of the image selection web page used to solve the online tasks. The image array contains 3 target images and 9 distractor images in randomized positions. An experimental advert in the high task relevance condition is presented in the top-right corner. The banner advert to the far right was added to make the web pages more realistic, and was kept constant in all trials. The participant's eye movements during the trial are superimposed on the web page image.

pause. The GIF animations were then looped in order to present the low-level saliency conditions continuously on the web pages during each trial. The onset speed manipulation gave the visual impression that the adverts disappeared and then reappeared softly or abruptly on the web pages (Supplementary Material). The onset speed factor also included a control condition, consisting of the static advert images. These low-level saliency conditions were then combined with three types of task relevance including a control condition, producing a total of 3 × 3 advert saliency conditions. The task relevance conditions were operationalized as two levels of task relevant pictorial content in adverts. Adverts in the low task relevance condition depicted system dialog windows and website login windows, while adverts in the high task relevance condition depicted mockup adverts that closely resembled the target pictures in tasks (**Figure 2**). The task relevance factor also included a control condition depicting irrelevant inanimate objects.

The advert conditions were presented in randomized order during the web-based tasks. Each advert saliency condition was repeated four times, and advert positions were randomized between the four corners of the web page (top-left, top-right, bottom-left, and bottom-right). These positions were assumed to emulate typical advertising positions on real web pages. All adverts except those in the high task relevance condition were based on naturally occurring adverts found on websites frequently used by children in the current sample.

2.3. PROCEDURE

Each child was first greeted and presented with a verbal outline of the web-based tasks to be performed. Careful consideration was taken to ensure that the children were kept naive about the focus on online adverts and the exact nature of our data recordings. Prior to all eye-tracking recordings the participants were calibrated using a 5-point calibration method available in the SMI iViewX software. Calibrations were done at an eye-monitor distance of ca 700 mm, and were repeated until the horizontal and vertical deviation was below 1° of visual angle. After the first calibration, each participant underwent a 9 plate Ishihara color vision test presented on screen (Hardy et al., 1945). Results of this test indicated that all participants had full color vision. After another calibration, an anti-saccade test was performed containing 4 initial test trials and 32 actual trials. A third calibration was then undertaken before a web browser loaded and presented the instructions for the web-based tasks. First, the participants were instructed on how to solve the tasks through a detailed verbal walk-through of two test trials. The participants were instructed to memorize an initial image for each task and then try to find and click on the most similar image on a second web page. No information was given about the number of target

FIGURE 2 | In the task relevance conditions, the pictorial content of the adverts was manipulated to different degrees of task relevance. On the left hand side, an irrelevant advert in the control condition is shown. In the middle and on the right hand side, advert content in the low task relevance and high task relevance conditions is shown respectively. In the latter condition, the advert were always based on the target image of the task. (Reprinted with permission.)

and distractor images. Instructions were given to complete each task as accurately as possible, rather than as quickly as possible. The participants were not given any information about the advert content accompanying each task, and thus they were not instructed to avoid any adverts. All participants received a movie ticket as reward for active participation in the study. When the data collection phase was finished, meetings were arranged with the children in order to inform them about the true purpose and methods of the experiment.

2.4. DATA ANALYSIS

The overall quality of the eye-tracking data was calculated as the average deviation between the calibrated point of regard (POR) and 4 validation points. The average horizontal and vertical deviation was 0.75 and 0.92° respectively. The amount of missing samples (including blinks) in the anti-saccade data was 12.6%. These quality measures were only calculated for the anti-saccade dataset, but it should generalize to the dataset for internet use as well, since the exact same calibration procedure was applied in both cases.

Eye movement data from the anti-saccade test were analyzed by using the Engbert and Kliegel algorithm in order to detect the first saccade in each trial (Engbert and Kliegl, 2003). A minimum saccade duration of 32 ms was provided as a parameter for the detection algorithm. The first saccades were then analyzed for latency, peak velocity and direction relative to target position using a second algorithm (Ahlström et al., 2013). Saccade latency was calculated using a minimum latency parameter of 0.08 ms, peak velocity was calculated using a maximum saccade velocity parameter of 1000°/s. Anti-saccades were categorized binomially as correct if they were terminated within a 45° angle in the opposite direction of the target location. Only the total proportion of correct anti-saccades for each participant was used for further analysis, as this construct was considered to be the most valid measure of gaze control.

Behavioral data from the children's task-oriented internet use were analyzed in two major steps. In the first step, the two performance measures were analyzed. Trial accuracy was determined by analyzing mouse click responses recorded by SMI Experiment Center 3.2 and encoding these responses as a binomial variable depending on whether the tasks had been solved correctly by clicking on one of the target images. The second product measure, trial duration, was also analyzed in this step by recording the time difference in milliseconds between trial onset (when the task web pages were loaded) and the participants' response (when the mouse click was used to solve the task). Since the SMI software logged the timing of these events, we could control for variable network latencies in the web-based stimulus presentation.

In the second step, the eye movement data from each trial were extracted and eye movement events such as fixations, saccades and blinks were detected using the SMI BeGaze 3.2 software. These event detected eye movement data were then used to calculate the two distraction measures in relation to the area of interest (or AOI) corresponding to the adverts. Dwell time on ads was calculated by adding all fixation durations on the experimental ads for each trial. This AOI-based measure is better known as *total dwell time* in the eye-tracking literature (Holmqvist et al., 2011). The function of this measure is often to provide a close approximation of the total amount of visual attention devoted to a specific region in the visual field. Saccades to ads were calculated by counting the number of saccades that originated outside the pixel coordinates of the experimental advert AOIs, and terminated inside this same region (a variation of the more common *number of saccades* and *number of transitions* measures) (Holmqvist et al., 2011). The denomination of the distraction measures was chosen in order to clearly contrast the functional difference between fixations and saccades. Thus, saccades to ads were assumed to measure the ads' attention attracting power, while dwell time on ads was assumed to measure their attention retaining power (Born and Kerzel, 2008).

3. RESULTS

3.1. CHILDREN'S GAZE CONTROL

The children's individual level of gaze control was measured with an anti-saccade test in the beginning of the experiment. The proportion of trials containing valid eye movement data was high (92.2%). However, the proportion of correct responses was low, indicating that the children had difficulties inhibiting saccades toward the distractor, and saccading in the opposite direction at target onset. The average proportion of correct saccades was 0.23 for 9-year-olds and 0.45 for 12-year-olds. The

overall proportion of correct anti-saccades was 0.36, which is considerably lower than what would be expected in an adult population in a similar task. Success rates around 80% have been reported for adults in recent large-scale studies (Hutton and Ettinger, 2006). Conversely, saccade latencies in the child sample were longer than what would typically be expected among adults. In correct anti-saccade trials, the average saccade latency was 409 ms among 9-year-olds and 325 ms among 12-year-olds (overall 344 ms), while the same latency measure among adults typically lies around 200 ms (Holmqvist et al., 2011). Although we report saccade latency in the current study, only the individual proportion of correct anti-saccades was used as an independent variable in the statistical analyses. The reason for this is that the latter measure seems to have a higher validity with regard to children's gaze control.

3.2. PERFORMANCE AND DISTRACTION MEASURES

Task performance was measured as two product measures, trial accuracy (whether the task was answered correctly or not) and trial duration (the time taken to provide a solution to the tasks). All 36 trials contained valid performance data for all 45 participants. The overall trial accuracy was high (95.9% correct), but there was significant differences between 9-year-olds (93.4%) and 12-year-olds (97.6%), as well as between boys (95.1%) and girls (96.6%). Looking at trial duration, the average time to complete a task was just over 10 s (11558 ms). There was no significant difference in trial duration depending on age, but girls were about one second faster than boys on average. Trial number had a significant negative effect on trial duration, but no effect on trial accuracy, meaning that the children became faster to solve tasks toward the end of the experiment. **Figure 3** shows the effect of children's age and gender on task performance.

The distraction measures used in this study were dwell time on ads (attention retention) and saccades to ads (attention attraction). All 36 trials contained valid eye movement data for all 45 participants. The average fixation time on ads was just over half a second (654 ms), with no significant differences depending on age or gender. However, there was a significant negative effect of trial number, meaning that children tended to spend less time on experimental adverts toward the end of the experiment. The average number of saccades to ads was just over one saccade (1.13), and there was no significant differences depending on children's age or gender. As in the case of the previous distraction measure, there was a significantly negative effect of trial number, which would indicate that the children became less prone to behavioral distractions over the course of the experiment (as well as more proficient in solving the tasks). **Figure 4** shows the effect of advert saliency conditions on task distraction.

3.3. EFFECTS ON TASK PERFORMANCE MEASURES

We hypothesized that children's task performance would depend on individual factors as well as advert saliency conditions. More specifically, our hypotheses were that trial accuracy and trial duration could be described as a function of subject age and gaze control (H1a), level of advert onset speed (H1b), and level of advert task relevance (H1c). To test these hypotheses, the dataset was analyzed using linear mixed models in which the unique identifier of the experimental adverts was treated as a random factor (using the lme4 package in R). Subject was not entered as a random factor, since the gaze control variable also contained values that were unique for each participant. Fitting the data to these multi-level models provided partial support for our hypotheses regarding trial accuracy, but only weak support regarding trial duration. In the case of trial accuracy, all individual factors proved to have significant effects. Thus, older children as well as children with better gaze control were able to solve the tasks significantly more accurately, which gives support for hypothesis H1a. In the case of trial duration, the only significant effect

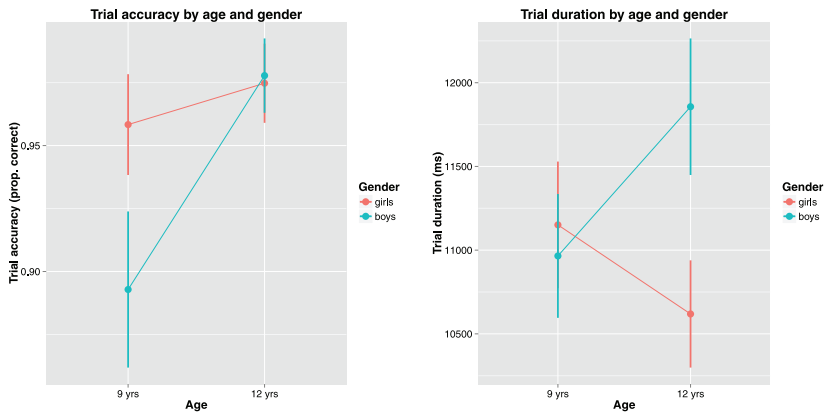

FIGURE 3 | Children's age and gender plotted against trial accuracy (left) and trial duration (right).

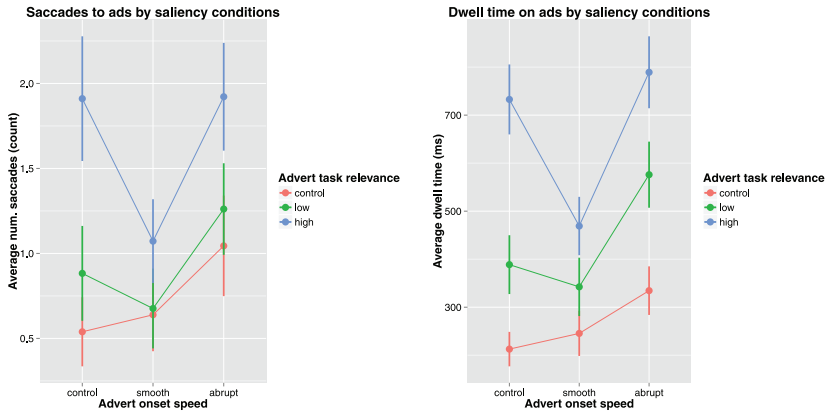

FIGURE 4 | Advert onset speed and task relevance plotted against saccades to ads (left) and dwell time on ads (right).

was associated with male gender. Thus, boys generally required more time to solve the tasks. The advert saliency conditions did not seem to have a negative impact on trial accuracy or trial duration, and thus hypotheses H1b and H1c failed to gain support. Taken together, the evidence suggests that individual factors had an effect on one aspect of task performance (trial accuracy), while neither advert onset speed nor advert task relevance had any significant impact task performance.

Table 1 shows how advert saliency conditions and individual factors affected children's task performance. Task performance was divided into trial accuracy and trial duration, and the same independent variables were then used to model effects on both these performance measures. Tables for these performance measures are shown side by side. The coefficients and *p*-values for each independent variable are shown in the order they were entered. The advert saliency conditions consisted of three levels, and the effects of these conditions were tested aginst the control condition in the intercept. The level of multicollinearity between independent variables was low. In order to describe the model fit of the independent variables, the deviance of the proposed models were compared to the deviance of unconditional null models which included only the intercept and the random factor as independent variables. The proposed models and their corresponding null models were compared using chi-square tests, which showed that the independent variables contributed significantly to explaining the observed variance in trial accuracy and trial duration. Since the proposed models were used for hypothesis testing rather than modeling the best combination of predictors, no further attempts were made to optimize the models by excluding non-significant independent variables.

3.4. EFFECTS ON TASK DISTRACTION MEASURES

We also hypothesized that individual factors and advert saliency conditions would have distractive effects on children's gaze behavior while processing the tasks. The distraction measures that we analyzed in this study were: (1) dwell time on ads, and (2) saccades to ads, and we hypothesized that these measures would be sensitive to subject age and gaze control (H2a), level of advert onset speed (H2b), and level of advert task relevance (H2c). To test these hypotheses, additional linear mixed models were constructed using the lme4 package in R, in which adverts where treated as a random factor. As in the previous models, subject was not entered as a random factor, since the gaze control variable also contained values that were unique for each participant. Fitting the data to these multi-level models provided strong evidence for our hypotheses concerning both task distraction measures. Advert onset speed and advert task relevance were associated with increases in both dwell time on ads and saccades to ads. Thus, higher levels of advert saliency caused increased attentional retention as well as increased attention attraction in children, which provides support for H2b and H2c. Overall, there was a significant decrease on both distraction measures among children with better gaze control, which gives partial support for H2a. Contrary to H2a, the results for dwell time on ads show that older children spent significantly more time on experimental ads than younger children, but no such effect was detected in saccades to ads. Children's gender did not have any significant effects on distraction measures. Taken together, this evidence suggests that advert saliency conditions had a stronger effect on task distraction measures than individual factors, but better gaze control in children was associated with less distraction.

Table 2 shows how advert saliency conditions and individual factors affected children's task distraction. Task distraction was divided into dwell time on ads and saccades to ads, and the same independent variables were then used to model effects on both these distraction measures. Tables for these performance measures are shown side by side. The coefficients and *p*-values for each independent variable are shown in the order they were

Table 1 | Effects of independent variables on task performance measures (trial accuracy and trial duration).

