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Web Users with Autism: Eye Tracking Evidence for Differences

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Anecdotal evidence suggests that people with autism may have different processing strategies when accessing the web. However, limited empirical evidence is available to support this. This paper presents an eye tracking study with 18 participants with high-functioning autism and 18 neurotypical participants to investigate the similarities and differences between these two groups in terms of how they search for information within web pages. According to our analysis, people with autism are likely to be less successful in completing their searching tasks. They also have a tendency to look at more elements on web pages and make more transitions between the elements in comparison to neurotypical people. In addition, they tend to make shorter but more frequent fixations on elements which are not directly related to a given search task. Therefore, this paper presents the first empirical study to investigate how people with autism differ from neurotypical people when they search for information within web pages based on an in-depth statistical analysis of their gaze patterns.

Keywords: web accessibility; autism; eye tracking; accessibility guidelines; scanpath trend analysis

Open Data

The materials of the eye tracking study (the information sheet, consent form, questionnaire and web pages with their visual elements) are available in our online external repository at `http://iam-data.cs.manchester.ac.uk/data_files/34`. The individual scanpaths in terms of the visual elements of the web pages with all our detailed statistical data analysis can also be found in this repository.

1. Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder which affects communication and social interaction (American Psychiatric Association 2013). The prevalence of autism grew from 0.5 to 14.7 per 1000 children over 1970-2010 (Dave and Fernandez 2014) and is currently known to affect about 1 in 100 people in the UK (Brugha et al. 2012). Attention also develops differently among those with autism, with a record of atypical attention patterns dating back to as early as the first mention of this condition by Leo Kanner in 1943 (Kanner 1943). For instance, an autistic individual may rely on only one sensory modality, while several are relevant to a task – a phenomenon known as stimulus overselectivity (Lovaas and Schreibman 1971). These characteristics may present themselves as challenges when people with autism use the web, which is why autism has been included in the WCAG 2.0 guidelines under the umbrella term "cognitive disabilities" (Caldwell et al. 2008).

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In spite of the large body of literature on the use of technology among people with autism, there are surprisingly few empirical investigations of the differences in the web searching strategies that people with autism may or may not employ. For example, the most recent and authoritative resource of understanding the needs of users with cognitive disabilities is the Cognitive Accessibility User Research (Seeman and Cooper 2015) issued by the WC3 Cognitive and Learning Disabilities Accessibility Task Force. However, the identification of ASD-specific challenges within this set is based on the ASD diagnostic criteria as a source of information for potential accessibility barriers and one interview with an anonymous user. Furthermore, out of all web accessibility papers for users with autism reviewed in the following section, only one of them included an empirical study but the study was conducted with only four people with autism.

Even though anecdotal evidence suggests that people with autism experience barriers and distractors when accessing web pages, only very limited empirical evidence is available to support this. In this paper, we aimed to investigate the similarities and differences between the way people with and without high-functioning autism search for information within web pages. To do this, we designed an empirical study with more participants and conducted an in-depth statistical analysis.

To achieve our aim, we carried out an eye tracking study with both 18 autistic participants and a control group of 18 neurotypical participants on six web pages with varying levels of visual complexity. In our preliminary work, we carried out a basic descriptive analysis of the way people with autism cope with search tasks within web pages (Eraslan et al. 2017). We also showed that the trending scanpaths (i.e., the most commonly followed paths) of these two user groups were $\approx$45% similar and $\approx$55% dissimilar to each other where the variance was higher within the group of people with autism (Eraslan et al. 2017). In this paper, we conducted a statistical analysis of the eye movements of these two user groups on the web pages by focusing on the performance differences between them in terms of their success in completing a given task, visits to irrelevant elements on web pages, transitions between the elements of web pages, fixation durations and differences in their scanpaths. The overall contributions of this paper are as follows:

- Empirical evidence for possible differences between the strategies employed by people with and without high-functioning autism when searching for information within web pages;
- Empirical investigation of the claim that web users with autism "may not pay attention to primary content because distracted by secondary content" (WC3 Cognitive Accessibility User Research paper (Seeman and Cooper 2015));
- A better understanding of the visual search strategies of people with and without autism when searching for information on web pages;
- Implications for better tailoring the presentation of web pages to the cognitive style of users with autism.

The remainder of this paper firstly gives background information about autism and discusses the related work (Section 2). We then describe our experimental design and research questions (Section 3), and present our statistical analysis (Section 4). After that, we discuss the results of the statistical analysis and its implications for improving the accessibility of the web for users with autism (Section 5). Finally, we present our concluding remarks (Section 7).

2. Background and Related Work

A main characteristic of ASD is its heterogeneity. While some individuals at the lower ends of the spectrum may remain non-verbal and suffer severe intellectual disability, others may be highly-able and have normal or above-normal intelligence. The latter are referred to as people with high-functioning autism or what was formerly known as Asperger's syndrome. Most people on the autism spectrum may experience issues with attention, language comprehension (both oral and written), visual comprehension and sensory integration in varying degrees (American Psychiatric

Association 2013). Sensory issues among those on the spectrum include hypersensitivity (over-sensitive) or hyposensitivity (under-sensitive) to particular smells, lights, textures, sounds and colours. However, although not unusual, sensory issues are not formally included as part of the diagnostic criteria for autism.

What is common between people from various degrees of autism severity is that their attention patterns often differ from the attention patterns of people without autism (Frith 2003). For example, the Weak Central Coherence Theory (WCCT) is one of the main theories aimed at explaining autism and it posits that the ASD cognitive profile is biased towards processing local sensory information with less account for global, contextual and semantic information (Happé and Frith 2006). In other words, people with autism tend to focus more on individual details and this prevents them from perceiving the "bigger picture". WCCT is in line with the stimulus overselectivity phenomenon in autism (Lovaas and Schreibman 1971), where a part of the sensory information is neglected, causing "tunnel vision" – a focus on detail to the exclusion of the bigger picture (Ploog 2010).

Individuals with autism have a particular interest in using technology (Putnam and Chong 2008), especially for developing their abilities (Bosseler, A and Massaro, D. W 2003), or aiding their daily life (Gentry et al. 2010a). Online communication is particularly important in the case of autism as it lacks the social complexities of face-to-face communication (Bosseler, A and Massaro, D. W 2003). While there is a large body of research discussing the reading difficulties of people with autism (Frith and Snowling 1983; Norbury 2014; O'Connor and Klein 2004; MacKay and Shaw 2004; Whyte, Nelson, and Scherf 2014; Yaneva, Temnikova, and Mitkov 2015), little is known about the way people with autism interact with web pages and more particularly how they use visual elements on web pages such as headers, footers and menus. In the following sections, we first discuss accessibility guidelines for web users with autism and then explain how eye tracking works and how it is being used for understanding the difficulties experienced by people with autism.

2.1. *Web Accessibility Guidelines for Users with Autism*

There are many web accessibility guidelines available (Harper and Yesilada 2008) but the most widely used and considered as standard is WCAG 2.0 by W3C/WAI group (Caldwell et al. 2008). WCAG is developed to meet the needs of all disabled user groups. Unfortunately, in spite of good intentions, it is widely known that cognitive disability problems are the least discussed in both WCAG and the literature (Harper and Yesilada 2008). For this reason, the Accessible Platform Architectures (APA) Working Group and the Web Content Accessibility Guidelines Working Group (WCAG WG) joined their efforts into the Cognitive and Learning Disabilities Accessibility Task Force, whose aim is to gain an understanding of the challenges that web users with autism face and possible design solutions for them. The group encourages empirical research for identifying such challenges, however empirical evidence for the challenges of web users with autism is almost non-existent.

To the best of our knowledge, an experiment conducted by Deering (2013) is the only existing experiment for investigating the differences between users with and without autism in processing the web. Yet, this master's thesis involves only four participants and does not report any differences between the two groups, possibly due to lack of statistical power. None of the other works related to web accessibility and autism are based on empirical studies.