	Trial accuracy (binomial)				Trial duration (ms)			
	Estimate	**Std. error**	***z* value**	***Pr*(>|*z*|)**	**Estimate**	**Std. error**	***t* value**	***Pr*(>|*t*|)**
(Intercept)	2.8843	0.6755	4.2700	0.0000	10926.6540	520.9880	20.9730	0.0000
Advert onset speed (smooth)	0.3231	0.6324	0.5110	0.6094	8.3820	472.3650	0.0180	0.9858
Advert onset speed (abrupt)	−0.5470	0.5884	−0.9300	0.3525	435.4470	472.3400	0.9220	0.3567
Advert task relevance (low)	0.0166	0.5757	0.0290	0.9770	160.2250	472.2880	0.3390	0.7345
Advert task relevance (high)	0.8351	0.6290	1.3280	0.1843	−215.8810	472.2690	−0.4570	0.6477
Advert position (bottom-right)	**0.0108**	**0.0050**	**2.1380**	**0.0325**	−2.6040	3.2140	−0.8100	0.4179
Child age (12 years)	**0.9242**	**0.3275**	**2.8220**	**0.0048**	123.7080	215.0440	0.5750	0.5652
Child gender (male)	**−0.8124**	**0.2901**	**−2.8000**	**0.0051**	**653.6960**	**185.1890**	**3.5300**	**0.0004**
Child gaze control	**2.2361**	**0.7643**	**2.9260**	**0.0034**	−44.9860	471.4690	−0.0950	0.9240

Significant effects are emphasized with bold face. Child gaze control values have been centered.

Table 2 | Effects of independent variables on task distraction measures (dwell time on ads and saccades to ads).

	Dwell time on ads (ms)				Saccades to ads (count)			
	Estimate	**Std. error**	***t* value**	***Pr*(>|*z*|)**	**Estimate**	**Std. error**	***t* value**	***Pr*(>|*z*|)**
(Intercept)	485.9071	68.1109	7.1340	0.0000	0.8091	0.1543	6.7270	0.0000
Advert onset speed (smooth)	−78.8628	52.8385	−1.4930	0.1358	**−0.3115**	**0.1195**	**−2.3970**	**0.0166**
Advert onset speed (abrupt)	**125.8762**	**52.8353**	**2.3820**	**0.0173**	**0.2992**	**0.1194**	**3.0960**	**0.0020**
Advert task relevance (low)	**185.6223**	**52.4182**	**3.5410**	**0.0004**	**0.2047**	**0.1195**	**2.1060**	**0.0353**
Advert task relevance (high)	**412.5676**	**52.8994**	**7.7990**	**0.0000**	**0.8984**	**0.1194**	**8.4320**	**0.0000**
Advert position (bottom-right)	**−3.4347**	**0.5302**	**−6.4780**	**0.0000**	−0.0016	0.0012	−1.3800	0.1677
Child age (12 years)	**92.3068**	**35.5833**	**2.5940**	**0.0096**	−0.0267	0.0805	−0.1530	0.8786
Child gender (male)	−14.0102	30.5717	−0.4580	0.6468	0.1700	0.0692	1.6180	0.1058
Child gaze control	**−265.1405**	**77.8884**	**−3.4040**	**0.0007**	**−0.3102**	**0.1764**	**−2.4340**	**0.0151**

Significant effects are emphasized with bold face. Child gaze control values have been centered.

entered. The level of multicollinearity between independent variables was low. In order to describe the model fit of the independent variables, the deviance of the proposed models were compared to the deviance of unconditional null models in which all independent variables were excluded except the random factor. The proposed models and their corresponding null models were compared using chi-square tests, which showed that the independent variables contributed significantly to explaining the observed variance in both distraction measures. Since the proposed models were used for hypothesis testing rather than modeling the best combination of predictors, no further attempts were made to optimize the models by excluding non-significant independent variables.

4. DISCUSSION

We have tested the effects of advert saliency conditions on children's internet use while controlling for individual factors. The reported effects are a result of fitting observational data to the statistical model specified by our hypotheses. The main findings on children's task-oriented internet use are as follows: (1) Individual factors such as age, gender and level of gaze control have clear effects on both performance measures as well as distraction measures associated with solving the tasks; (2) Advert onset speed and advert task relevance only have a marginal effect on task performance, but have a clear effect on task distraction. A possible interpretation of these results is that children between 9 and 12 years of age are sensitive to advert saliency conditions on a behavioral level, but are still able to compensate for (or cope with) this distraction on a higher cognitive level, and consistently produce accurate responses during task-oriented internet use.

4.1. INDIVIDUAL FACTORS AND TASK-ORIENTED INTERNET USE

When focusing on task-oriented internet use in relation to individual differences, a general pattern emerges revealing that individual factors tend to have a more profound impact on performance measures such as trial accuracy and trial duration (supporting H1a), than on distraction measures such as dwell time on ads and saccades to ads (disproving H2a). This difference is seen most clearly when looking at the gender variable, which shows that male gender affects both trial accuracy and trial duration negatively, whereas gender does not have any significant effects on distraction measures. In other words, boys had more difficulty solving the tasks than girls, and boys also needed more time to complete the tasks. However, in terms of distraction measures, boys and girls showed no differences. Looking at the age factor, the results give partial support for our hypotheses in that older children were associated with higher scores on trial accuracy

(supporting H1a), but contrary to our expectations, older children were also associated with a significant increase in fixations on adverts (disproving H2a). Thus, older children unsurprisingly performed better than younger children on task accuracy, but children in the older age group also spent more time looking at the adverts. A possible interpretation of this pattern would be that older children have developed a better working memory, enabling them to engage in longer "detours" of attentional distraction, while still keeping track of the task at hand and produce accurate answers.

Still looking at individual factors, the strongest predictor of task performance and task distraction was not age or gender, but gaze control. In this study, gaze control was measured as children's ability to inhibit reflexive eye movements in an anti-saccade task. High scores on gaze control were clearly associated with higher scores on task accuracy (supporting H1a) and lower scores on both distraction measures (supporting H2a). The implication of these results is that children with better gaze control are more able to focus on the actual web-based task at hand while avoiding being distracted by salient internet adverts in the periphery. This interpretation fits nicely with other psychological research that has found strong positive correlations between gaze control and cognitive functions, e.g., working memory (Eenshuistra et al., 2004). According to the experimental design of the current study, we have chosen to investigate the age, gender and gaze control factors independently with regard to the dependent measures. The evidence suggests that children's individual level of gaze control plays an important role as a predictor of task performance and advert distraction. However, these results open up to other interesting lines of research in which the combined effects of these individual factors could be studied more carefully. Such a research direction could allow us to pinpoint various sub-groups among children that are particularly sensitive to advert saliency. For example, gaze control might develop differently in boys and girls, and by examining an interaction between age and gender with regard to gaze control, vulnerable sub-groups might be identified. Also, the contribution of motivational factors on task performance should be addressed in future research.

4.2. ADVERT SALIENCY AND TASK-ORIENTED INTERNET USE

Contrary to our expectations, advert saliency conditions did not appear to affect performance measures in this study (disproving H1b and H1c). However, advert position, which was entered as a control variable, had a significantly positive effect on trial accuracy. This positive effect on task performance was associated with the bottom-right advert position, which was compared to the top-left position. The implication is that adverts that were placed in the top-left corner of the web page were associated with significantly more errors in trial accuracy, irrespective of advert saliency condition. This result applies directly to previous research on advertising effects where advert position has generated inconsistent results, mostly because of the fact that this property have been difficult to control for (Gidlöf et al., 2012). The present study can therefore conclude that adverts placed in the top-left corner of the web page are associated with a strong detrimental effect on task performance and a strong distractive effect in terms of total dwell time on adverts. A plausible explanation as to why the top-left advert position has a detrimental effect on web page interaction could be that this position tends to coincide with the typical starting position when reading text or when initiating a visual search task (Zelinsky, 1996).

In accordance with the expectations of this study, the advert saliency conditions proved to have strong effects on distraction measures (supporting H2b and H2c). Focusing first on advert onset speed and low-level visual features (H2b), our evidence suggests that abrupt onset speed in adverts caused a significant increase in dwell time on ads, as well as significantly more saccades to ads. That is, abrupt and dynamic visual features of internet adverts affect children's task-oriented internet use by causing distraction from the task, both in terms of attention retention and in terms of attention attraction. Slightly curiously, when investigating the effects of smooth advert onset speed the results tend to run counter to the hypothesized scenario. Thus, this dynamic visual feature is actually associated with less dwell time on ads and significantly less saccades to ads compared to the static control condition. Lower scores on these measures would mean that smooth advert onset speed causes reduced task distraction. To find these diametrically opposed behavioral effects caused by different levels of the same saliency factor (advert onset speed) is puzzling, and consequently this effect should be investigated further. One interpretation would be that smooth advert onset speed allows children to identify and avoid advert content through peripheral vision, while abrupt onset speed exerts a more coercive stimulus on the visual system, causing children to saccade toward the ads and also to fixate on the ads for an extended period of time. Recapitulating the arguments presented in the introduction, abrupt onset speed in adverts could represent a concrete example of "forced exposure" reported by previous internet advertising research done with children. Since advert onset speed is an objective and quantifiable visual feature, it seems to be an advertising property that could effectively be regulated in order to facilitate children's interaction with websites.

Changing focus to advert task relevance (H2c), the results show that this type of saliency causes more consistent and unequivocal effects on the distraction measures utilized in this study. Thus, both levels of advert task relevance were associated with significantly more dwell time on ads as well as significantly more saccades to ads. That is, pictorial advert content that is relevant to the task in some sense, affects children's task-oriented internet use by causing distractions from the task, both in terms of attention retention and in terms of attention attraction. Compared to the onset speed factor, advert task relevance thus appears to have a more powerful and detrimental effect on children's visual interaction with the web pages. These results are consistent with previous research on visual saliency, which have argued that task relevance have a more profound effect on gaze behavior and attention (Findlay and Walker, 1999). The downside of investigating task relevance is that these visual properties are considerably more difficult to define compared to low-level visual features. In the current study, low task relevance was operationalized as pictorial content that consisted of fake dialog windows,

while high task relevance consisted of pictorial content that was similar to the target images that the children were solving the tasks for. The effects of these advert conditions were compared to pictorial content in a supposedly task irrelevant control condition. The problem with fake dialog windows and irrelevant advert content is that the subjective relevance of these types of pictorial content is difficult to control for since to some extent they depend on individual interests. Notwithstanding, the high task relevance condition had a more objective implementation in this experiment, and since this condition caused the strongest behavioral effects, we argue that we have successfully managed to document the effects of task relevance in internet adverts. Because of the difficulties in defining task relevance, it would probably be harder to regulate this aspect of internet adverts in order to facilitate children's internet use. The effects of task relevant advert content, could motivate further research into so-called behavioral targeting in advertising, in which web interaction metrics are collected in order to serve up more relevant adverts to users.

From a research perspective, it would be fruitful to develop the experimental paradigm used in the current study to include tests of other types of visual saliency in internet ads. We think that our study design offers a robust combination of ecological validity and experimental control that is well-suited for obtaining reliable and valid behavioral data on children's task-oriented internet use. Consequently, this design could easily be extended to investigate other eye movement measures such as fixation durations and blink rate. Developing our research in this direction would allow us to address questions about cognitive load in children when engaged in task-oriented internet use in commercial online environments. A limitation with the present study was the high overall scores on trial accuracy, which could indicate a ceiling effect on this measure. If the web-based tasks were too easy to solve accurately, then there would be less need for the children to compensate for attentional distractions in order achieve high task accuracy. In order to address the cognitive relationship between task distraction and task performance more thoroughly, we recommend increasing the task difficulty or limiting the trial duration.

From a policy and regulation perspective on online advertising, it is important to take these new findings into consideration when discussing possible restrictions of ads directed to children. Children in different age groups have repeatedly given verbal statements of how annoying, disturbing, and irritating online advertising is during their daily internet activities (Sandberg et al., 2011). Our study has provided empirical evidence that demonstrates how children's task-oriented internet use is disturbed by advertising saliency factors as well as advert positions. However, the children seem to cope with this distraction by adjusting their responses to accommodate for coercive advertising features and thus manage to compensate to some degree for these visual demands when involved in task-oriented internet use, i.e. children's task performance is adequate, but their experience of online advertising might be strenuous, especially for children that suffer from poor gaze control.

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SUPPLEMENTARY MATERIAL

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Paper III

Media Psychology

Advert animation impairs children's online reading differently depending on individual level of gaze control: An experimental approach to investigating children's media and information literacy on commercial websites

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Manuscript ID	MEP-2016-0146
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Keywords:	Children, Advertising, Cognitive processing, Internet, Visual attention, Media effects

Abstract

In this study we argue that experimental psychology on visual attention can be used to analyze children's media and information literacy (MIL). Thus, the present study investigates four key components of children's MIL on commercial websites: 1) advert distraction, 2) text processing, 3) reading comprehension, and 4) gaze control. 57 children in third grade (9-year-olds) were presented with multiple reading-for-comprehension tasks featuring concurrent online adverts. Eye movement data were collected during their task-oriented internet use. Our results show that advert animation increased children's advert distraction, while text processing measures remained relatively unaffected. Most importantly however, the present study showed that animated adverts had a significantly negative effect on children's reading comprehension, and that this effect was stronger among children with poor gaze control (as measured with an anti-saccade task). The study discusses how these findings can be used in the context of current media research on children's MIL on commercial websites.

Keywords: children, online advertising, reading comprehension, media and information literacy, visual attention, visual saliency

Advert Animation Impairs Children's Online Reading Differently Depending on Their Gaze Control: An Experimental Approach to Investigating Children's Media and Information Literacy on Commercial Websites

According to UNESCO, children and youth from industrialized societies spend at least twice as much time immersed in electronic media (television, internet, video games, mobile phones, etc.) as they do receiving formal education in schools (Carlsson, 2012, 2013). This represents a paradigm shift, both in terms of information availability and media consumption. Given the fact that much of the media children consume is aimed at selling them products or ideologies, UNESCO argues that media and information literacy is becoming an increasingly important prerequisite for fostering equitable access to information and knowledge, and building inclusive knowledge societies (Carlsson, 2012; Catts & Lau, 2008).

Media and information literacy (MIL) includes both the behavioral aspects of navigating and interacting with information systems (e.g. websites), as well as the more cognitive aspects of critically interpreting and evaluating information (Koltay, 2011; Livingstone, 2008; Metzger, Flanagin, Markov, Grossman, & Bulger, 2015). In the present study we focus on the basic skills of children's MIL, in as much as children were asked to navigate through a number of factual online texts and subsequently answer comprehension questions associated with each text (Potter, 2004, 2010). We argue that online reading along with information search represent some of the most important types of "task-oriented internet use" that children need to perform (Flanagin & Metzger, 2001), and that these basic media competencies underly and support higher-order information literacy (Catts & Lau, 2008). Furthermore, we argue that these basic components of children's MIL so far have been under-researched from a quantitative and evidence-based perspective (de Vord, 2010; Hargittai, 2005; Carlsson, 2013).