Existing guidelines relevant to ASD are gathered together and analysed by Britto and Pizzolato (2016). They grouped the guidelines into the following categories: engagement, affordance, customisation, redundant representation, multimedia, feedback, system status, navigability and interaction with touch screen. The selected works come from nine countries which are USA, Brazil, Italy, UK, Israel, India, Malaysia, Chile and Hong-Kong. Crucially, none of the reviewed guidelines are based on empirical research with people with autism. For example, Friedman and Bryen (2007) propose 22 guidelines for people with autism based on a literature review of existing guidelines for people with cognitive disabilities. Darejeh and Singh (2013) propose ASD-relevant guidelines based on other sets of recommendations developed for people with low literacy. The closest to using empirical data for accessibility recommendations for users with autism is a parent-and-teacher survey conducted by Putnam and Chong (2008). However, their study does not define design recommendations but rather highlights aspects that can help build technology for people with ASD. Other works which discuss design issues particularly related to ASD (and not cognitive disabilities in general) are entirely based on literature reviews or matching the diagnostic criteria to potential accessibility barriers (Millen, Edlin-White, and Cobb 2010; Goldsmith and LeBlanc 2004; Moore 2011). Participants with ASD have been involved in several studies that focused on the evaluation of particular tools or applications for users with autism, which provided little or no advice on accessibility issues (Battocchi et al. 2010; Millen et al. 2012; Gentry et al. 2010b; Sitdhisanguan et al. 2012; Weiss et al. 2011).

As mentioned earlier, the identification of ASD-specific challenges within the Cognitive Accessibility User Research paper (Seeman and Cooper 2015) issued by WC3 is based on the ASD diagnostic criteria as a source of information for potential accessibility barriers (see "How Symptoms Result in Challenges for This Group") and one interview with an anonymous user. The set of challenges derived is as follows:

- People with autism may not pay attention to primary content because distracted by secondary content.
- People with autism may be confused by instructions that are not well-defined, transitions among content-delivery types (such as, text to video), presentations of content with different formats or designs.
- People with autism may not participate in web-based interactions with other people.
- People with autism may not recall instructions when subsequently presented with an action to perform.
- People with autism may react negatively to auto-playing video or audio.

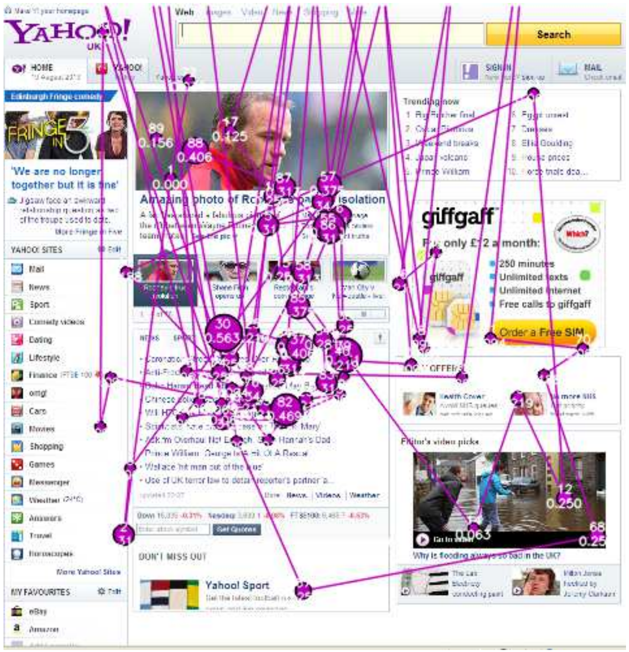
The paper then makes some recommendations for addressing these challenges such as "use color coordination for different parts of the site relating to each other" and "use key for different colors for different sections". It also mentions some time management solutions: "in some cases, poor concept of time means can be looking at one site/page/document for many hours without realizing - timer on screen to alert user to how long they have been on that page". We are not aware of any research which empirically tests the above mentioned challenges nor evaluates the effectiveness of the proposed adjustments.

The existence of many sets of design recommendations for users with autism signifies the importance of designing web pages better suited to the profile of this population and the lack of empirical basis for the development of these recommendations illuminates a gap in the current state of the art in accessibility research. We aim to address this gap by providing empirical understanding of some aspects of the way people with autism interact with web pages by using eye tracking. Specifically, we focus on investigating the first two challenges listed above: distraction caused by secondary content and confusion caused by transitions between the elements of web pages.

2.2. *Eye Tracking*

Eye tracking is a process where an eye tracking device measures the point of gaze of an eye (fixation) or the motion of an eye (saccade) relative to the head and a computer screen. Fixations and revisits (go-back fixations to a previously fixated object) have widely been used as measures of text and web processing difficulty by taking the fixation durations and the places where longer fixations occur into account (Reichle, Rayner, and Pollatsek 2003; Goldberg et al. 2002). The idea that the durations of fixations could be used as a proxy for measuring cognitive load dates back to the *strong eye-mind hypothesis*, according to which, “there is no appreciable lag between what is fixated and what is processed” (Just and Carpenter 1980). That is, when a subject looks at something, he/she also processes it cognitively. The hypothesis also states that the amount of time the subject spends on processing a particular object is equal to the amount of time his/her gaze stays fixated on this object.

(a) A control group user scanpath



(b) An ASD group user scanpath

Figure 1.: User scanpaths on the Yahoo! web page

One of the obvious applications of eye tracking is in improving the standard design and layout of web pages and evaluating their usability (Ehmke and Wilson 2007). Eye tracking studies have also examined the saliency of elements on a web page under varying conditions (Granka, Joachims, and Gay 2004) – how eye movements vary according to information scent (Pirolli and Card 1999) and how looking for a menu is influenced by page complexity and prior expectations (McCarthy, Sasse, and Riegelsberger 2003). Previous work has investigated fixations and saccades to understand how people use visual elements of web pages, how they allocate their attention to dynamic content and how they process simple and complex pages (Yesilada et al. 2008; Brown, Jay, and Harper 2009). Alternative metric for analysing eye tracking data is scanpath which is a series of fixations (Takeuchi and Habuchi 2007). Scanpath analysis is typically conducted based on visual elements of web pages (such as, headers and footers) to investigate which elements are mostly used and which paths are typically followed in terms of these elements (Eraslan, Yesilada, and Harper 2016b). A number of algorithms have been developed to analyse individual scanpaths on a particular web page for discovering the most commonly followed path(s) in terms of the visual element of the page (Eraslan, Yesilada, and Harper 2016a).

Figure 1a shows a scanpath of a neurotypical user on the Yahoo! page where the circles represent the points fixated by the user and the largest circle illustrates the longest fixation. In contrast, Figure 1b shows a scanpath of a user with high-functioning autism on the same page. As can be seen from these figures, the neurotypical user focused on specific parts of the page whereas the autistic user looked at many parts.

There are a number of eye tracking studies involving participants with autism; however, these have mainly been focused on investigating visual social attention and the processing of socially salient stimuli (Boraston and Blakemore 2007; Riby and Hancock 2009; Sterling et al. 2008; Guillon et al. 2014) and reading (Yaneva, Temnikova, and Mitkov 2015; Yaneva 2016; Yaneva, Temnikova, and Mitkov 2016; Štajner et al. 2017). These studies have been extremely useful for understanding the differences in attention between people with autism and neurotypical people, highlighting the potential of gaze data to account for such subtle processes. To the best of our knowledge, there have been no eye tracking studies conducted which investigate the way people with autism interact with the web.

Eye tracking research provides valuable insights for understanding how people interact with web pages. These insights can be used to develop some web accessibility guidelines or transcode (i.e., structurally adapt) web pages to make them more accessible for users with disabilities. In this paper, we aim to gain an understanding of the way people with autism interact with web pages to contribute both the development of future guidelines and transcoding techniques (Caldwell et al. 2008; Asakawa and Takagi 2008).

3. Experimental Design

Our eye tracking study was designed to compare the performance of people with autism and neurotypical people on web search tasks. While performing the tasks, the eye movements of our participants were recorded by using an eye tracker. The experimental design used in this study was initially developed and used for another study involving neurotypical participants only (Eraslan, Yesilada, and Harper 2014; Eraslan and Yesilada 2015; Eraslan, Yesilada, and Harper 2016b). Detailed information about this original study can be found in Eraslan, Yesilada, and Harper (2016b).