In this study we acknowledge that task-oriented internet use under natural conditions rarely occurs without distracting elements such as advertising. Recent studies estimate that 80-90% of websites for children are commercial (Sandberg, 2014; Montgomery, 2012). Thus, children's MIL on commercial websites needs to be connected to their cognitive processing of persuasive messages. A recently proposed theoretical framework in this area is called the "processing model of commercial media content" (PCMC) (Buijzen, Van Reijmersdal, & Owen, 2010). This framework attempts to integrate several influential theories concerning how recipients process persuasive messages, such as the "elaboration likelihood model" (Cacioppo, Petty, Kao, & Rodriguez, 1986), and more general theories about cognitive processing, such as the "limited capacity model of mediated message processing" (Lang, 2007). These theoretical frameworks allow the PCMC model to formulate some relevant, quantitative predictions about how children process online advertising during task-oriented internet use.

The present study combines the PCMC model with experimental psychology on visual attention in order to investigate children's MIL on commercial websites. In so doing, we have replicated a previous psychological experiment testing adults' task-oriented internet use on commercial websites (Simola, Kuisma, Öörni, Uusitalo, & Hyönä, 2011). This experiment consisted of an online reading-for-comprehension task featuring concurrent salient adverts. The participants' attentional processes during website interaction were measured quantitatively by recording their eye movements, and reading comprehension was measured through online questionnaires. We replicated this research design with 9-year-old children, and their MIL on commercial websites was operationalized and measured on three levels: 1) advert distraction, 2) text processing, and 3) reading comprehension. In order to account for individual differences in children's cognitive development, we also added a developmental component: 4) prefrontal

executive control. Based on the fourth measure, this study discusses potential risk groups among children engaging in task-oriented internet use on commercial websites.

Advert Distraction

The current study investigates advert distraction as a key component of children's MIL by combining the PCMC model with experimental psychology on visual attention during task-oriented internet use. Thus, this study introduced children with two competing stimuli: 1) realistic primary reading tasks, and 2) concurrent distracting adverts featuring high levels of perceptual prominence, as well as age-appropriate content. Previous research within experimental psychology was used to select perceptual prominence features that have been proved to maximize advert distraction (Simola et al., 2011; Wolfe & Horowitz, 2004; Yoo, Kim, & Stout, 2004; Kuisma, Simola, Uusitalo, & Öörni, 2010). Also, physiological methods allowing precise measurements of children's visual attention were adapted from the same field of research. Crucially, by utilizing a research design previously tested on adults, our study allows us to compare advert distraction levels between adults and children under similar internet usage conditions.

Regarding advert distraction, the reference study on adults found that online adverts in the animated condition attracted significantly more visual attention than in the static condition. An important conclusion drawn from this result was that advert animation attracts overt visual attention, as opposed to covert attention, which does not require eye movements. In our replication study with children, we used this conclusion in a media literacy context. In order to investigate children's MIL within the framework of the PCMC model, this study featured online adverts in two perceptual prominence conditions: static (low prominence) and animated (high prominence). Higher levels of MIL in children were expected to be associated with the ability to

filter out prominent adverts (i.e. lower levels of advert distraction in the animated condition), in order to focus on the reading task (Blades, Oates, Blumberg, & Gunter, 2014). Consequently, our first hypothesis concerning the attentional effects of animation in online adverts was expressed as follows:

- H1a: Animated adverts will be associated with more advert distraction compared to static adverts.

Text Processing

The second component of children's MIL on commercial websites involves their ability to allocate cognitive resources on the primary task while being exposed to concurrent salient adverts. In the present study, the children's primary task consisted of an online reading-for-comprehension task, and consequently, attention on the primary task was measured as a number of text processing measures. The PCMC model predicts that perceptually prominent adverts may "steal" cognitive resources allocated to a primary reading task, but it is not clear whether these effects are expected to impact the task processing, the task performance, or both. In this section we review empirical and theoretical research concerning the impact of salient online adverts on several text processing measures.

The allocation of visual attention during reading has been studied extensively in adults, and a number of eye movement measures have been proved to vary reliably with reading proficiency and text difficulty. Most notably, as children develop their reading skills between early primary school and late secondary school, three reading measures undergo profound changes: 1) average fixation duration gets shorter, indicating that less cognitive resources are required, 2) number of regressive saccades gets fewer, indicating better reading comprehension,

and 3) reading rates get faster due to more automated and effortless reading behavior (Buswell, 1922; Rayner, 1998).

In order to allow for comparisons between our child sample and adults in terms of media literacy on commercial websites, our research design was implemented to replicate the results previously obtained with adults (Simola et al., 2011). This previous study found that concurrent animated adverts had only marginal effects on three key text processing measures in adults: average fixation duration, number of regressions, and reading rate (words per minute). Although other studies have found some evidence indicating that advert animation actually do affect these reading measures negatively (Pasqualotti & Baccino, 2014), we decided to rely our reference study when formulating the following hypothesis concerning the effects of advert animation on children's text processing measures:

- H1b: Animated adverts will not affect children's text processing measures compared to static adverts.

Reading Comprehension

The third, and arguably the most important, aspect of children's media and information literacy on commercial websites targets the outcome measure of reading comprehension. In the present study, we distinguish between the reading process, as measured by previously mentioned text processing measures, and the reading outcomes, as measured by comprehension questions presented after each text. The reason for this distinction is that perceptually prominent adverts may impact children's overt visual attention (advert distraction and text processing), but not reading comprehension. However, it is equally possible that perceptually prominent adverts impact children's covert visual attention (reading comprehension), but not their text processing. According to the PCMC model, animated adverts are predicted to divert cognitive resources

from the primary task in children, but the model does not explicate whether this diversion of cognitive resources will impact task processing or task performance, or both.

Previous research on children's task-oriented internet use have shown that animated online adverts does not seem to impact task performance measures such as trial accuracy and trial duration (Holmberg, Sandberg, & Holmqvist, 2014). These results were interpreted such that, although animation impacts participants' overt visual attention, children are able to compensate for this distraction, and maintain high task performance regardless of the perceptual prominence of adverts. Similar results were obtained with adults in an online reading-for-comprehension task, where equally high reading comprehension scores were found regardless of static or animated adverts (Simola et al., 2011). Since online reading comprehension is an important aspect of children's MIL, the current study was designed to allow for comparisons between adults and children on this outcome measure. Thus the third hypothesis of the current study is formulated as follows:

- H1c: Animated adverts will not affect children's reading comprehension compared to static adverts.

Children's Gaze Control

So far we have discussed three components of children's media and information literacy on commercial websites: 1) advert distraction, 2) text processing, and 3) reading comprehension. The fourth and last component was selected in order to address individual and developmental differences in children's attentional sensitivity to advert saliency (Tipper, Bourque, Anderson, & Brehaut, 1989). Although this level of analysis should clearly be relevant in explaining children's processing of commercial media content, the PCMC model does not include this factor, but rather generalizes over entire age groups (e.g. middle childhood or 6-9 years old). Similarly, by

controlling for individual differences in gaze control in adults, psychophysiological research on advert saliency might find greater effects on adults' task-oriented internet use.

Although we cannot measure "gaze control" directly, it is possible to approximate this factor through an anti-saccade test. This test has been used extensively to evaluate prefrontal executive control in adults (Munoz & Everling, 2004; Antoniades et al., 2013), and also to diagnose some psychiatric disorders (Hutton & Ettinger, 2006). From the perspective of children's MIL, the anti-saccade task is interesting since it can be used to gauge individual difference in children's development of oculomotor control. It has been shown that this ability undergoes rapid development during middle childhood, and that the variability in anti-saccade accuracy is considerably higher in children than in adults (Kramer, Gonzalez de Sather, & Cassavaugh, 2005; Eenshuistra, Ridderinkhof, & Molen, 2004; Klein & Foerster, 2001; Fukushima, Hatta, & Fukushima, 2000). For these reasons, this test offers an interesting measure of children's individual ability to inhibit oculomotor reflexes towards salient animated adverts, and maintain voluntary attention on the primary task.

When we measured gaze control in 9-year-olds in previous studies, we found that their average anti-saccade accuracy was about 20%, whereas adults typically score around 80% (Holmberg et al., 2014; Holmberg, Holmqvist, & Sandberg, 2015). This suggests that children as a group are more vulnerable to salient adverts compared to adults. However, since the variation in gaze control in children is quite high, this measure could also indicate potential risk groups among children. To this effect, our previous studies have found evidence that low gaze control in children is positively associated with advert distraction and negatively associated with task performance. In order to further investigate children's gaze control as part of their MIL on commercial websites we formulated the following set of hypotheses:

- H2a: Children's level of gaze control will be negatively correlated with advert distraction measures.
- H2b: Children's level of gaze control will not be associated with text processing measures.
- H2c: Children's level of gaze control will be positively correlated with reading comprehension measures.
- H2d: Higher level of gaze control in children will moderate negative effects of advert animation on reading comprehension.

Materials and Methods

The empirical data underlying this study were collected in two subsequent experiments: 1) first an anti-saccade task was administered to assess the children's individual level of gaze control, and 2) an experiment on online text reading was performed in order to measure the effects of animated online advertising on children's text processing and reading comprehension. In order to ensure good ecological validity of the data, all parts of the study was undertaken in the childrens' school environment.

Participants and Apparatus

The participants were recruited from three parallel 3rd grade classes in a Swedish public school (N = 57). The recruitment phase was initiated in November 2014 and was completed in January 2015. The children had mixed ethnic backgrounds, but were all fluent in Swedish. The children were presented with a cover story about participating in a study on internet surfing, and our research questions about online advertising was not mentioned. Parental consent forms were distributed in the school classes, and we received written consent from all caretakers of the children that participated in the study. Before entering into the study, each child was also asked

verbally for individual consent. Participants varied between 9 years (55) and 10 years (2) during their 3rd grade year. The gender distribution was fairly equal between boys (27) and girls (30). No participants were excluded due to insufficient data quality.

Visual stimuli in the anti-saccade experiment and the online reading experiment were presented on an SMI laptop computer (Intel Core i7-2640M CPU @ 2.80 GHz, 4.00 GB RAM), using the SMI Experiment Center 3.5 stimulus presentation software. The laptop screen resolution was set to 1600 × 900 pixels and the physical dimensions of the LCD screen were 474 × 296 millimeters. The stimulus presentation laptop was connected to a video-based SMI RED-m remote eye-tracking system, and the participants' visual interaction with the web pages was recorded at 120 Hz using the SMI iView RED-m 3.2 software. The eye-tracking camera was placed in the laptop monitor fold, and was connected to the computer via a USB port (c.f. Fig. 1a). The geometry of the setup used a head-monitor distance of 639 mm. The laptop computer was connected to the internet through a 4G wireless router. The web pages were presented using Microsoft Internet Explorer 11, and participants navigated through the web pages using an optical USB mouse (no keyboard interaction was needed). Along with the eye-tracking data, the SMI software suite also recorded synchronized triggers for trial onsets (page completely rendered) and offset (user mouse clicks). Thus, network latencies in HTTP requests were controlled for.

Study Design and Materials

In order to measure each participants' individual level of gaze control, a pre-test experiment was administered in the form of an anti-saccade task. In each trial, a central fixation cross was replaced by a peripheral target, and participants were instructed to look in the opposite direction relative to the target location. After four practice trials with verbal instructions, a series

of 32 anti-saccade trials were presented to each participant. The stimulus parameters of the anti-saccade test were chosen in accordance with recently suggested standards (Antoniades et al., 2013). Thus, the test was designed with no temporal gap between central fixation offset and target onset. The central fixation foreperiod was set to a duration of 1500-2000 ms, and the target duration was set to 1000 ms. After target offset, a blank screen was presented for 500 ms. Targets were presented in four randomized locations (top, bottom, left, and right) at an eccentricity of ca 10◦ from the central fixation cross. To reduce retinal fatigue in the children, the stimuli were constructed as white objects on a dark background.

Web pages were constructed that simultaneously presented a short factual text in the main column, along with an online advert in the right column (c.f. Fig. 1b). Six texts were selected from the Swedish translation of The New International Reading Speed Texts (Vision, 2012). The texts had an equal length of 146 words, and several text properties were controlled for (such as word length and lexical difficulty). The online adverts were presented in a static control condition and an animated experimental condition. These conditions were generated by recording authentic movie commercials from the LEGO™ YouTube™ channel. The advert content was balanced between male, female and non-human figures. The animated advert condition was constructed by splitting the video into frames, and converting a random sequence of 100 frames into short animated GIF files at 10 fps. The mean edge density was calculated for the frame sequence using the Python OpenCV package (Bradski, 2000), and the static advert condition was constructed by selecting one frame that was closest to the mean edge density (Holmberg et al., 2015). The advert image dimensions in both the static and animated condition were 306 × 618 pixels, which is the same aspect ratio as used in previous similar research

(Simola et al., 2011). Texts and adverts were presented on a mock-up news site that was held constant across all trials.

The web page material was presented using a randomized repeated measures design in which each participant read all six text in random order while the static and animated advert conditions were repeated three times each and presented next to the texts. The combination of text instance and advert condition was randomized using a latin square design. Each web page containing combinations of factual texts and online adverts was presented with a maximum duration of 90 seconds. After this time period the trial ended and the web page automatically redirected to a web form containing three comprehension questions with five multiple choice alternative for each question. However, research shows that 90 s is considerably longer than the time typically required for a 9-year-old to read a 146-words text, so at the end of each text a link was presented to allow the participants to proceed manually to the comprehension questions (Vision, 2012; Johansson, Pansell, Ygge, & Seimyr, 2014). The reason for this design was to accommodate as much as possible for variations in reading speed among 9-year-olds. After each pair of factual text and comprehension questions, the participants were presented with visual search task to minimize carry-over effects and reduce fatigue.

[Insert Fig. 1 here.]

Procedure

After a preliminary calibration, participants were introduced to the anti-saccade task. Verbal instructions were given to the children to think of this task as an "eye movement game", where each trial would consist of the appearance of a peripheral target dot in a random location, while the objective was to avoid looking at the target and instead look as quickly as possible in the opposite direction on the screen. When the participants had understood the task, a 4-trial

training session was conducted. After these training trials, a new two-point calibration was initiated and repeated until the horizontal and vertical deviation was below 1◦ of visual angle. When sufficient calibration accuracy had been achieved, 32 actual anti-saccade trials were presented in two blocks of 16 trials each, with a short pause in-between.

On completion of the anti-saccade task, verbal instructions were given to the children that they would read six factual texts, and answer three multiple choice comprehension questions after each text. The children were instructed to read the texts carefully so that they could answer the comprehension questions as correctly as possible. Instructions were also given that each text would be presented for a maximum duration of 90 seconds, and that participants could use a hyperlink at the end of each text in order to proceed to the questions when they were ready (c.f. Fig. 1b). Finally, the children were instructed that after each reading-for-comprehension trial, they would perform a short visual search task. When the children had understood the instructions, a training trial was conducted, and afterwards a new two-point calibration was initiated and repeated until the horizontal and vertical deviation was below 1◦ of visual angle. When sufficient calibration accuracy had been achieved, 6 online reading trials were presented.

Data Analysis and Measures

The overall quality of the eye-tracking data was calculated as the average deviation between the calibrated point of regard (POR) and four validation points. The average horizontal and vertical deviation was 0.66 degrees and 0.80 degrees of visual angle respectively. The average amount of null data in the eye movement samples was 4.75% (including blinks).

Computed gaze position samples were analyzed in order to detect fixations and saccades. Different event detection algorithms were used for the anti-saccade dataset and the online reading dataset. The reason for this approach was to achieve maximum compatibility with

previous studies. Eye movement data from the anti-saccade test were analyzed by using the Engbert and Kliegel algorithm in order to detect the first saccade in each trial (Engbert & Kliegl, 2003). A minimum saccade duration of 32 ms was provided as a parameter for the detection algorithm. The first saccades were then analyzed for latency, peak velocity and direction relative to target position using a second algorithm (Ahlström et al., 2013). By contrast, eye movement data from the reading trials were first imported into the SMI BeGaze 3.5 software. Due to the 120 Hz sampling rate, the raw gaze data was analyzed using the I-DT or "low-speed" event detection algorithm. The default values of 80 ms min. duration and 100 px max. dispersion were used for detecting eye movement events in the current dataset (Holmqvist et al., 2011).

Gaze control measures. Each anti-saccade trial was categorized binomially as correct if they were terminated within a 45◦ angle in the opposite direction of the target location (Antoniades et al., 2013). The proportion of correct anti-saccades trials for each participant was then used as a measure of children's gaze control.

Advert distraction measures. Two validated advert distraction measures were calculated in each reading trial. The first measure was calculated as the number of fixations on advert areas of interest (AOIs). Fixations approximates the amount of foveal visual intake dedicated to adverts during reading (Holmqvist et al., 2011), interest towards pictorial content, and the attention retaining power of the visual design of adverts (Holmberg et al., 2014). The second measure was calculated as the number of saccades into the advert AOI. This measure was used to approximate the attention attracting power of adverts (Holmberg et al., 2014).

Text processing measures. Three widely-used text processing measures were calculated for each reading trial. First, average fixation duration was calculated, since longer fixation durations are often assumed to be positively correlated with cognitive load and increased

processing difficulty (Rayner, 1998). Second, the number of words per minute was also calculated since lower reading rate is assumed to be indicative of text processing difficulties (Rayner, 1998). Third, the total number of regressive saccades were calculated since such regressions indicate problems with understanding the meaning of the text caused by distractions (Rayner, 1998). Saccades inside the text AOI were classified as regressive if their endpoint coordinate was both to the left and above the starting point coordinate.

Reading comprehension measures. Each text was associated with three comprehension questions, with five multiple choice alternatives for each question. Reading comprehension was measured for each question as a binomial variable depending on whether the correct alternative was selected (Simola et al., 2011).

Results

The results section is divided according to the order of hypotheses presented. First, results are shown concerning the effects of advert animation on the MIL dependent measures (hypotheses H1a-c). Second, the results on the effects of children's individual level of gaze control on the MIL dependent measures are presented (hypotheses H2a-d).

Effects of Advert Animation

The overall reading comprehension scores differed considerably between adults and children. In the adult sample, the overall reading comprehension score was around 88%, while the corresponding statistic in our child sample was merely around 50%. The average time required by children to read an online text (i.e. trial duration) was just over one minute (75 s). Overall, children looked at around 60% of the adverts presented in the online reading experiment. This overall figure is considerably higher than in the adult sample, where the corresponding figure was around 27% (Simola et al., 2011). In the following sections, we will

present results showing the effects of advert animation on the dependent measures used to analyze children's media and information literacy (hypotheses H1a-c).

Animation and advert distraction. Advert distraction was measured as the amount of visual attention towards online adverts. Two advert distraction measures were used in the current study, and the results show clear effects of advert animation on both measures, c.f. Fig. 2a. The mean number of fixations on adverts was higher in the animated condition (1.95 ± 2.31 SD) compared to the static condition (1.41 ± 1.98 SD). Similarly, the mean number of saccades to adverts (or advert entries) was higher in the animated condition (0.43 ± 0.95 SD) than in the static condition (0.19 ± 0.57 SD). These effects were examined by using linear regression models in which advert condition was used as predictor of number of fixations on adverts, and saccades into adverts, respectively (subject and trial were used a random factors). These regression analyses showed that advert animation was associated with an increase in number of fixations on adverts ($t = 3.917$, $p \leq 0.001$) as well as number of saccades to adverts ($t = 3.300$, $p \leq 0.001$). Taken together, this evidence strongly supports H1a: animated adverts are in fact associated with more advert distraction compared to static adverts.

This result replicates the corresponding effects found in adults (Simola et al., 2011), but relative to adults, the child sample shows more advert fixations and fewer advert entries in both conditions, c.f. Fig. 2a. This result indicates that, overall, children tend to make fewer saccades to adverts, but in return they make more fixations while their gaze remains inside the advert area. The results concerning advert animation and advert distraction measures are also compatible with the PCMC model, which predicts that higher personal relevance (age-appropriate content) and perceptual prominence (animation) in adverts would drive attentional resources towards the adverts, even though the primary reading task is cognitively demanding (Buijzen et al., 2010). In

terms of media and information literacy, the current data suggest that children allocate more cognitive resources to task-irrelevant adverts compared to adults.

[Insert Fig. 2 here.]

Animation and text processing. Children's text processing was measured using three standard eye movement measures within reading research, but contrary to aforementioned distraction measures, advert animation did not seem to significantly affect any of these reading measures. Average fixation duration during reading was almost identical in the static condition (457.13 ± 190.23 SD) compared to the animated condition (453.61 ± 194.66 SD). Similarly, advert animation only resulted in a small numerical increase in number of regressive saccades (16.86 ± 11.60 SD) compared to the static condition (16.60 ± 10.87 SD). The third text processing measure, number of words per minute, also showed no significant difference between static adverts (124.71 ± 36.52 SD) and animated (127.99 ± 44.45 SD). The differences between advert conditions on text processing measures were analyzed using linear regression models (with subject and trial as random factors). These effects proved non-significant on average fixation duration ($t = -0.596$, $p = 0.55$), number of regressive saccades ($t = 0.621$, $p = 0.53$), and number of words per minutes ($t = 1.232$, $p = 0.22$), respectively. All in all, this evidence suggest that animated adverts does not affect children's text processing measures compared to static adverts, which supports our second hypothesis H1b.

Hypothesis H1b was formulated such that: Animated adverts will not affect children's text processing measures compared to static adverts. The motivation for this expectation was primarily that no significant effects were found on the same reading measures in adults, depending on animated or static advert stimuli (Simola et al., 2011). The explanation given for this result in adults was that, although salient right column ads occasionally captured overt visual

attention and thus interrupted the reading process, they did not affect covert visual attention and overall text processing measures. According to the PCMC model, this result is indicative of a situation when cognitive resources required by, and allocated to, the primary reading task are high, leaving few remaining resources available for salient adverts (Buijzen et al., 2010). In this sense, the current study on children replicated previous findings with adults. However, there were large overall differences in reading measures between age groups. Thus, average fixation duration was considerably higher in children (457.13 ms) than in adults (208.19 ms). Conversely, the reading rate in terms of words per minute was considerably lower in children (124.71 wpm) than in adults (216.91 wpm). Somewhat surprisingly, overall number of regressions were quite similar between children (16.60) and adults (18.20). Since shorter fixation durations and higher reading rate indicate less cognitive load associated with reading, the current study shows that text processing, as part of children's media and information literacy, is lagging behind that of adults. However, our evidence also suggests that, at age 9, children's visual text processing behavior seems to be sufficiently automatized to withstand major impact from salient concurrent online adverts.

Animation and reading comprehension. Reading comprehension is an important outcome measure in the current study. Children's reading comprehension was measured as correct or incorrect answers on three comprehension questions presented after each text. Thus, reading comprehension was encoded as a binomial variable. Since each question was associated with 5 multiple choice alternatives, the chance level of correct answers was 20%. The overall comprehension score was above chance, and the mean comprehension score was higher in the static advert condition (0.50 ± SD) compared to the animated condition (0.44 ± SD), c.f. Fig. 2b. In order to analyze the statistical reliability of this difference, a linear mixed effects model was

constructed using the glmer function for binomial response variables provided in the R software package (Bates, Maechler, Bolker, & Walker, 2013). Subject and trial number was entered as random factors. The regression analysis showed that advert animation was associated with a significant decrease in reading comprehension ($z = -2.129$, $p \leq 0.05$). This evidence fails to support H1c, and instead suggests that animated adverts actually have a high probability of impairing children's online reading comprehension.

Contrary to H1a and H1b, the results on advert animation and reading comprehension (H1c) failed to replicate similar studies on adults (Simola et al., 2011). This previous research shows that adults have a very high overall comprehension score (88%) and that this score is maintained across advert saliency conditions, while the overall comprehension score of children is about half (47%), with a significant decrease in the animated advert condition, c.f. Fig. 2b. This result extends the PCMC model by showing how perceptually prominent adverts, not only drives cognitive resources towards commercial messages, but also "de-allocates" cognitive resources needed to maintain performance levels during a primary task (Buijzen et al., 2010). Compared to adults, the reading comprehension module identifies an important vulnerability in children's MIL on commercial websites. We propose that an explanation for this age-related difference in reading comprehension resides in the developmental difference in gaze control.

Effects of Gaze Control

The children's individual level of gaze control was measured with an initial anti-saccade experiment. The overall proportion of trials containing valid eye movement data was fairly high (87.0%). However, the proportion of correct responses was low, indicating that the children had difficulties inhibiting saccades toward the distractor. The average proportion of correct saccades was 0.34, which is similar to other research in this area (Holmberg et al., 2015, 2014; Bucci &

Seassau, 2012; Fukushima et al., 2000). However, this level of gaze control is considerably lower than what would be expected in an adult population in a similar task, where success rates around 80% have been reported in recent large-scale studies (Hutton & Ettinger, 2006). Conversely, saccade latencies in the child sample were longer than what would typically be expected among adults. In correct anti-saccade trials, the average saccade latency was 444 ms (367 ms in incorrect trials), whereas the same latency measure among adults typically lies around 200 ms (Holmqvist et al., 2011). Previous research has found evidence that children's individual level of gaze control is positively associated with performance measures during task-oriented internet use (Holmberg et al., 2014). Furthermore, we also argue that the development of voluntary gaze control in children is an integral component in their MIL on commercial websites. In the following sections, results are presented concerning the effect of children's voluntary gaze control on advert distraction, text processing, and reading comprehension.

Effects of gaze control on advert distraction and text processing. In order to further investigate the effects of advert animation on advert distraction and text processing, we hypothesized that children's gaze control would be associated with less advert distraction (H2a), while text processing measures would remain relatively unaffected (H2b). In order to test these hypotheses, linear regression models were constructed in which gaze control was used as a predictor of advert distraction and text processing measures. Concerning advert distraction, these models showed that gaze control had a significant negative effect on number of fixations to adverts ($t = -2.784$, $p \leq 0.01$), while no effect was found regarding number of saccades into adverts, c.f. Fig. 3a. In effect, this means that children with higher levels of gaze control were less distracted by adverts regardless of advert animation condition, which supports hypothesis

H2a. These results are relevant for the PCMC model in as much as advert distraction (number of fixations on adverts) seems to vary on an individual level with children's gaze control.

In case of the text processing measures, linear relationships were tested between gaze control and average fixation duration, number of regressive saccades, and number of words per minute. No effects were found, thus supporting hypothesis H2b. An explorative analysis was made on one other text processing measure, saccade amplitude. This measure had a strong negative association with gaze control, meaning that higher levels of gaze control was associated with shorter reading saccades across advert conditions. Long saccade amplitudes during reading could result in words being skipped, which in turn, could have negative effects on reading comprehension. An example of long reading saccades (low gaze control) is shown in Fig. 1b.

[Insert Fig. 3 here.]

Effects of gaze control on reading comprehension. In order to further investigate the negative effect of advert animation on reading comprehension (as proved by H1c), we hypothesized that children's gaze control would be positively associated with reading comprehension (H2c), and that higher level of gaze control in children would moderate negative effects of advert animation on reading comprehension (H2d). In order to test which of these alternatives that provided the best fit of the observed comprehension scores, a linear mixed effects model was constructed using the glmer function for binomial response variables provided in the R software package (Bates et al., 2013). Since reading comprehension can be considered a performance measure, on which process measures such as advert distraction and text processing can have causal effects, we decided to add the advert distraction measures into the regression model. No text processing measures were included since they did not vary significantly with

advert saliency conditions. Subject and trial were entered as random factors. The results of this regression analysis are presented in Table 1.

[Insert Table 1 here.]

In order to evaluate the effect of gaze control, a preliminary model was created without this factor included (Model 1). This model was tested against a null model with intercept only. As can be seen in Table 1, Model 1 fails to account for the significant negative effect of advert animation on comprehension. In Model 2, gaze control was added as a mediator of comprehension. This model still fails to account for the negative effect of advert animation, and thus gaze control does not mediate the effect of advert animation on comprehension. Additionally, deviance is not significantly better than in the previous case. In Model 3, an interaction between advert animation and gaze control was added. This model introduced two effects: 1) The negative effect of advert animation on reading comprehension became stronger than previously described ($z = -2.684$, $p \leq 0.01$), and 2) A significant positive interaction between advert animation and gaze control was revealed ($z = 2.107$, $p \leq 0.05$), indicating that children with higher levels of gaze control achieved higher comprehension scores in the animated condition. Pairwise comparisons of these models suggest that the best model fit is achieved when an interaction between advert animation and gaze control (Model 3). This allows us to discriminate between our last hypotheses. The hypothesis that gaze control would have a positive effect on reading comprehension can be rejected (H2c), and the hypothesis that gaze control in children would moderate negative effects of advert animation on reading comprehension can be accepted (H2d).