3.1. *Research Questions*

In this paper, we are investigating the following research questions for the case where people search for specific information or items on web pages:

Task Success Do people with autism provide fewer correct answers to web search tasks under

limited time constraints?
This question is for investigating whether people with autism experience actual difficulties in searching for specific information or items on web pages in comparison with neurotypical people. Our preliminary basic descriptive analysis showed that people with autism tend to be less successful (Eraslan et al. 2017). In this paper, we investigate this research question with an in-depth statistical analysis.

Irrelevant Elements Do people with autism get more distracted by irrelevant elements compared to neurotypical people?
It is widely referred in the literature that people with autism get distracted by irrelevant content (Britto and Pizzolato 2016; Martos et al. 2013) and this question aims to empirically investigate this assumption.

Scanpath Lengths Do people with autism have longer scanpaths compared to neurotypical people?
This question investigates possible differences between the lengths of individual scanpaths of people with autism and neurotypical people. In the literature, a longer scanpath on a web page is related to less efficient searching as more elements are visited to complete a task (Ehmke and Wilson 2007). Therefore, investigating the scanpath lengths will help us investigate the users' efficiency in terms of the number of elements visited.

Transitions Between Elements Do people with autism make more transitions between the elements of web pages compared to neurotypical people?
This question investigates possible differences between people with autism and neurotypical people in terms of how many times they change their focus from one element to another which would also show us the uncertainty experienced in searching (Ehmke and Wilson 2007).

Fixation Durations Do people with autism make shorter fixations compared to neurotypical people?
Fixation duration is typically associated with information processing (Follet, Meur, and Baccino 2011; Velichkovsky et al. 2002), and therefore this question aims to show possible differences between people with autism and neurotypical people in terms of information processing when a task is completed.

Trending Scanpath Is there a difference between the trending scanpaths of people with autism and neurotypical people on web pages?
This question investigates possible differences between the typical paths followed by autistic and neurotypical people for the completion of their tasks. By analysing their trending scanpaths, we aim to understand whether the two groups use the same elements in the same order to complete a given task (Eraslan, Yesilada, and Harper 2016b). In Eraslan et al. (2017), we reported the preliminary results of this question, however the full detailed results are presented in this paper.

3.2. *Apparatus*

The device used for recording the gaze of the participants during task performance was a Gazepoint GP3 video-based eye-tracker (Gazepoint 2015) (60Hz sampling rate and accuracy of 0.5-1 degree of visual angle). The screen shots of the web pages were presented on a 19" LCD monitor. The distance between each participant and the eye-tracker was controlled by using a sensor integrated within the Gazepoint software, and was roughly 65 cm.

3.3. *Materials*

In this study, we used the screen shots of six web pages that were initially selected and used by Eraslan, Yesilada, and Harper (2014). This means that all our participants visited the same version of the web pages. These web pages had been selected from the top websites listed by ALEXA.com[1]. The six web pages had varying visual complexity, as measured by the ViCRAM tool (Michailidou 2010): Apple (Low), Babylon (Low), AVG (Medium), Yahoo! (Medium), Godaddy (High) and BBC (High).

The areas of interest (visual elements or regions) were initially automatically defined by Eraslan, Yesilada, and Harper (2014) based on the extended and improved version of the Vision-Based Page Segmentation (VIPS) algorithm, which segments web pages by using their source code and visual representations based on different granularity levels (Akpınar and Yeşilada 2013). The segmented web pages are provided in our external repository. An example of the segmented Apple web page can be seen in Figure 4.

3.4. *Procedure*

Prior to the recruitment of participants, ethical approval was sought and received from the University of Wolverhampton Ethics Committee[2]. All the participants performed the experiment in a quiet room with only the researcher (second author). All the participants were given both verbal instruction and an information sheet, as well as an opportunity to ask questions and have a break whenever they felt tired. After getting familiar with the purpose and procedure of the experiment they all signed a consent form and the verbal instruction was reinforced. The demographic data about their age, gender and diagnosis was collected and a nine-point calibration of the eye-tracker was performed. After the successful calibration, the participants were presented with the six web pages in a randomised order to deal with possible memory effects (specifically, the pages were randomised for each participant) and asked two verbal questions per web page about finding relevant information or items on the page. The full set of these tasks is provided in Table 1. Those tasks could be completed without scrolling, and therefore the participants were not allowed to use any device to scroll such as mouse or keyboard.

Table 1.: The searching tasks used in the eye tracking study

Page	**Tasks**
Apple	(a) Can you locate the link that allows to watch the TV ads relating to iPad mini? (b) Can you locate a link labelled iPad on the main menu?
Babylon	(a) Can you locate the link that you can download the free version of Babylon? (b) Can you find and read the names of other products of Babylon?
AVG	(a) Can you locate the link which you can download the free trial of AVG Internet Security 2013? (b) Can you locate the link which allows you to download AVG Antivirus Free 2013?
Yahoo!	(a) Can you read the titles of the main headlines which have smaller images? (b) Can you read the first item under the News title?
Godaddy	(a) Can you find a telephone number for technical support and read it? (b) Can you locate the text box where you can search for a new domain?
BBC	(a) Can you read the first item of Sport News? (b) Can you locate the table that shows market data under the Business title?

Our procedure was a replication of the procedure presented by Eraslan, Yesilada, and Harper (2016b) with a slight difference in the fact that the participants were only given 30 seconds to complete the search tasks on each page instead of 120 seconds, so that the tasks could be sensitive enough to capture potential difficulties in performance. When the participants completed their tasks in less than 30 seconds on a particular page, they directly moved on to the next page without

[1]http://www.alexa.com

[2]All the relevant documents are in our external repository.

waiting.

After the completion of the eye tracking part, the participants were also asked to fill in a short survey including questions about how often they use the web and how often they have visited the six websites (1: Daily, 2: Weekly, 3: Monthly, 4: Less than once a month, 5: Never), where the web pages were selected from, in order to control for familiarity effects. Additional survey questions were: “How easy or difficult is it for you to find the information you need when you search the web?” and “When you search for something in Google (or other search engines), how easy or difficult is it for you to know which links to open in order to find the information you need?”. The latter was based on the findings from previous research stating that people with cognitive disabilities may have issues: “recognising the most appropriate choice when faced with a large number of options” (Slatin and Rush 2002). Although these questions did not focus on searching for information within web pages, they explore other areas of difficulty web users with autism may experience and suggest avenues for future research in the broader context of web accessibility for users with autism. The answers to these questions were measured on a five-point Likert scale starting from very difficult, difficult, medium, easy and very easy.

3.5. *Participants*

The participants in this eye tracking study were 18 adult volunteers diagnosed with high-functioning autism or Asperger’s syndrome (12 male and 6 female) and 18 non-autistic control participants (10 male and 8 female).

Recruitment Channels: All participants with autism were recruited through a Birmingham-based UK charity organisation, where they had to provide a copy of their formal diagnosis in order to access the services of the charity. The participants without autism were recruited through open advertisement across Birmingham, UK.

Inclusion and Exclusion Criteria: The inclusion criteria for the experimental group was a formal diagnosis of high-functioning autism or Asperger’s syndrome, to be over 18 years of age and to be able to use a computer. The exclusion criteria was presence of any degree of intellectual disability in their diagnoses. For the control group, the inclusion and exclusion criteria were similar with the important distinction that no control participant should have exhibited any features of autism. In order to control for this, all the participants from the control group were asked to fill in an Autism Quotient (AQ) test (Baron-Cohen et al. 2001) to make sure that none of them had a high incidence of autistic traits without having received a formal diagnosis. None of the control participants included in the study had a AQ score higher than 32, which meant that they all had “little or no autistic traits”. All participants were regular users of the web and had normal or corrected vision.