Since reading comprehension was encoded as a binomial variable, the logistic regression analyses produced model estimates on the logit scale (Crawley, 2014). In order to visualize the

interaction described in Model 3, these logit estimates were used to calculate children's probability of correct reading comprehension using the plogis function in the R software. The probability of correct reading comprehension were then plotted against children's individual level of gaze control, both in the static advert condition, and in the animated condition. In Fig. 3b, it is shown how the effect of advert animation on reading comprehension depends on individual level of gaze control. In terms of the PCMC model, this evidence suggests that children process commercialized media content differently depending on their individual level of gaze control and the perceptual prominence of online adverts. The current analysis identifies a vulnerable group of children with low gaze control.

Discussion

Websites targeting child audiences are often commercial in nature, which means that children are likely to be exposed to salient online advertising while using the internet to gather information or perform other tasks. In this study we introduced an online reading-for-comprehension task for investigating children's MIL on commercial websites. In order to provide meaningful quantitative evidence about this competency, we replicated the experimental methods used for investigating the impact of salient adverts on adults' reading performance. By using the same advert saliency conditions (static, animated) and the same measures of visual attention, we were able to quantify some key aspects of children's MIL and compare the outcomes to an adult population. Objective and reliable measures of advert distraction and task performance are necessary conditions for evaluating how children interact with commercial web pages, and which concrete interventions can be applied in order to improve their online task performance. From a theoretical perspective, our research suggests how current media reception theories, such as the processing model of commercial media content (PCMC) can be

operationalized and tested in terms of advert distraction measures. Furthermore, the current research suggest an interdisciplinary approach to operationalizing and measuring the basic internet interaction components of children's MIL under ecologically valid conditions.

Effects of Advert Animation in Children and Adults

The current study investigated the effects of animated online adverts on children's task-oriented internet use (hypotheses H1a-c). In order to compare the effects of advert saliency between age groups, the current study replicated the methods used in psychological research on adults (Simola et al., 2011). In terms of advert distraction measures, we found that advert animation had similar effects on visual attention across age groups. Thus, animated adverts was associated with significant increases in fixations on adverts and saccades to adverts in both children and adults, compared to static adverts (H1a). However, children made fewer saccades to adverts than adults overall, but conversely, they made more fixations on adverts overall. From a cognitive load perspective, this result suggests that the online reading task may have been more demanding for children, causing them to make fewer attentional shifts towards adverts than adults. Conversely, the age appropriate content and perceptual prominence of the adverts may have stimulated children's interest, causing them to devote more dwell time (or attentional resources) on the adverts compared to adults, i.e. the adverts exerted a stronger attention retaining power on children (Holmberg et al., 2014). The cognitive and attentional implications of this difference in "advert distraction profiles" between children and adults merits closer examination in future research.

In terms of text processing measures, previous research on adults found negligible effects of animated online adverts. In order to extend this research to children's online reading, three commonly used reading measures were investigated: 1) average fixation duration (cognitive

load); 2) number of regressive saccades (understanding context); and 3) reading rate (reading proficiency). Similarly to adults, the present results on children showed that none of these text processing measures were affected by advert animation (H1b). This might indicate that the text processing measures associated with reading have already become quite automated in children at 9 years of age, and that advert animation is not capable of altering these visual processes. In previous research on adults, this results was explained such that salient online adverts exert an effect on overt visual attention (advert distraction measures), rather than covert attention (text processing measures) (Simola et al., 2011). In terms of text processing, this interpretation might also be valid for children, but in terms of reading comprehension, the current study shows an important difference between age groups. While adults' reading comprehension was generally high, and unaffected by advert animation, children's reading comprehension was relatively low, and was also negatively impacted by animated adverts (H1c). This indicates that advert animation may capture children's covert visual attention and interfere with reading comprehension to a significantly larger extent than in adults. Since reading comprehension is a critical outcome measure of children's MIL on commercial websites, the current study also investigated the interaction between advert animation and children's gaze control.

Children's Gaze Control and Reading Comprehension

The current study investigated the role of gaze control in children's MIL on commercial websites (Holmberg et al., 2014, 2015). First, the independent effect of gaze control on advert distraction and text processing was investigated (hypotheses H2a-b). Second, we investigated if gaze control mediated or moderated the effect of advert animation on children's reading comprehension (hypotheses H2c-d). Consistent with previous research, we found that higher levels of gaze control in children were strongly associated with lower levels of advert distraction

(H2a). Thus, we found a significant negative association between gaze control and number of fixations on adverts, as well as number of saccades to adverts (Holmberg et al., 2014, 2015). Thus, there is strong evidence that suggest large individual differences in gaze control among children, and that children with higher levels of gaze control, in general dedicate lower amounts of attentional and cognitive resources to processing commercial media content. Given the fact that children with lower gaze control get more exposed to online advertising, an interesting topic for future research would be to investigate the long term effect of this exposure, e.g. in terms of recognition and recall of adverts. Gaze control was not related to any of the reading measures (H2b), except saccade amplitude. The impact of this reading measure on advert distraction and reading comprehension should be studied further.

As we have argued previously, reading comprehension is an important outcome measure of children's MIL on commercial websites since this measure is a clear indicator of children's task performance. In contrast to adults, our results provided evidence that advert animation in itself have a significant negative effect on children's reading comprehension. However, since higher level of gaze control in children have proved to be a strong predictor of better task performance, the current research set out to examine if it was the case that gaze control benefits task performance independently (mediator), or if this measure interacts with the saliency level of commercial messages (moderator). Using reading comprehension as binomial dependent variable, a logistic regression analysis showed that gaze control did not mediate reading comprehension directly (H2c), but that it in fact moderated the negative effects of advert animation (H2d). In effect, this means that children with better developed gaze control are able to perform equally well in terms of task performance regardless of the saliency level of online adverts, while children with lower gaze control suffer a considerably demininshed ability for

reading comprehension when the advertising context is high in visual saliency. If these results are replicated in future studies, an implication would be that the anti-saccade task could be used as a pedagogical tool, both for evaluating and training children's MIL on commercial websites.

Children's MIL on Commercial Websites

This study shows that current media research models of children's processing of commercial messages (PCMC) can be operationalized and tested by using quantitative measurements of children's visual attention in an experimental web surfing task. The focus on how commercial messages affect and distract young audiences is important since advertising penetrates these media channels so deeply. However, the current study also suggests key aspects through which existing models of how children process commercial content can be extended in order to provide evidence-based research on the broader issue of children's online media and information literacy. This broadened perspective can be achieved by introducing a task-oriented research paradigm, which allows us to measure and monitor children's task solving process as well as their task performance (and how these measures are related). In response to UNESCO's call for further research on children's MIL, we suggest that our current research paradigm should be applied to other "literacy modules" such as advertising literacy, information search, and humlan-computer interaction. In doing so, we have a chance to improve the internet for future generations.

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Tables and Figures

Table 1

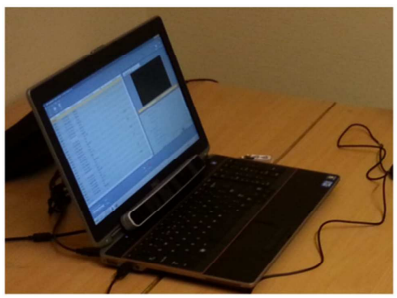
Regression Models Including Predictors of Children's Reading Comprehension.

Predictors	**Model 1**		**Model 2**		**Model 3**	
Level 1	z value	p value	z value	p value	z value	p value
(Intercept)	0.412	0.681	-0.589	0.556	0.621	0.534
Adv. Condition (animated)	-1.808	0.071	-1.828	0.068	-2.684	0.007
Adv. Number of fixations	-2.320	0.020	-2.171	0.030	-2.068	0.039
Adv. Number of saccades	1.259	0.208	1.199	0.230	1.083	0.279
Level 2						
Subj. Gaze control			0.951	0.342	-0.500	0.617
Cross level						
Adv. Condition (animated) × Subj. Gaze control					2.107	0.035
Model deviance	1398.2 (p = 0.02)		1397.3 (p = 0.35)		1393.0 (p = 0.04)	

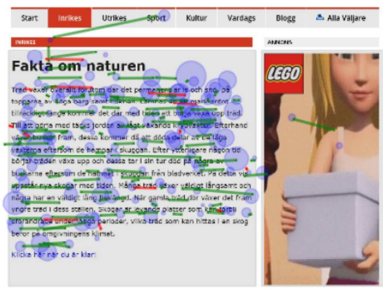
Model 1-3 include random effects of participant and trial. In logistic regression, z-values are given to indicate the direction of linear effects (instead of t-values), and coefficients are given on the logistic scale, and have therefore been excluded.

Figure 1

Unobtrusive single-computer setup used for stimulus presentation and data recordings. Eye movement data relative to web pages and online adverts were analyzed into fixations and saccades.



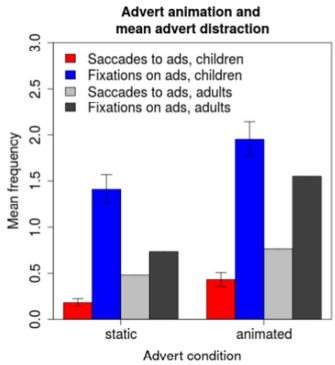
(a) **Data recordings.** A remote eye-tracking device (SMI RED-m) was installed in the school environment. The device consisted of an ordinary DELL laptop computer that was used for both stimulus presentation and eye movement recordings. The eye-tracking camera was placed in the laptop fold, between the screen and the keyboard.



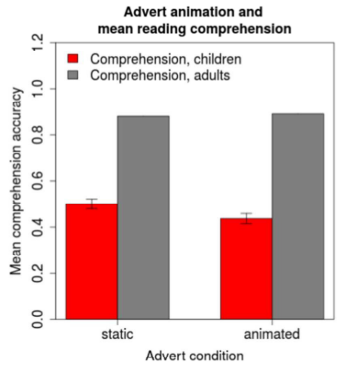
(b) **Web page stimuli.** A factual text was shown in the main column, while experimental adverts were presented in the right column. Eye movement data from one participant have been superimposed on the stimulus. Fixations are represented as blue circles, while saccades are shown as green lines. Red lines indicate regressive saccades.

Figure 2

Advert animation was associated with an increase in distraction measures and a decrease in reading comprehension. These effects appear to be stronger in the child sample compared to adults. (Adult sample from Simola et al., (2011), Experiment 1, conditions S+S and S+A.)



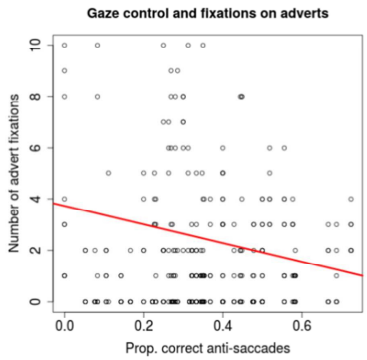
(a) **Advert distraction.** Both fixations on adverts and saccades into adverts (number of entries) increased with advert animation, among children as well as adults (gray bars). But children tended to make fewer saccades into adverts and more fixations on adverts compared to adults.



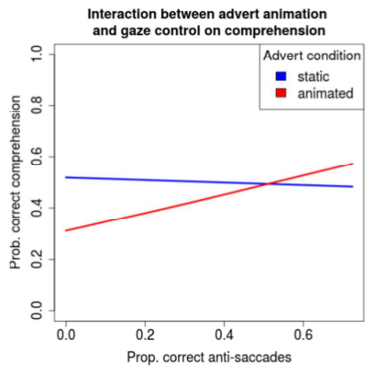
(b) **Reading comprehension.** Children's overall average reading comprehension was low compared to adults, and decreased with advert animation. In adults, the overall average reading comprehension was very high and did not vary significantly with advert animation (gray bars).

Figure 3

Effects of children's gaze control on advert distraction and reading comprehension. Higher level of gaze control predicted less advert distraction and better chances of answering text comprehension questions correctly.



(a) **Advert distraction.** A negative relation between advert distraction and gaze control was found. Children with lower levels of gaze control made a significantly higher number of fixations on adverts regardless of advert condition, while children with higher levels of gaze control made fewer fixations on adverts in general.



(b) **Reading comprehension.** Children with higher levels of gaze control (right side) had an equally high probability of correct reading comprehension regardless of advert saliency condition, while children with lower gaze control (left side) had a siginificant decrease in expected comprehension accuracy in the animated condition.

Paper IV

Children's attention management on commercial websites: Effects of task type and advert prominence

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Abstract

Many commercial websites used by children present them with mixed messages in terms of task-relevant information and task-irrelevant online display advertising. Previous research has described this situation as a potential conflict between two models: communication as information transmission (text, images) and communication as attentional capture (advertising). This present experiment was designed in order to investigate how children cope with salient online advertising while engaging in task-oriented website interaction. 57 children in 3rd grade (9-year-olds) participated in the experiment. Each participant was introduced to a mock-up website and was instructed to solve two types of online tasks: reading for comprehension and information search. The web pages used by the children contained both task-relevant textual information as well as task-irrelevant online display advertising. The adverts were presented in two saliency conditions: static and animated. In order to obtain detailed data about how online advertising affected children's advert distraction across online task types, we measured their visual attention continuously using non-invasive eye-tracking equipment. The eye movement data were used to differentiate task types in terms of cognitive load, and to construct an advert distraction measure. Pupil dilation data were used to measure children's cognitive load and fixation location data were used to measure attentional advert distraction. The results of the study showed that animated online adverts reliably caused increases in both task-related cognitive load and advert-related fixations compared to static adverts. However, the results also showed that children's level of advert distraction differed between task types, such that advert distraction was higher during task types associated with lower cognitive load (reading for comprehension). The results are discussed in relation to existing cognitive load theory, as well as current media and communication research.

Keywords: children, online advertising, attention management, visual attention, cognitive load, advert distraction, visual saliency, task types, task-orientation

Children's attention management on commercial websites: Effects of task type and advert prominence

Introduction

The world wide web of commercial websites seems to fit several of the models of mass communication proposed by McQuail (2010). In this study, we focused on a particular type of commercial website that has the primary function of transmitting (textual) information to its online users (the transmission model of communication) (chandler 1994), while simultaneously also presenting display advertising in order to gain the attention and interest of potential consumers (the publicity model of communication) (Turow, 2011). This type of website fits a large portion of the news sites available on the internet, but conceivably, many online video sites, social media, and online search services could also fall into this website category. Mixed messages in the form of commercial and editorial content is common on the internet, and most users have grown accustomed to the human-computer-interaction scenario of e.g. reading a news article in the main column of a web page, while banner advertising is presented in the spatially adjacent right column. Although many adult users might perceive such real-life situations as a nuisance, they usually have the cognitive capacity to focus on the task-relevant information presented on websites, while filtering out most of the "noise" coming from task-irrelevant adverts. Children's cognitive resources, however, are known to be more limited, and thus the purpose of this study was to investigate how online advertising affected several communication outcomes in children while they engaged in two types of task-oriented interaction with commercial websites.

Current research on children's internet usage habits shows a growing trend in the amount of time that children spend online. [number of hours in Sweden, western world] While younger children mostly use the internet for entertainment purposes (online video and online gaming), an interesting shift in internet usage patterns occur in children aged around 8-10 years. In this age group, children start using the internet for more task-oriented purposes, e.g. social media, searching for information, and other school-related activities. A possible reason for this change in internet habits towards a more functional usage is that children in this age group undergo

significant cognitive developments which enable them to engage in more task-oriented internet use. This cognitive developments are driven by growth in the prefrontal brain regions, which enhances several executive functions required by task-oriented behavior (Lapierre, 2013; Moses & Baldwin, 2005). The emergence of task-oriented internet use raises questions about how children [are able to handle commercial websites, conflict, split attention, gaze control measure]

Media effects and communication outcomes

Online advertising adheres to the media logic of the so-called publicity model of communication inasmuch as the primary intended effect of display advertising generally is to catch and hold users' visual attention in the short-term perspective (McQuail, 2010). [maximizing quantity of attention under competition] More long-term and indirect effects such as positively influencing consumers' brand attitudes purchase behaviors are of course desirable, but such effects have proved considerably more difficult to measure and determine (). Thus, the intended communication outcomes of the publicity model used by online advertising are largely summed up in terms of so-called hierarchy of effects models, such as AIDA (attention, interest, desire, action) or CAB (cognition, affect, behavior). According to these advertising models, successful short-term media effects on the lower levels, such as visual attention, act as prerequisites for improved long-term outcomes higher up in the effect hierarchy.

By contrast, the transmission model of communication describes processes of transporting information from sender to receiver over some kind of channel (McQuail & Windahl, 2015). As opposed to the publicity model of advertising, the transmission model of communication is more associated with communicative situations in which the effectiveness of communication is crucial, such as news reporting, educational materials, and other types of task-oriented media interaction. It follows that the transmission model of communication is also associated with different communication outcomes as compared to advertising. Typical communication outcomes under the transmission model of communication has to do with effective reconstruction of information between sender and receiver, e.g. reading comprehension and information search. In this study,

we were interested in how children are affected by commercial websites that simultaneously adhere to both the transmission model and the publicity model of communication, which exposes children to conflicting communication intentions.

Commercial websites and eye movements

In the current study, we presented children with mock-up versions of commercial websites which consisted of web pages featuring both informational content (factual texts) along with adjacent commercial content (online display adverts). The web pages thus combined the transmission model of communication with the publicity model. On each such web page, we instructed the children to successively perform two interactive tasks: reading for comprehension and information search. The children performed these web-based tasks individually while their visual attention was recorded using eye movement measurements. The purpose of this procedure was to investigate empirically to what extent the intended effect of online advertising (visual attention) conflicted with the intended communication outcomes of information transmission (text processing and reading comprehension). In other words, an overarching research question in this study was to uncover if the intended effects of online advertising could have unintended effects on children's online reading outcomes (i.e. online advert distraction).

When designing this study, we utilized a research framework developed within recent media psychological research in order to investigate children's processing of commercial media content, referred to as the PCMC model (). According to this model, children around the age 8–10 years have the ability to identify advertising and understand persuasive intent, but these competencies have not reached the level of flexibility found in adults, which can render children more susceptible to advertising. More importantly, the PCMC model predicts that communication outcomes on commercial websites will depend on an interplay between online advertising saliency and the amount of cognitive resources required by contextual factors such as online tasks. When highly salient advertising (e.g. animation) co-occurs with online tasks that are demanding (e.g. reading-for-comprehension), children are expected to allocate high levels of

cognitive resources towards adverts (visual attention) although the task-oriented context requires these cognitive resources. Such situations may then result in cognitive overload in children (), which in turn may be associated with higher advert distraction and lower task performance. Apart from advertising saliency factors and contextual factors such as online task type, the PCMC model emphasizes that communication outcomes on commercial websites also depends on individual and developmental factors, such as children's individual level of executive function, which is referred to as conditional media effects (Valkenburg, Peter, & Walther, 2016).

In the current study, we used static and animated online adverts to systematically vary advertising saliency on web pages that children used for task-oriented website interaction, and we used two different task types to vary the level of cognitive resources required by the interaction context (reading-for-comprehension and information search). Furthermore, we used behavioral and physiological tests to control for children's individual level of executive function. Several communication outcomes of children's website interaction were measured: 1) task performance was measured as reading comprehension scores and information search accuracy, and 2) advert distraction was measured as visual attention on online adverts and task-related cognitive load. Thus, the advert distraction measures were constructed using eye movement measurements from children's real-time website interaction.

Task types and cognitive load

In the terminology of cognitive load theory, the workload inherent in various cognitive tasks is called intrinsic load, while workload associated with task-irrelevant distractors is called extraneous load (). During interaction with commercial websites, task-irrelevant adverts could represent an important source of extraneous load in children. Media psychological models suggest that the cognitive resources required to interact with web pages depend on the context of internet use. Whereas free or undirected internet use is often characterized by low resource requirements, highly task-oriented or directed internet use requires greater resource allocation. Following the theory of limited cognitive capacity, the PCMC model further suggests that salient

online advertising will compete with web-based tasks for children's allocation of cognitive resources, and that such situations may result in higher cognitive load. In order to test this claim empirically, the current research measured children's cognitive load while interacting with commercial websites by means of measuring their pupil size. Several studies within cognitive psychology confirms that larger pupil diameter in adults is reliably associated with higher cognitive load (). Studies on such task-evoked pupillary responses suggest that task types involving high demands on working memory and language processing are associated with the highest levels of cognitive load. Based on this previous research, this study tested the hypothesis that the online reading-for-comprehension task type would cause higher levels of intrinsic cognitive load in children compared to the information search task type (H1a). We also tested the hypothesis that salient animated online advertising presented concurrently with the online tasks would give rise to an additional extraneous load compared to less salient static adverts (H1b).

- H1a: Reading tasks will be associated with higher levels of task-related cognitive load (average pupil size) than information search tasks.
- H1b: Animated adverts will be associated with higher levels of task-related cognitive load (average pupil size) than static adverts.

Task types and advert distraction

Based on research on task-evoked pupillary responses, the previous section hypothesized that reading-for-comprehension tasks would be associated with higher levels of intrinsic cognitive load than information search tasks (H1a). This assumption, that cognitive load differs depending on task type, leads to a second set of hypotheses. Since the PCMC model incorporates the theory of limited cognitive capacity, this model also predicts that task types that require children to allocate high levels of cognitive resources towards solving the task will be associated with lower levels of cognitive resources available for allocation to online adverts. This is also stated by the load theory of attention (Lavie, 2005). In order to test this prediction in terms of visual attention, this study measured children's resource allocation to advertising during task processing as the

number of fixations targeting the online adverts on each web page stimulus. Since the adverts were completely task-irrelevant, resource allocation to adverts in the form of fixations on adverts, was defined as a measure of advert distraction. However, not only the intrinsic load of the task can be expected to determine the the amount of advert distraction. Several studies within applied psychology shows that when online task type is kept constant, the visual saliency of adverts have a strong positive relation to the number of fixations on adverts (Holmberg, Holmqvist, & Sandberg, 2015; Kuisma, 2015; Simola, Kuisma, Öörni, Uusitalo, & Hyönä, 2011; ?, ?). Confirmation of the intended effects of hierarchy of effects models. Based on this research, the present study hypothesized that online tasks associated with high intrinsic cognitive load, such as reading-for-comprehension tasks, would cause lower levels of advert distraction in children (H2a). We also hypothesized that online adverts associated with high levels of visual attention, such as advert animation, would cause higher levels of advert distraction (H2b).

- H2a: Reading tasks will be associated with lower levels of advert-related distraction (number of fixations) than information search tasks.
- H2b: Animated adverts will be associated with higher levels of advert-related distraction (number of fixations) than static adverts.

Individual differences and gaze control

According to the PCMC model and other media psychological theories, communication outcomes and media effects are primarily dependent on three factors: 1) the context of media use, e.g. type of online tasks that children engage in, 2) properties of the media message, e.g. advert animation and other types of visual saliency, and 3) individual differences pertaining to the media user, e.g. children's individual level of executive function (Valkenburg, 2004). In this section, we address the third and final factor in that we consider measures of children's cognitive development when investigating the effects of online advertising on children's cognitive load and advert distraction. When it comes to finding indicators of children's individual level of cognitive development, a growing body of research stress the importance of utilizing measures of executive

function, especially in media and advertising research involving children around 8–10 years (Lapierre, 2013; Moses & Baldwin, 2005). The reason for this is that executive function is closely related to prefrontal brain growth, which undergoes rapid development in this age group, and which therefore is potentially a more sensitive measure than other demographics such as age and gender. In order to measure children's executive function, we used a standardized physiological method called an anti-saccade task (Antoniades et al., 2013). This task measures children's ability to inhibit a reflexive eye movement (saccade) towards a peripheral distractor, and instead make a voluntary eye movement in the opposite direction (anti-saccade). The average number of successful anti-saccades elicited in an individual provides a reliable measure of inhibitory control and general executive function (Holmberg et al., 2015; Holmberg, Sandberg, & Holmqvist, 2014). This measure was called gaze control, and we hypothesized that higher levels of gaze control in children would be associated with lower levels of intrinsic and extraneous load (H3a). We also tested the hypothesis that higher level of gaze control would be associated with lower levels of advert distraction (H3b).

- H3a: Higher levels of gaze control in children will be associated with lower levels of task-related cognitive load (average pupil size).
- H3b: Higher levels of gaze control in children will be associated with lower levels of advert-related distraction (number of fixations).

Methods

Participants and apparatus

In order to ensure good ecological validity of the data, all parts of the study were undertaken in the children's school environment. The participants were recruited from three parallel 3rd grade classes in a Swedish public school (N = 57). The recruitment phase was initiated in November 2014 and was completed in January 2015. Parental consent forms were distributed in the school classes, and we received written consent from all caretakers of the children that

participated in the study. Before entering into the study, each child was also asked verbally for individual consent. The children were presented with a cover story about participating in a study on internet surfing, and our research questions about online advertising was not mentioned. The children had mixed ethnic backgrounds, but were all fluent in Swedish. The age of our participants varied between 9 years (55) and 10 years (2). The gender distribution was fairly equal between boys (27) and girls (30). No participants were excluded due to insufficient data quality.

The children participated in two subsequent experiments: 1) an anti-saccade task to measure individual level of gaze control, and 2) two types of task-oriented website interaction in which distraction from online advert was measured. In both experiments, eye movement data were registered using an SMI RED-m laptop system (Intel Core i7-2640M CPU @ 2.80 GHz, 4.00 GB RAM). The eye-tracking camera was placed in the laptop-monitor fold, and was connected to the computer via a USB port, and the participants' eye movements were recorded at 120 Hz using the SMI iView RED-m 3.2 software (cf. Figure 1a). The geometry of the eye movement recordings consisted of the laptop LCD screen with the physical dimensions of 474 $\times$ 296 millimeters (the screen resolution was 1600 $\times$ 900 pixels), and the distance between the laptop screen and the participants' eyes was set at 639 mm. Stimuli presentation was handled using the SMI Experiment Center 3.5. Web page stimuli were presented using Microsoft Internet Explorer 11, and participants navigated through the web pages using an optical USB mouse (keyboard interaction was not needed). The laptop computer was connected to the internet through a wireless 4G router. Along with the eye-tracking data, the SMI software suite also recorded synchronized triggers for trial onsets (page completely rendered) and offset (user mouse clicks). Thus, network latencies in the setup could be controlled for.

[Insert Figure 1 here.]

Study design and materials

In order to investigate children's task-oriented interaction with commercial websites, we constructed a number of mock-up web pages which presented a short factual text in the central

main column and an online advert in the spatially adjacent right column. The web pages were designed to mimic a Swedish online news site for children (8sidor). Six texts were selected from the International Reading Speed Test (Trauzettel-Klosinski & Dietz, 2012), which were highly similar in terms of word count (149 words), text difficulty, and subject area (natural sciences). Each text was presented on a separate web page that also contained an online advert. Thus, six online adverts were constructed using commercial videos from the Youtube channel of the LEGO company. Three such videos were selected, and presented in a static (low saliency) and an animated (high saliency) advert condition. The six resulting web pages containing a factual text and an online advert were also presented in two task type conditions: reading-for-comprehension (high intrinsic load) and information search (low intrinsic load). These task type conditions were constructed such that each web page was first presented in the reading-for-comprehension condition and subsequently in the information search condition. In between each of these tasks the participants were presented with a distractor task to avoid carry-over effects. Thus, each task type condition was repeated six times, and the two advert saliency conditions were repeated three times within each task condition (or six times in total across task types). The presentation order of the texts was randomized as well as the combination of text and advert saliency condition. However, the order between task types was fixed. Since each participant was presented with all conditions in a total of 12 task-oriented website interaction trials, the whole study design consisted of a 2 (task type) x 2 (advert saliency) within-subjects repeated measures design. See Figure 2 here.

[Insert Figure 2 here.]

Task-oriented website interaction was elicited by introducing the participants to a mock-up website that consisted of a sequence of web pages that was navigated by clicking hyperlinks on each web page. The web pages were linked such that the participants read each of six factual texts twice under two successive task conditions: 1) in the reading-for-comprehension tasks children were instructed to read the text carefully for a maximum duration of 90 seconds in order to answer three multiple-choice comprehension questions presented on a subsequent web page, and

2) in the information search tasks participants were presented with a single word from the previously read text, and instructed to search for this word in the text and click on it within 30 seconds. In between these two task types, the participants were presented with an unrelated distraction task (max duration 60 sec) in order to minimize the possibility of memorizing the spatial location of words in the texts (i.e. a carry-over effect between the reading-for-comprehension task and the information search task). Crucially, in both task types, the right column advert area was designed as a completely task-irrelevant distractor.

In order to measure each participants' individual level of gaze control, a pre-test anti-saccade task was administered. In each trial, a central fixation cross was replaced by a peripheral target, and participants were instructed to look in the opposite direction relative to the target location. After four practice trials with verbal instructions, a series of 32 anti-saccade trials were presented to each participant. The stimulus parameters of the anti-saccade test were chosen in accordance with recently suggested standards (Antoniades et al., 2013). Thus, the test was designed with no temporal gap between central fixation offset and target onset. The central fixation foreperiod was set to a duration of 1500–2000 ms, and the target duration was set to 1000 ms. After target offset, a blank screen was presented for 500 ms. Targets were presented in four randomized locations (top, bottom, left, and right) at an eccentricity of ca 10° from the central fixation cross. To reduce retinal fatigue in the children, the stimuli were constructed as white objects on a dark background.