Demographic Characteristics: Table 2 shows the demographic characteristics of the participants in the ASD and control groups. The mean age for the ASD group was $\mu = 37.22$ with standard deviation $SD = 10.3$ whereas the mean age was $\mu = 34.18$ with $SD = 8.05$ for the control group. The number of years spent in education for the ASD group were $\mu = 16$ with $SD = 3.33$ and for the control group $\mu = 18.35$ with $SD = 2.47$. The participants in both groups covered a wide range of professions and were all based in the greater area of Birmingham, UK.

Table 2.: Demographic characteristics of the participants in the ASD and control groups

	ASD		**CONTROL**	
Demographic Characteristic	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Age	37.22	10.30	34.18	8.05
The number of years spent in education	16.00	3.33	18.35	2.47

Familiarity with using the Web: Table 3 shows the usage of the pages by both of the ASD and control groups.

Table 3.: The usage of the pages by both of the ASD and control groups

Page	G	Never	Less than once a month	Monthly	Weekly	Daily
Apple	A	52.94%	47.06%	0.00%	0.00%	0.00%
	C	12.50%	25.00%	37.50%	25.00%	0.00%
Babylon	A	100.00%	0.00%	0.00%	0.00%	0.00%
	C	81.25%	18.75%	0.00%	0.00%	0.00%
AVG	A	82.35%	17.65%	0.00%	0.00%	0.00%
	C	62.50%	31.25%	6.25%	0.00%	0.00%
Yahoo!	A	23.53%	29.41%	17.65%	11.76%	17.65%
	C	43.75%	43.75%	6.25%	6.25%	0.00%
Godaddy	A	94.12%	5.88%	0.00%	0.00%	0.00%
	C	75.00%	18.75%	6.25%	0.00%	0.00%
BBC	A	0.00%	11.76%	23.53%	23.53%	41.18%
	C	12.50%	25.00%	37.50%	25.00%	0.00%

[G: Group where A represents the ASD group and C represents the Control Group]

Three of the ASD group participants were subsequently excluded from the analysis of the eye tracking data due to their inability to calibrate the device. We also recognised some problems in the recordings of two participants in the ASD group and one participant in the control group (such as, the recording of fixations), and therefore we also had to exclude them from the eye tracking data analysis.

Our first survey question asked was "How easy or difficult is it for you to find the information you need when you search the web?". As illustrated in Figure 2, 77.8% of the control group affirmed it was "very easy" for them to find the necessary information compared to 66.7% of the ASD group. In both groups, 16.7% of the users selected the option "easy", while the option "medium" was selected by 11.1% of the ASD group and 5.6% of the control group. While all the answers of the control group spanned from "very easy" to "medium", 5.6% of the ASD group reported that it was "very difficult" for them to find the information they need when they search the web.

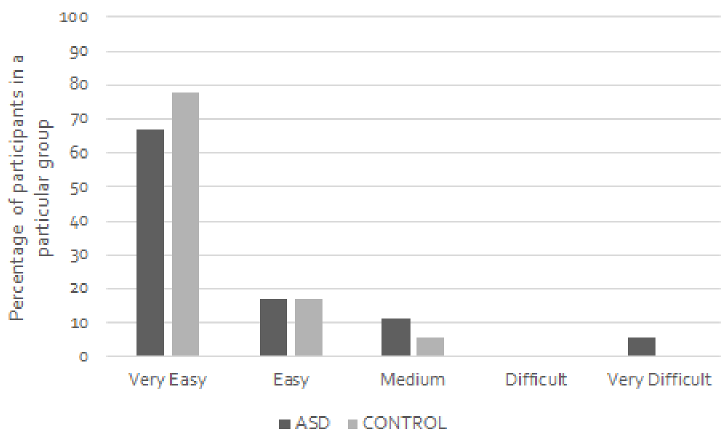


Figure 2.: How easy or difficult is it for you to find the information you need when you search the web?

The second survey question was: "When you search for something in the web, how easy or difficult is it for you to know which links to open to find the information you need?". As shown in Figure 3, similar to the previous survey question, 77.8% of the users in the control group and 66.7% of the ones in the ASD group reported that it was "very easy" for them to select a relevant link. 16.7% from both groups selected the option "easy", and 5.6% selected "medium". However, 11.1% of the ASD group reported that this task was "very difficult" for them, which corresponds to 0% in the control group and is an indication that certain autistic users tend to find it challenging to filter information when it comes to web search.

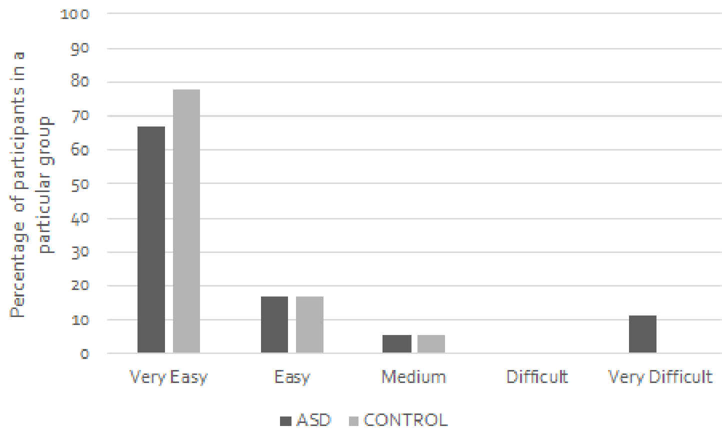


Figure 3.: When you search for something in the web, how easy or difficult is it for you to know which links to open to find the information you need?

4. Data Analysis and Results

To investigate our research questions (see Section 3.1), we firstly created the scanpaths in terms of the visual elements of the web pages. For instance, if a particular user fixated the elements X, Y, X and Z respectively (i.e., his/her fixations fell into the elements X, Y, X and Z respectively), his/her scanpath was generated as XYXZ by keeping the fixation durations. All the individual scanpaths of the ASD and control groups are provided in our external repository .

With our research questions, we aimed to compare two unrelated groups (the ASD and control groups) based on the same dependent variable (such as, the number of irrelevant elements in their scanpaths or their average fixation duration). Therefore, we applied the independent T-Test with 95% confidence interval or its non-parametric alternative Mann-Whitney U-Test when the dependent variable was not normally distributed at least in one of the groups. The Shapiro-Wilk test was used to test whether the dependent variable is normally distributed or not.

We also reported the effect sizes to show the strength of the differences. Hence, we provided the Cohen's d (0.2: Small Effect, 0.5: Medium Effect, 0.8: Large Effect (Cohen 1988)) for the independent T-test and r (0.1: Small Effect, 0.3: Medium Effect, 0.5: Large Effect (Pallant 2007) the Mann-Whitney U-Test.

In the following subsections, we present the data analysis and the main findings pertaining to each of our research questions.

4.1. *Task Success*

Do people with autism provide fewer correct answers to web search tasks under limited time constraints?

To investigate whether people with autism are less successful in locating the correct information or items on web pages under limited time constraints, we compared the responses of the participants to the given tasks. Each correct response was given a score of one whereas each incorrect response was given a score of zero. Table 4 shows the mean, median, standard deviation of the response scores for each group on each web page. The maximum score on each page could be two because there were two tasks on each web page. We observed that all the participants on the Godaddy page completed their tasks successfully as the mean score is equal to two and the standard deviation is equal to zero for both of the groups. Besides, the mean scores of the ASD and control groups on the Apple and Babylon pages are very close to each other. In contrast, the mean scores on the rest of the pages are higher for the control group. Because of these differences in the scores among the pages, we decided to look at the overall scores of the participants. Therefore, we firstly calculated an overall score for each participant. For example, if a particular participant successfully completed his/her two tasks on four of six pages, his/her score would be eight. We then applied the statistical test to the overall scores.