Procedure

The first step of the procedure introduced the participants to the anti-saccade task. The children received verbal instruction to think of the anti-saccade task as "a game played with the eyes", in which each trial started with the the appearance of a peripheral dot in a random location on the stimulus screen. The objective of the game was described as avoiding to look at the target dot and instead look as quickly as possible in the opposite direction on the screen. When the participants had understood the task, a four-trial training session was performed. After these

practice trials, a two-point calibration was initiated and repeated until the horizontal and vertical deviation was below 1° of visual angle. When sufficient calibration accuracy had been achieved, 32 actual anti-saccade trials were presented in two blocks of 16 trials each, with a short pause in-between.

The second step of the procedure introduced the children to the website interaction tasks. Verbal instructions were given that they would interact with six short factual texts in two different task types, and that they would start with a practice trial exemplifying each task type. The stimulus program was started and a web browser automatically navigated to the reading-for-comprehension practice trial. Before starting the trial, the children were instructed to read the texts carefully so that they could answer the following comprehension questions as correctly as possible. They were also instructed that the text would be presented for a maximum duration of 90 seconds, and after that the browser would automatically redirect to a web page containing three multiple choice comprehension questions. Instructions were also given that they could use a hyperlink at the end of the text that would take them directly to the questions, in case they finished reading before the maximum duration (cf. Figure 2). The reason for this procedure was to accommodate for variations in reading speed among 9-year-olds (Trauzettel-Klosinski & Dietz, 2012; Johansson, Pansell, Ygge, & Seimyr, 2014).

When the participants had completed training for the reading-for-comprehension task, they navigated to a web page containing instructions for the distraction task. After the distraction task, the web page automatically redirected to a web page that introduced the practice trial for the information search task. On this web page, the participants were presented with a single word that had occurred in the text read in the previous task. Instructions were given to search for the target word somewhere in the text and click on it within 30 seconds. If the information search task had not been completed within 30 seconds, the trial was ended, and the web page automatically redirected to the next reading-for-comprehension task. When the children had understood and completed all practice trials, a new two-point calibration was initiated and repeated until the horizontal and vertical deviation was below 1° of visual angle. After this final calibration, the

actual trials commenced, and the experiment leader receded to a nearby chair.

Data analysis and measures

The overall quality of the eye-tracking data was calculated as the average deviation between the calibrated point of regard (POR) and four on-screen validation points. The average horizontal and vertical deviation was 0.66 degrees and 0.80 degrees of visual angle respectively. The average amount of null data in the eye movement samples was 4.75% (including blinks).

Computed gaze position samples were analyzed in order to detect fixations and saccades. Different event detection algorithms were used for the anti-saccade dataset and the online reading dataset. The reason for using different event detection approaches was to achieve maximum compatibility with previous studies. Eye movement data from the anti-saccade test were analyzed by using the Engbert and Kliegel algorithm in order to detect the first saccade in each trial (Engbert & Kliegl, 2003). A minimum saccade duration of 32 ms was provided as a parameter for the detection algorithm. The first saccades were then analyzed for latency, peak velocity and direction relative to target position using a second algorithm (Ahlström et al., 2013). By contrast, eye movement data from the reading trials were first imported into the SMI BeGaze 3.5 software. Due to the 120 Hz sampling rate, the raw gaze data was analyzed using the I-DT or "low-speed" event detection algorithm. The default values of 80 ms min. duration and 100 px max. dispersion were used for detecting eye movement events in the current dataset (Holmqvist et al., 2011).

Eye movement data collected from children's task-oriented interaction with commercial web pages were processed in order to extract individual fixations for all participants and all trials. Using so-called area of interest analysis (Holmqvist et al., 2011), each fixation was then labeled as task-related (if the fixation was located on the task-relevant central text area) or advert-related (if the fixation was located on the task-irrelevant right-hand advert area). This dataset of labeled fixations was then further analyzed in order to extract two dependent measures. *Cognitive load* was calculated using only task-related fixations. Each fixation was associated with a number of

attributes such as duration in milliseconds and pupil dilation in pixels (cf. Figure 1a). The cognitive load measure was calculated as the average pupil dilation in pixels for each participant and each trial, thus yielding a total of 684 measurements. *Advert distraction* was calculated using only advert-related fixations (located on the advert area). This measure was calculated by dividing the total number of fixations on the advert in each trial with the duration in minutes of the associated trial. Advert distraction was calculated as a relative measure in order to compare it across task types with different maximum durations. A total of 684 observations was registered.

Results

The web pages used by children in this study were designed according to two experimental conditions. These web pages contained a central task-relevant text area and a right-hand task-irrelevant display advert. Before each interaction with the web pages, the participants were given a task instruction. *Task type* thus constituted a factor with two levels, reading-for-comprehension and information search. In order to test the effect of advert prominence on children's visual behavior, we varied the visual saliency of the display adverts presented on the web pages. *Advert prominence* constituted a factor with two levels, static and animated content. Based on previous research we also decided to include an indicator of children's inhibitory control as a predictor (control variable) of their advert distraction. *Gaze control* was measured as the proportion of correct anti-saccades trials for each participant. The results describe the effects of these three independent variables (task type, advert prominence, and gaze control) on two dependent measures which are indicative of children's attention management on commercial websites: cognitive load and advert distraction.

The first part of the results summarizes the descriptive statistics on children's task performance and attention management measures. Since task performance measures are specific for each task type, they cannot be compared across task types and used as a dependent measure. These results also include descriptive statistics on children's level of gaze control, which was used as indicator of their individual level of inhibitory control and executive function. The second part

of the results focuses on children's cognitive load as an attention management measure. It was hypothesized that higher levels of cognitive load would be caused by reading tasks as compared to information search tasks (H1a), and by animated online adverts as compared to static adverts (H1b). It was also expected that children's individual level of gaze control would have a general decreasing impact on levels of cognitive load (H3a). The final part of the results focuses on advert distraction as the second attention management measure. It was hypothesized that higher levels of advert distraction would be caused by information search tasks as compared to reading tasks (H2a), and by animated online adverts as compared to static adverts (H2b). In addition, it was expected that higher levels of gaze control in children would be associated with lower levels of advert distraction (H3b).

Task performance measures

Children's website interaction was measured both in terms of task performance and attention management. The main performance measure was defined as task accuracy, and this measure was analyzed as a binomial variable depending on correct or incorrect solution to each task. The second performance measure analyzed was trial duration measured in seconds. However, since none of these two task performance measures can be meaningfully compared across reading-for-comprehension tasks (comprehension scores) and information search tasks (target localization), mean task performance measures are only presented depending on advert prominence for each task.

[Insert Table 1 here.]

Since it is uninformative to compare different task types such as reading-for-comprehension and information search in terms of task accuracy, the only performance measure analyzed was trial duration measured in seconds. The average trial duration in the reading-for-comprehension task (74.56 $\pm$ 17.14 SD) was considerably higher than in the information search task (23.39 $\pm$ 7.77 SD), which partly reflects the fact that these task types required different amounts of time and also had different maximum trial durations (90 seconds for reading, and 30 seconds for

information search).

Attention management measures

Cognitive load and advert distraction were used as indicators of children's attention management on commercial websites. Cognitive load was measured as average pupil dilation in pixels while solving online tasks (cf. Figure 1b), and advert distraction was measured as the number of fixation on online adverts presented concurrently with the tasks. Descriptive statistics of these attention management measures show that they varied depending on task type (reading vs search) and advert prominence (static vs animated), see Figure 3. Task-related cognitive load was higher during information search trials (15.05 $\pm$ 2.00 SD) than during reading-for-comprehension trials (13.98 $\pm$ 1.81 SD). Similarly, average cognitive load was slightly higher when the right column advert was animated (14.57 $\pm$ 1.95 SD) than when the advert was static (14.46 $\pm$ 2.00 SD). The task type condition and the advert prominence condition was combined in a 2 $\times$ 2 experimental design, and average cognitive load in each condition is shown in Figure 3a.

[Insert Figure 3 here.]

The second indicator of children's attention management on commercial websites was advert distraction. Advert distraction was measured as the average number of fixations on task-irrelevant adverts in each trial relative to trial duration in minutes. As opposed to cognitive load, advert-related fixations were higher during reading-for-comprehension tasks (2.64 $\pm$ 5.39 SD) than during information search (0.88 $\pm$ 3.18 SD). Also, advert distraction was higher in trials with high advert prominence (2.47 $\pm$ 5.56 SD) than in trials featuring static adverts (1.06 $\pm$ 2.97 SD). Average advert distraction in each task type and advert prominence condition is shown in Figure 3b.

Effects on cognitive load

We hypothesized that task type and advert prominence would cause effects on children's cognitive load, such that reading-for-comprehension tasks would cause higher cognitive load than information search tasks, and animated adverts would cause higher cognitive load than static

adverts. We also hypothesized that children's individual level of gaze control would be negatively associated with their cognitive load. In order to test these hypotheses, a linear mixed effects model was constructed using mean pupil dilation as the dependent variable () and task type, advert prominence, and gaze control was entered as predictors (participant was entered as a random factor). The results of the regression analysis are shown in Table 2.

[Insert Table 2 here.]

Contrary to our expectations, the regression analysis in Table 2 shows that the information search task type caused a significant increase in mean pupil dilation compared to the search task type ($t = 12.835$, $p \leq 0.000$), indicating that search task was associated with significantly more cognitive load. Thus, the current experiment did not provide support for hypothesis H1a, and the reverse effect proved significant. However, in accordance with our expectations, the regression analysis shows that high advert prominence also caused significantly higher levels of cognitive load compared to low advert prominence ($t = 2.520$, $p \leq 0.012$), and therefore the analysis provides support for hypothesis H1b. Furthermore, individual level of gaze control had an expected negative impact on children's overall cognitive load, but since this effect did not quite reach significance ($t = -1.665$, $p = 0.096$), we could not find strong support for hypothesis H3a. The regression analysis also tested for an interaction effect between task type and advert prominence on cognitive load, but since this interaction did not prove significant, it was assumed that task type and advert prominence affect cognitive load independently of each other. In conclusion, this evidence supported hypothesis H1b, but failed to support H1a and H3a.

Effects on advert distraction

We also hypothesized that task type and advert prominence would cause effects on children's advert distraction, such that reading-for-comprehension tasks would cause lower advert distraction than information search tasks, and such that animated adverts would also cause higher advert distraction than static adverts. Furthermore, we hypothesized that children's individual level of gaze control would be negatively associated with their advert distraction. In order to test

these hypotheses, a second linear mixed effects model was constructed using mean number of fixations on adverts per minute as the dependent variable () and as in the previous analysis, task type, advert prominence, and gaze control was entered as predictors (participant was entered as a random factor). The results of the regression analysis are shown in Table 3.

[Insert Table 3 here.]

Again, contrary to our expectations, the regression analysis in Table 3 shows that the information search task type caused a significant decrease in mean advert fixations compared to the reading-for-comprehension task type ($t = -3.320$, $p \leq 0.001$), and thus the current experiment did not provide support for hypothesis H2a, and the reverse effect proved significant. However, in accordance with our expectations, the regression analysis shows that high advert prominence caused significantly higher levels of advert distraction compared to low advert prominence across task types ($t = 3.533$, $p \leq 0.000$), and therefore the analysis provides support for hypothesis H2b. Furthermore, individual level of gaze control had an expected negative impact on children's overall advert distraction, but this effect was not significant, and thus we could not find any support for hypothesis H3b. The regression analysis also tested for an interaction effect between task type and advert prominence on advert distraction, but since this interaction did not prove significant, it was assumed that task type and advert prominence affect advert distraction independently of each other. In conclusion, this evidence supported hypothesis H2b, but failed to support hypotheses H2a and H3b.

Discussion

Effects of advert prominence

In summarizing the hypothesis testing undertaken in this study, we can conclude that both hypotheses concerning the effects of perceptual prominence in adverts were supported by the empirical evidence. Adverts in the animated high prominence condition did indeed cause increases in task-related cognitive load (H1b) as well as increases in advert-related distractive fixations (H2b) as compared to adverts in the static low prominence condition. The first result can

be explained such that, based on cognitive load theory, we expected that animated adverts would function as a source of extraneous load that emanates from ineffective design or presentation of an interface or task (H1b). Animated adverts are more ineffective than static adverts. The second result can be explained such that, based on previous research on advert saliency, we expected that salient animated adverts would attract children's visual attention to a larger extent than static adverts (H2b). Thus, the experiment supports both hypotheses regarding advert prominence.

Effects of task types

Continuing the outcomes of the hypothesis testing, we can also conclude that none of the hypotheses concerning the effects of task types were supported by the collected data. Based on previous research on task-evoked pupillary responses, we expected that reading-for-comprehension tasks would generate higher levels of cognitive load than information search tasks, due to the fact that reading comprehension would seem to require more cognitive resources in terms of working memory and language processing (Beatty, 1982). By contrast, the information search task only required children to keep a single word in working memory, while trying to locate it within a short text. According to cognitive load theory, reading tasks would be expected to generate higher levels of intrinsic load than information search, since reading seems to involve mental manipulation of more information (H1a). Contrary, to this hypothesis, the actual outcomes of the experiment indicated that information search tasks were associated with significantly higher levels of cognitive load than reading.

The second hypothesis concerning the effects of task types expressed the expectation that reading task would be associated with lower levels advert-related distractive fixations (H2a). Rather than being based on previous research findings, this hypothesis is actually a corollary of H1a. According to H1a, reading tasks would generate higher levels of cognitive load than information search tasks, and based on the limited cognitive capacity theory (Lang, 2000), this means that less attentional resources would be available for advert distractions during reading than during information search. However, since H1a failed to gain support, this means that the

corollary hypothesis H2a must also necessarily fail to be supported, and this is indeed what the data seem to suggest. Contrary to our initial expectations, the information search tasks actually generated significantly higher levels of task-related cognitive load, which according to the theorem of limited cognitive capacity, would entail that information search tasks would also be characterized by less cognitive resources available for advert distraction. This is exactly what we found when testing hypothesis H2a. Contrary to our expectations, we found that information search tasks were associated with lower levels of advert distraction.