Table 4.: The responses of the ASD and control groups to the tasks

	ASD Group				**Control Group**			
Page	**N**	**M**	**MD**	**SD**	**N**	**M**	**MD**	**SD**
Apple	18	1.89	2.00	0.32	18	1.94	2.00	0.24
Babylon	18	1.89	2.00	0.32	18	1.94	2.00	0.24
AVG	18	1.67	2.00	0.59	18	1.94	2.00	0.24
Yahoo!	18	1.50	2.00	0.79	18	1.72	2.00	0.57
Godaddy	18	2.00	2.00	0.00	18	2.00	2.00	0.00
BBC	18	1.89	2.00	0.47	18	2.00	2.00	0.00

N: Sample Size, M: Mean, MD: Median, SD: Standard Deviation

Although the ASD group (μ = 10.83, SD = 1.72) tended to be less successful compared to the control group (μ = 11.56, SD = 0.86) in locating the correct information or items on web pages under limited time constraints, the Mann-Whitney U Test shows that the difference between these groups was not significant (U = 122.000, z = -1.451, p = 0.107, r = 0.2).

4.2. *Irrelevant Elements*

Do people with autism get more distracted by irrelevant elements compared to neurotypical people?

In this context, if an element was not part of the task, it was considered as an irrelevant element. For example, on the Apple page (see Figure 4), the participants were asked to find the link which allows them to watch the TV ads related to iPad mini, and then find the iPad menu item from the main menu. To complete the task, the participants needed to fixate the elements E and B respectively, and therefore these elements were defined as relevant elements and other elements became irrelevant elements.

To investigate whether people with autism get more distracted by irrelevant elements compared to neurotypical people while searching information or items on web pages, we firstly counted the irrelevant elements in their scanpaths. Figure 5 shows the mean of the number of irrelevant elements in the individual scanpaths of the ASD and control groups for each web page with the error bars based on the standard deviation. From this figure, we can observe that the ASD group looked at more irrelevant elements compared to the control group.

Table 5 shows our statistical analysis which was conducted to determine whether the individual scanpaths of the ASD group have significantly more irrelevant elements in comparison with the individual scanpaths of the control group. According to our statistical analysis, the ASD group looked at significantly more irrelevant elements in comparison with the control group on the Babylon page with a large effect size and the BBC page with a medium effect size. For example, on the Babylon page, a participant from the ASD group looked at ≈32 irrelevant elements on average whereas a participant from the control group looked at ≈19 irrelevant elements on average and the independent T-Test showed that there was a significant difference between these groups on this page (t = 3.651, df = 19.843, $p < 0.01$, d = 1.4). Even though the ASD group looked more irrelevant elements in comparison with the control group on average, no significant difference was detected between them on the Apple, AVG, Yahoo! and Godaddy pages.

Figure 4.: The Apple page which is segmented into its elements by using the VIPS algorithm (Akpınar and Yeşilada 2013)

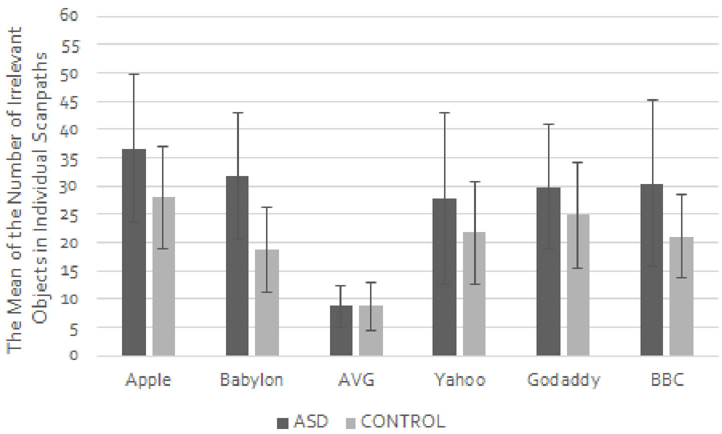


Figure 5.: The mean of the number of irrelevant elements in the individual scanpaths of the ASD and control groups

Table 5.: The number of irrelevant elements fixated by the ASD and control groups

	ASD Group				Control Group				Independent T-Test			Mann-Whitney U-Test		
Page	N	M	MD	SD	N	M	MD	SD	t	df	d	U	z	r
Apple	13	36.69	38.00	13.08	17	28.00	27.00	9.08	NA	NA	NA	71.000	-1.657	0.3
Babylon	13	31.77	32.00	11.09	17	18.76	18.00	7.40	3.651**	19.843	1.4	NA	NA	NA
AVG	13	8.77	8.00	3.72	17	8.71	9.00	4.24	0.043	28.000	0.0	NA	NA	NA
Yahoo	13	27.77	23.00	15.13	17	21.76	19.00	9.09	1.267	18.475	0.5	NA	NA	NA
Godaddy	13	29.85	29.00	11.07	17	24.88	22.00	9.33	NA	NA	NA	77.000	-1.406	0.3
BBC	13	30.46	27.00	14.63	17	21.12	21.00	7.38	NA	NA	NA	64.000*	-1.948	0.4

N: Sample Size, M: Mean, MD: Median, SD: Standard Deviation, *p<.05, **p<.01, ***p<.0005

4.3. *Scanpath Lengths*

Do people with autism have longer scanpaths compared to neurotypical people?

To investigate whether people with autism have longer scanpaths in comparison with neurotypical people while searching information or items on web pages, we firstly calculated the lengths of the individual scanpaths of the participants in the ASD and control groups (i.e., the total number of the visual elements in their scanpaths including the repetitions). Figure 6 illustrates the means of the lengths of the individual scanpaths of the ASD and control groups with the error bars based on the standard deviations. This figure allows us to observe that the ASD group looked at more points, and therefore they had longer scanpaths compared to the control group.

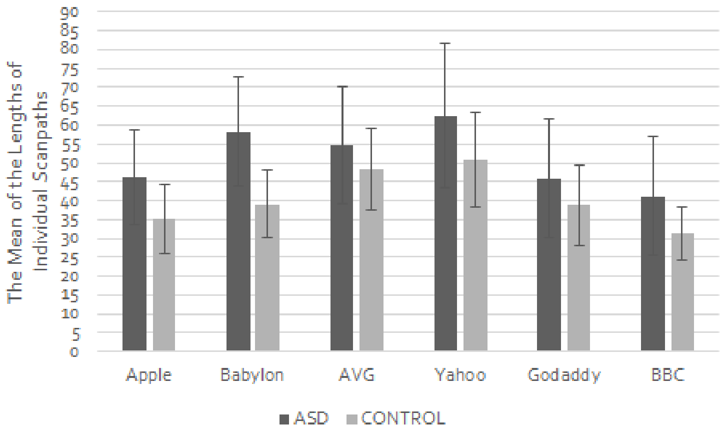


Figure 6.: The mean of the lengths of the individual scanpaths of the ASD and control groups

Our statistical analysis (see Table 6) shows that there was a significant difference between these user groups on the most of the pages in terms of their scanpath lengths, apart from the AVG and Godaddy pages. The effect size was large on the Apple and Babylon pages whereas the effect size was medium on the Yahoo! and BBC pages. In particular, the mean scanpath length was ≈46 for the ASD group, but ≈36 for the control group on the Apple page.

Table 6.: The lengths of individual scanpaths of the ASD and control groups

	ASD Group				**Control Group**				**Independent T-Test**			**Mann-Whitney U-Test**		
Page	**N**	**M**	**MD**	**SD**	**N**	**M**	**MD**	**SD**	**t**	**df**	**d**	**U**	**z**	**r**
Apple	13	46.31	45.00	12.47	17	35.24	36.00	9.25	NA	NA	NA	46.000**	-2.714	0.5
Babylon	13	58.15	61.00	14.50	17	39.18	42.00	8.83	4.164**	18.649	1.6	NA	NA	NA
AVG	13	54.77	48.00	15.48	17	48.24	46.00	10.76	1.365	28.000	0.5	NA	NA	NA
Yahoo	13	62.46	69.00	19.23	17	50.88	51.00	12.71	1.985*	28.000	0.7	NA	NA	NA
Godaddy	13	45.92	41.00	15.70	17	38.82	38.00	10.51	NA	NA	NA	84.500	-1.089	0.2
BBC	13	41.23	39.00	15.69	17	31.35	34.00	7.11	NA	NA	NA	56.000*	-2.291	0.4

N: Sample Size, M: Mean, MD: Median, SD: Standard Deviation, *p<.05, **p<.01, ***p<.0005

4.4. *Transitions Between Elements*

Do people with autism make more transitions between the elements of web pages compared to neurotypical people?

Our next research question aims to investigate whether people with autism make more transitions between the elements of web pages compared to neurotypical people. Therefore, we calculated the transitions made by the participants in the ASD and control groups between the elements of the web pages. For example, if the scanpath AABBCDDDAA was available, the number of transitions would be equal to five (A → B → C → D → A). When we looked at the mean values of the number of transitions made by the ASD and control groups between the elements of the web pages (see Figure 7), we observed that people with autism tend to make more transitions between the elements of web pages in comparison with neurotypical people.

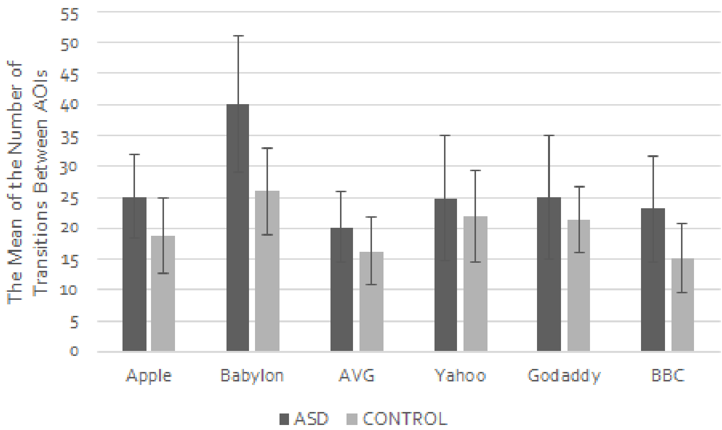


Figure 7.: The mean of the number of transitions made by the ASD and control groups

According to our statistical analysis (see Table 7), the ASD group made significantly more transitions between the elements in comparison with the control group on the most of the web pages, except from the Yahoo! and Godaddy pages. The effect size was large on the Apple, Babylon and BBC pages whereas the effect size was medium on the AVG page. For example, on the Apple page, the ASD group made ≈25 transitions where the control group made ≈19 transitions on average.

Table 7.: The number of transitions between the elements made by the ASD and control groups

	ASD Group				**Control Group**				**Independent T-Test**			**Mann-Whitney U-Test**		
Page	**N**	**M**	**MD**	**SD**	**N**	**M**	**MD**	**SD**	**t**	**df**	**d**	**U**	**z**	**r**
Apple	13	25.08	26.00	6.70	17	18.82	19.00	6.01	2.687**	28.000	1.0	NA	NA	NA
Babylon	13	40.15	42.00	11.04	17	26.00	26.00	6.99	4.045**	19.142	1.5	NA	NA	NA
AVG	13	20.15	19.00	5.76	17	16.29	17.00	5.38	1.889*	28.000	0.7	NA	NA	NA
Yahoo	13	24.85	24.00	10.07	17	22.00	23.00	7.42	0.892	28.000	0.3	NA	NA	NA
Godaddy	13	25.08	21.00	10.05	17	21.35	20.00	5.22	NA	NA	NA	91.500	-0.797	0.1
BBC	13	23.08	22.00	8.55	17	15.18	16.00	5.51	NA	NA	NA	43.000**	-2.833	0.5

N: Sample Size, M: Mean, MD: Median, SD: Standard Deviation, *p<.05, **p<.01, ***p<.0005

4.5. *Fixation Durations*

Do people with autism make shorter fixations compared to neurotypical people?

To investigate the differences between the durations of the fixations made by the participants in the ASD and control groups, we also calculated the mean fixation duration for each user on each web page. As shown in Figure 8, people with autism are likely to make shorter fixations in comparison with neurotypical people while searching information or items on web pages.

Table 8 illustrates our detailed statistical analysis, including the mean, median, standard deviation of the mean fixation durations of the ASD and control groups on the six web pages, and the results of the independent T-Test. The statistical tests showed that there was a significant difference between these user groups on the Yahoo! page with a medium effect size and the Godaddy page with a large effect size in terms of their fixation durations. However, no significant difference

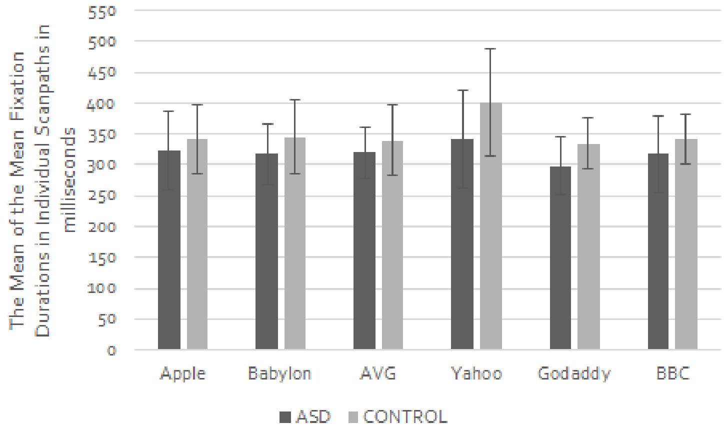


Figure 8.: The mean of the mean fixation durations in the individual scanpaths of the ASD and control groups in milliseconds

was detected on the other pages, even though the mean of the average fixations was lower in the ASD group on the pages.

Table 8.: The mean fixation durations of the individual scanpaths of the ASD and control groups in milliseconds

	ASD Group				Control Group				Independent T-Test			Mann-Whitney U-Test		
Page	**N**	**M**	**MD**	**SD**	**N**	**M**	**MD**	**SD**	**t**	**df**	**d**	**U**	**z**	**r**
Apple	13	323.46	320.00	63.94	17	341.65	340.00	56.03	-0.829	28.000	0.3	NA	NA	NA
Babylon	13	317.15	314.00	48.82	17	344.53	337.00	59.79	-1.342	28.000	0.5	NA	NA	NA
AVG	13	319.77	317.00	40.66	17	339.88	342.00	56.56	-1.084	28.000	0.4	NA	NA	NA
Yahoo	13	342.54	340.00	79.26	17	400.06	361.00	86.85	-1.866*	28.000	0.7	NA	NA	NA
Godaddy	13	298.31	301.00	46.54	17	334.24	344.00	41.10	-2.241*	28.000	0.8	NA	NA	NA
BBC	13	317.08	310.00	63.28	17	341.41	347.00	39.78	-1.290	28.000	0.5	NA	NA	NA

N: Sample Size, M: Mean, MD: Median, SD: Standard Deviation, *p<.05, **p<.01, ***p<.0005

4.6. *Trending Scanpath*

Is there a difference between the trending scanpaths of people with autism and neurotypical people on web pages?

This research question was differently investigated compared to other research questions above because there is no single corresponding value for each participant (such as, the scanpath length for each participant). To investigate this research question, we firstly focussed on the variance within the groups because it might affect the identification of the trending scanpaths. For example, when there are two completely different individual scanpaths in terms of their coverage such as ABCD and EFGH (the highest variance), it is not possible to identify any trending scanpath.

To investigate the variance within the groups, we used the String-edit algorithm because it has widely been used in eye tracking research (Eraslan, Yesilada, and Harper 2016a). The String-edit algorithm calculates a distance between two scanpaths which are represented as strings (such as, ABCD and ABED) by transforming one scanpath to another with the minimum number of editing operations (addition, deletion and substitution). For example, the String-edit algorithm calculates the distance between ABCD and ABED as one because only one substitution operation between C and E is sufficient to transform one of them to another. The similarity between the two scanpaths can then be calculated as a percentage based on the String-edit distance. For the identical scanpaths, there is no variance. However, the variance is at the maximum level for the completely different scanpaths.

According our analysis, the mean similarity within the control group ($\mu = 37.8$, $SD = 13.2$) is higher than the mean similarity within the ASD group ($\mu = 33.4$, $SD = 10.5$), and therefore we can suggest that the variance is higher in the ASD group in comparison with the control group. The mean similarity within the combination of the groups is equal to 36.7 ($SD = 12.1$) which is less than the mean similarity of the control group. This is caused by the ASD group because of the high variance within the group. We observed the same situation when we randomly selected some users from the control group and some users from the ASD group ($\mu = 34.5$, $SD = 11.5$). Our variance analysis can also be found in our external repository.