In conclusion, the outcomes of the experiment fits with the limited cognitive capacity theorem. When large amounts of attentional resources are devoted to the primary task (information search), low levels of attentional resources remain available for task-irrelevant advert fixations, and when relatively low levels of attentional resources are devoted to the primary task (reading), higher levels of attentional resources are available for advert processing. If this reasoning is correct, then the problematic assumption in this experiment resides in our interpretation of the previous research on task-evoked pupillary responses. While we used this research in order to motivate our expectation that reading-for-comprehension task types would generate more cognitive load than information search tasks, the reverse actually seems to be true. This leaves us with the challenge of explaining why information search tasks are so high in cognitive load compared to reading tasks. While there might be several possible reasons for this, one likely explanation seems to that informations search tasks were perceived by children as being more fun, interesting, and stressful (because shorter trial max duration), thus giving rise to higher levels of arousal and stress, which also have a positive relation with pupil dilation. Thus the cognitive load measurements conducted in this experiment might suffer from confounds with other mental processes that also are associated with increased pupil dilation.

Effects of gaze control

- smaller effects in this study, non-significant trend, explanation

Children's attention management

- children's attention management differs depending on task types - more relative advert distraction during automated tasks such as reading - demanding tasks makes children less susceptible to online advertising

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Table 1

Descriptive statistics of children's task performance (task accuracy, task duration) in two task types (reading comprehension, information search) depending on advert prominence (static, animated).

	Reading, task accuracy (binomial)			**Search, task accuracy (binomial)**		
	Mean	**SD**	**SE**	**Mean**	**SD**	**SE**
Static	0.501	0.500	0.022	0.556	0.498	0.038
Animated	0.437	0.496	0.022	0.526	0.501	0.038

	Reading, task duration (90 seconds max)			**Search, task duration (30 seconds max)**		
	Mean	**SD**	**SE**	**Mean**	**SD**	**SE**
Static	74.90	16.64	1.27	23.42	7.62	0.58
Animated	74.23	17.66	1.35	23.37	7.94	0.61

Table 2

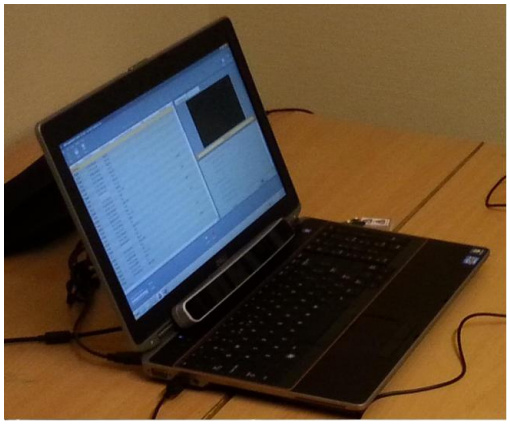
Effects of task type and advert prominence on task-related cognitive load (mean pupil dilation).

Predictors	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	14.678	0.525	27.939	0.000
Task type (information search)	1.149	0.090	12.835	0.000
Advert prominence (animation)	0.181	0.072	2.520	0.012
Gaze control (anti-saccades)	-2.222	1.334	-1.665	0.096
Interaction				
Task type × Advert prominence	-0.119	0.099	-1.199	0.231

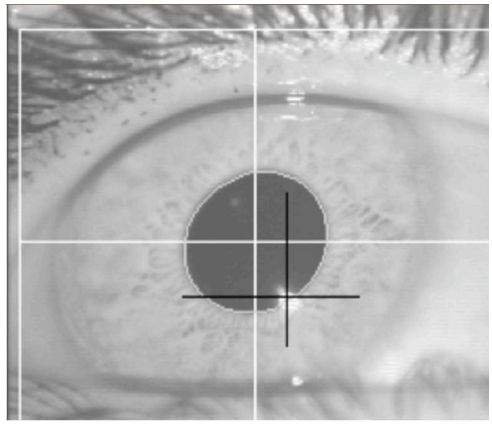
Table 3

Effects of task type and advert prominence on advert-related distraction (fixations per minute).

Predictors	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	2.177	0.690	3.154	0.002
Task type (information search)	-1.311	0.395	-3.320	0.001
Advert prominence (animation)	1.861	0.527	3.533	0.000
Gaze control (anti-saccades)	-1.335	1.572	-0.849	0.396
Interaction				
Task type × Advert prominence	-0.902	0.585	-1.542	0.123



(a) **Remote eye-tracking device.** A remote eye-tracking device (SMI RED-m) was installed in the school environment. The device consisted of an ordinary DELL laptop computer that was used for both stimulus presentation and eye movement recordings. The eye-tracking camera was placed in the laptop fold, between the screen and the keyboard.



(b) **Video-based eye-tracking.** System illuminates the participant's eyes with infrared light (IR) and records the participants eyes in the infrared spectrur The image processing software has detected the pup (white crosshair) and IR corneal reflex (black crosshair) needed to calculate the point of regard (POR) and pupil dilation measure in pixels.

Figure 1. Some caption.

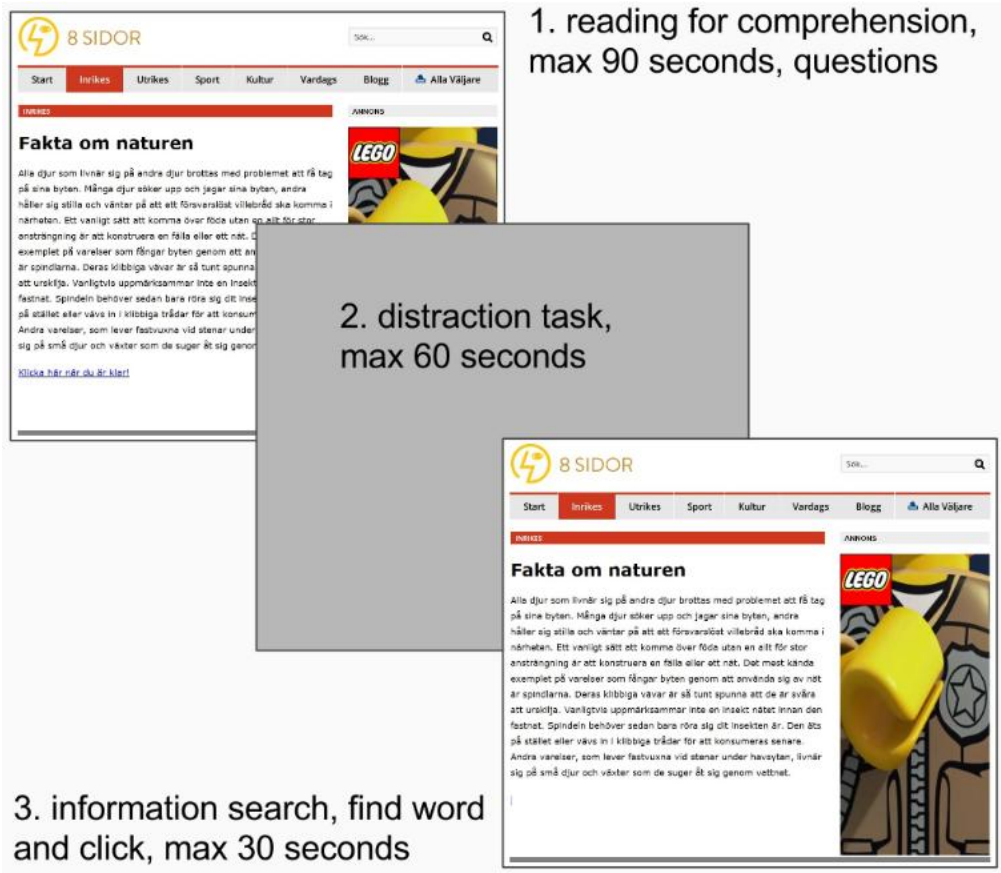


Figure 2. The figure shows a web page from the mock-up commercial news website. The web page consists of a short factual text presented in the main column, and a banner display advert presented in the right column. This web page was used both for the reading-for-comprehension task type as well as the information search task type. In the reading trials, a hyperlink to the comprehension questions was shown at the en d of the text. Adverts presented in the right column were randomized and controlled according to experimental conditions.

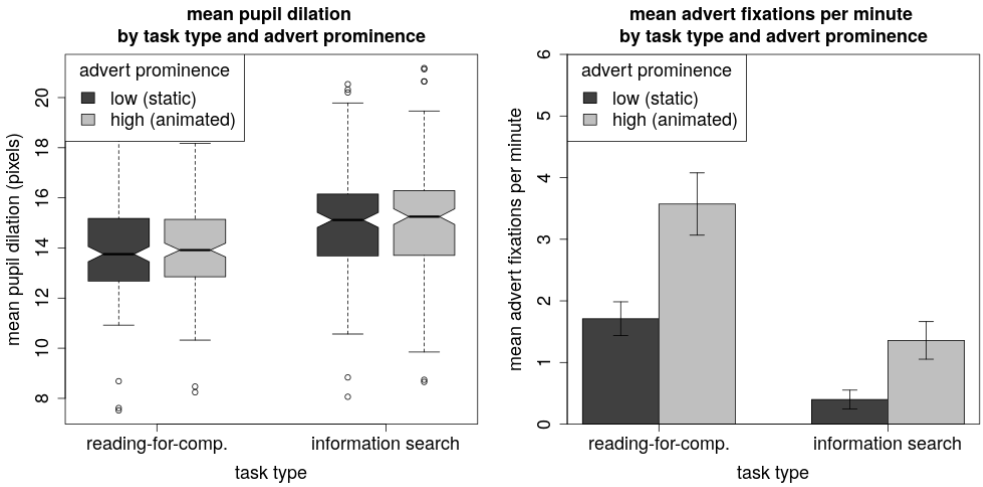


Figure 3.

(a) **Left.** Cognitive load, measured as average pupil dilation in pixels, was lower in reading tasks than in search tasks. Similarly, cognitive load was lower during low advert prominence than during high prominence.

(b) **Right.** Advert distraction, measured as average number of fixations on adverts per minute, was higher in reading tasks than in search tasks. By contrast, advert distraction was lower during low advert prominence than during high.

Appendix

Appendix: Co-author declarations

This co-author declaration is a required enclosure when requesting that a thesis be evaluated for a doctoral degree at the Department of Communication and Media (the Faculty of Social Sciences) at Lund University.

Description of the independent research contributions of the candidate and each co-author

This declaration should describe the independent research contributions of *both* the candidate and *each* of the co-authors for each paper constituting the thesis. The descriptions follow the recommendation from The International Committee of Medical Journal Editors (the "Vancouver Declaration") See the three criteria for authorship below. All three criteria *must* be fulfilled in order to be named co-author:

1. The candidate's/co-author's contribution to conception and design, or development and analysis of a theoretical model, or acquisition of data, or analysis and interpretation of data
2. The candidate's/co-author's contribution to drafting the article or revising it critically for important intellectual content
3. The candidate/co-author have approved the version to be published

For each article the declaration should be completed (capital letters if handwritten) and (electronic) signed by the candidate and the co-author(s). Use additional form(s) if necessary. The last page should include all authors' signatures to ensure that you have looked through the declarations, and find the descriptions in accordance with your view of the co-operation that has taken place.

Paper 1: Children's attention to online adverts is related to low-level saliency factors and individual level of gaze control

Authors: Holmberg, N., Holmqvist, K., & Sandberg, H. (2015)
Candidate: Nils Holmberg
Contribution of the candidate:

1. The candidate has participated throughout the whole research process, starting with the piloting of the experimental design. He has participated in the recruitment of research participants and performed all eye-tracking data collections as experiment leader. He has also been principally responsible for all data analysis and statistical interpretation of the results.
2. The candidate has written and revised all versions of the article, from the first draft and throughout the review process.
3. The candidate has approved the final version of the manuscript to be published.

Candidate (capital letters): **NILS HOLMBERG**

Contribution of co-author 1:

1. Kenneth Holmqvist has been part of the research group conducting the study. He has participated in project meetings throughout the whole study period. He has participated in establishing ideas of experimental design, has worked closely with the candidate regarding choice of strategies for data analysis and have participated in discussions related to interpretation of findings.
2. Kenneth Holmqvist has revised all drafts of the article and revised it critically for important intellectual content.
3. Kenneth Holmqvist has approved the final version of the manuscript to be published.

Name (capital letters): **KENNETH HOLMQVIST**

Contribution of co-author 2:

1. Helena Sandberg has led the research group as principal investigator. She has participated throughout the whole research process, from establishing ideas of design,

and piloting. She has participated in the recruitment of research participants, data collection, as well as in discussions regarding data analysis and interpretation.

2. Helena Sandberg has revised all drafts of the article and revised it critically for important intellectual content.

3. Helena Sandberg has approved the final version of the manuscript to be published.

Name (capital letters): **HELENA SANDBERG**

Paper II: Advert saliency distracts children's visual attention during task-oriented internet use

Authors: Holmberg, N., Sandberg, H., & Holmqvist, K. (2014)
Candidate: Nils Holmberg
Contribution of the candidate:

1. The candidate has participated throughout the whole research process, starting with the piloting of the experimental design. He has participated in the recruitment of research participants and performed all eye-tracking data collections as experiment leader. He has also been principally responsible for all data analysis and statistical interpretation of the results.
2. The candidate has written and revised all versions of the article, from the first draft and throughout the review process.
3. The candidate has approved the final version of the manuscript to be published.

Candidate (capital letters): **NILS HOLMBERG**

Contribution of co-author 1:

1. Helena Sandberg has led the research group as principal investigator. She has participated throughout the whole research process, from establishing ideas of design, and piloting. She has participated in the recruitment of research participants, data collection, as well as in discussions regarding data analysis and interpretation.
2. Helena Sandberg has revised all drafts of the article and revised it critically for important intellectual content.
3. Helena Sandberg has approved the final version of the manuscript to be published.

Name (capital letters): **HELENA SANDBERG**

Contribution of co-author 2:

1. Kenneth Holmqvist has been part of the research group conducting the study. He has participated in project meetings throughout the whole study period. He has

participated in establishing ideas of experimental design, has worked closely with the candidate regarding choice of strategies for data analysis and have participated in discussions related to interpretation of findings.

2. Kenneth Holmqvist has revised all drafts of the article and revised it critically for important intellectual content.

3. Kenneth Holmqvist has approved the final version of the manuscript to be published.

Name (capital letters): **KENNETH HOLMQVIST**

I have looked trough the declaration from the other co-authors, and find the descriptions of their contribution in accordance with my view of the cooperation that has taken place.

Signature of candidate NILS HOLMBERG

Signature of co-author HELENA SANDBERG

Signature of co-author KENNETH HOLMQVIST

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Eye-tracking gives us a rare opportunity to look at the world through someone else's eyes. In this dissertation we are looking at online advertising through the eyes of children aged 9 and 12 years. These children are surfing the world wide web to gather information, to play games, or to visit their favorite websites. In this environment, online advertising is omnipresent, waiting for the moment to capture someone's visual attention through a sudden movement or a seductive motif. If the commercial internet keeps getting smarter, maybe one day, adverts will look back at us?

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