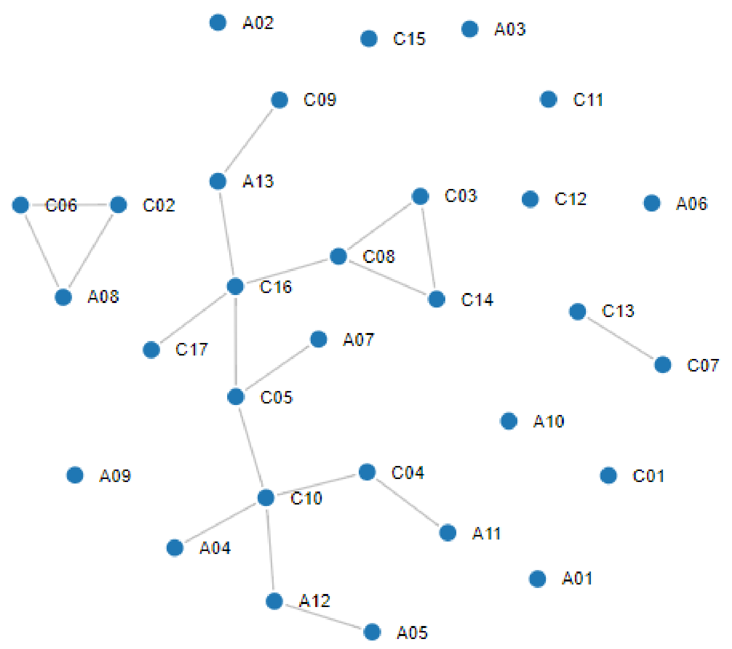


Figure 9.: Scanpath similarity between people with autism (A) and control group participants (C) produced using the ScanGraph tool (Dolezalova and Popelka 2016) – This graph shows that the scanpaths of the control group are more connected to each other compared to the scanpaths of the ASD group, and therefore the scanpaths of the control group are more similar to each other compared to the scanpaths of the ASD group in this study [This image is created with the online ScanGraph tool: `http://eyetracking.upol.cz/scangraph/?source=21022153975a37a935702e73.00776805` (Eraslan et al. 2017)].

To clearly illustrate the high variance within the ASD group, we also used the ScanGraph tool (Dolezalova and Popelka 2016). This tool is publicly available[3] and it is able to construct a visual graph by using the String-edit similarity where similar scanpaths are connected to each other. As a representative example, Figure 9 illustrates the advised graph (a graph with 5% of the possible edges) on the Apple page for the ASD group users (A01, A02, A03,...) and the control group users (C01, C02, C03, ...) who participated in this study. This graph illustrates that the scanpaths of the control group are more connected to each other as they are more similar to each other in comparison with the ASD group in this study.

After our variance analysis, we investigated the differences between the trending scanpaths of the ASD and control groups (two already “known” groups). To identify their trending scanpaths on the six web pages, we applied the Scanpath Trend Analysis (STA) algorithm to the scanpaths

[3]`http://eyetracking.upol.cz/scangraph/`

of the successful participants in the ASD and control groups who completed the tasks by fixating certain elements in an expected order (Eraslan, Yesilada, and Harper 2016b).

Unlike other algorithms which provide multiple common paths or patterns for individual scanpaths (Eraslan, Yesilada, and Harper 2016a), the STA algorithm provides the most popular scanpath as a trending scanpath for multiple users on a particular page in terms of the visual elements of the page. It initially takes a series of fixations for each user on a web page and the visual elements of that page. It then finds the corresponding element for each fixation to create the individual scanpaths in terms of the visual elements. Following this, it analyses the individual scanpaths to discover the visual elements which deserve to be in the trending scanpath by choosing the elements shared by all users and the elements that get at least the same attention as the shared elements in terms of the total fixation durations and total fixation counts. In the end, the algorithm puts the chosen elements into the trending scanpath according to their overall positions in the individual scanpaths. Specifically, when most users firstly fixate a specific visual element, the element will be at the beginning of the trending scanpath. The full description of the STA algorithm can be found in (Eraslan, Yesilada, and Harper 2016b). Figure 10 and Figure 11 show the trending scanpaths of the ASD and control groups on the Yahoo! page respectively. Other trending scanpaths can be found in our external repository.

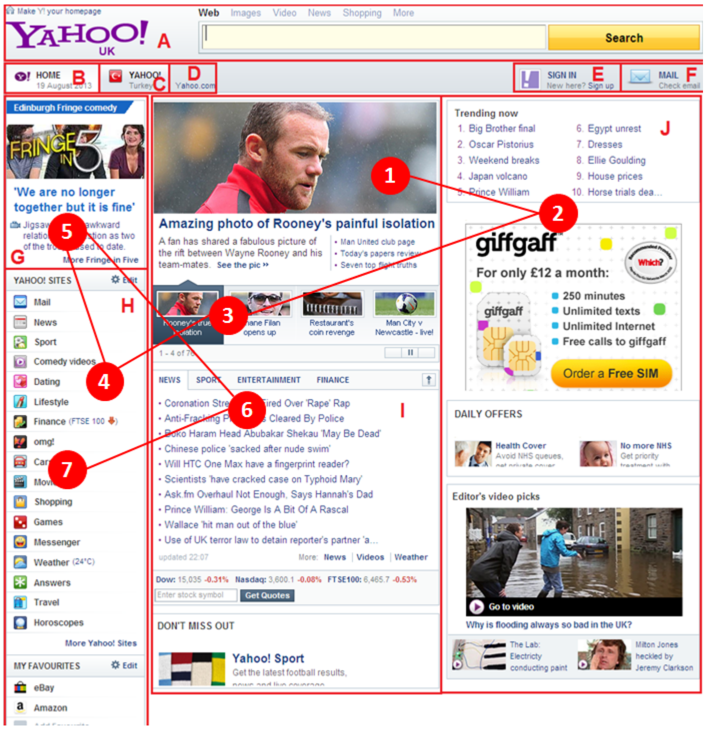


Figure 10.: The trending scanpath of the ASD group on the Yahoo! page

As can also be seen from Figure 10 and Figure 11, the trending scanpaths of the ASD and control groups looked different. When we compared the trending scanpaths of these two groups by using the String-edit algorithm, we found that the trending scanpaths of the control group were ≈55% dissimilar to the trending scanpaths of the ASD group. However, as there were also some similarities between the trending scanpaths of these groups (≈45% similarity), we cannot conclude that people with autism and neurotypical people follow completely different paths while they are searching for specific information or items on web pages.

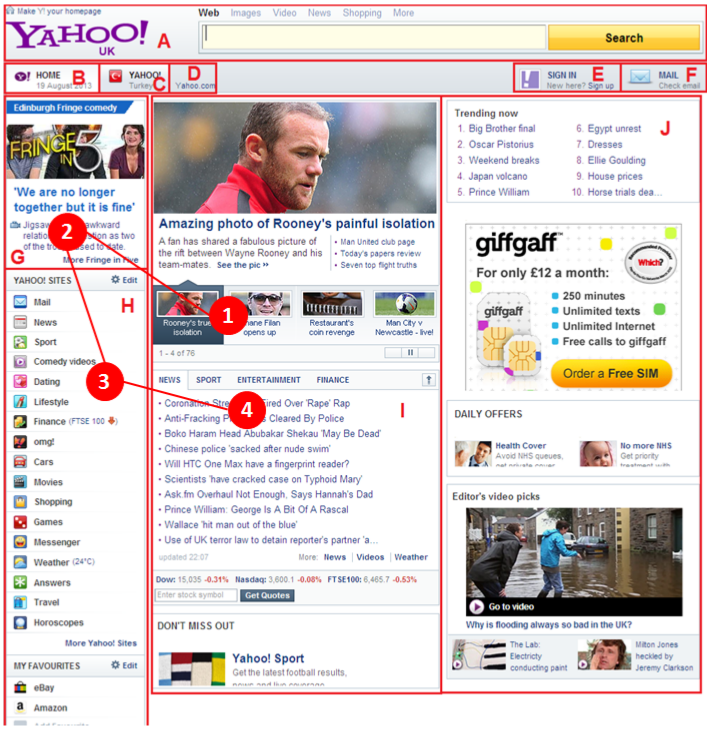


Figure 11.: The trending scanpath of the control group on the Yahoo! page

5. Discussion

Our results showed that the participants with autism did not have significantly lower success in finding relevant information on the web pages. However, comparison of the mean values revealed a tendency for the autistic participants to have lower scores under a limited time and this could be associated with the possible between-group differences raised by the eye tracking data. We showed that the participants with autism had a tendency to look at more irrelevant elements compared to the control group participants and have longer scanpaths. The participants with autism also made more transitions between the elements of the web pages but the duration of their fixations was likely to be shorter than those of the control group. Finally, we compared the trending scanpaths of the two groups (where higher variance was found within the ASD group) and we observed that their trending paths were not completely different from each other.

5.1. *Locating Information and Fixations on Irrelevant Elements*

Even though our analysis shows that the participants with autism tended to be less successful in searching specific information or items on web pages in comparison with the neurotypical participants (see Table 1), there was no statistically significant difference between the numbers of correct answers given by the two groups (see Section 4.1). It is important to note that the participants in our study were highly-able individuals on the autism spectrum who also used the web on a regular basis. People at the lower ends of the autism spectrum are likely to experience greater difficulty with web search tasks depending on the level of severity of their condition and their experience with using the web.

It can be argued that a between-group difference may have existed if there was no time limit. While we acknowledge that this might have been the case, we argue that the timely location of information is important in a number of competitive work and school environments. We address the limitations of our approach with regards to limiting the time in Section 6.

Inspired by the WCCT theory (Happé and Frith 2006) which posits that people on the autism spectrum tend to use a bottom-up approach to visual processing and focus on specific elements to the exclusion of context, we decided to explore whether focusing on irrelevant elements could be a possible reason for their lower performance with our tasks. We identified those elements which were not directly relevant to the task and compared the number of such elements which appeared in the scanpaths of the participants from both groups (Section 4.2). The results show that the participants with autism looked at more irrelevant elements and there was a significant difference between the two groups on the Babylon and BBC pages in terms of the number of irrelevant elements visited. The control group participants on the other hand seemed to be better able to dismiss certain visual elements as irrelevant or to follow organisation cues and grasp the principle according to which a web page is structured. To improve the processing of web pages for users with autism, either a web page has to be designed with better engagement in mind or a web page needs to be transcoded to support or aid a search task. Experiential transcoding could be a good approach to transcode the content of web pages such that they are easier to access by people with autism (Yesilada, Harper, and Eraslan 2013). However, further research needs to be conducted to confirm this.

5.2. *Scanpath Length, Transitions Between Elements and Fixation Duration*

The ASD group tended to have more fixations across a higher number of visual elements (Figure 6), make more transitions between the elements (Figure 7) and have shorter fixations (Figure 8) in comparison with the control group.

We firstly discuss the implications of these results in terms of the trade-off between efficiency[4] and the number of visual elements. According to the eye tracking literature, a longer scanpath on a web page is related to less efficient searching (Ehmke and Wilson 2007), since the processing of more visual elements requires higher cognitive effort. The transitions between separate elements is associated with uncertainty in searching (Ehmke and Wilson 2007), which also makes the process of locating the necessary information less efficient. On the other hand, the fixations in the ASD group were likely to have shorter than the fixations in the control group, suggesting that the participants in the ASD group were scanning the elements at a higher pace.

The shorter fixations within the ASD group could also provide an explanation for their lower number of correct answers given when solving the tasks. Compared the ASD group, the control group participants had a tendency to exclude certain elements as irrelevant, spend longer times for processing the relevant visual elements and thus grasp their meaning and complete the task in time. The participants with autism on the other hand tended to pay less attention to the meaning of the individual elements (relevant or irrelevant) and use their time to scan as many elements as possible. They would often continue searching even after they had already seen the correct element as shown in Figure 10.

These results have practical implications for web accessibility for users with autism. First, the results reported in the previous section revealed that the web page should be designed with better engagement in mind where the relevance of the elements to the main purpose of the page is more salient. Second, the number of visual elements on a web page is important since users with autism follow a bottom-up approach in screening large portions of the web pages (Happé and Frith 2006). Web pages with fewer visual elements would reduce the cognitive effort required for scanning the pages by people with autism and optimise their task completion time.

[4]In the context of this research, efficiency is defined as the time and effort required by the participants to successfully complete a task.

5.3. *Trending Scanpaths*

The data analysis revealed that the variance within the ASD group was higher than the variance within the control group, even though they were people with high-functioning autism. The higher variance within the ASD group was confirmed by the String-edit algorithm and visualised by the ScanGraph tool (see Figure 9). The ScanGraph tool constructs a graph where similar scanpaths are connected to each other. In the graph constructed for our participants, there are more connections between the control group participants (for example, C03-C08-C14, etc..). However, the graph also shows some exceptions. For example, it shows that A08 is closer to both C02 and C06. Therefore, we can suggest that the searching behaviours of people with autism can be similar to the searching behaviours of neurotypical people.

We also compared the trending scanpaths of the ASD and control groups and we found that their trending scanpaths were ≈45% similar and ≈55% dissimilar to each other. Based on these results, we cannot conclude that the participants with autism followed an entirely different approach to find the necessary information. Instead, the between group differences are more likely to have arisen due to other quantitative differences, such as the lengths of their scanpaths, the number of transitions they made between the elements of web pages, and their average fixation durations.

5.4. *Impact of the Results on Web Accessibility*

As discussed in the related work section of this paper, current web accessibility guidelines for people with autism are characterized by three main drawbacks:

(1) They are usually derived by matching the diagnostic criteria to potential web accessibility barriers for people with autism;
(2) The proposed accessibility solutions have never been evaluated;
(3) The guidelines use the umbrella term "cognitive disabilities" without consideration of the important aspects of its heterogeneity.

The results presented in this paper advance the state-of-the-art in web accessibility by addressing these limitations in the following ways:

(1) Web searching strategies in people with high-functioning autism and accessibility guidelines: The findings presented above provided evidence for a bottom-up approach to searching for information within web pages in people with autism: they tend to scan more elements of the page, some of which irrelevant to the task, and they tend to have shorter fixations compared to the control group who would focus their attention longer on the elements that could potentially contain the correct answer. The implications of these findings for the design of web pages with better engagement of users with autism are discussed below. We tested the first assumption from the WC3 Cognitive Accessibility User Research under the ASD header: "may not pay attention to primary content because distracted by secondary content". This assumption is now empirically supported with evidence from eye tracking data. Furthermore, while not aimed at directly testing it empirically, our results are also relevant to another statement in the guidelines, namely, that "People with autism may not recall instructions when subsequently presented with an action to perform". The fact that there was no statistically significant difference between the number of correct answers the two groups gave to the search tasks suggests that, at least in the case of people with high-functioning autism, this may not be true. However, as mentioned previously, this may not be the case with people at the lower ends of the spectrum and, in that sense, it is paramount that our results are not generalised to all levels of autism severity and that more research should be conducted to provide conclusive evidence.

(2) Improving the web accessibility guidelines for people with autism: Based on our results, we propose improvements to the WC3 Cognitive Accessibility User Research and existing web accessibility guidelines:

- **Reduce the number of elements on the web page.** Our findings presented in Section 4.2 suggest that having fewer elements would reduce cognitive load and timing for people with autism as they have a tendency to look at many elements and the processing of more elements requires higher cognitive effort.
- **Adding extra media would likely have a negative impact.** Furthermore, adding extra media (e.g. videos and sound), as suggested by the WC3 research paper, may have negative impact, since autistic users are likely to examine web pages incrementally, as shown in Sections 4.3 and 4.4.
- **Focus on reducing time and effort rather than providing different means for obtaining the information.** The similarity of the trending scanpaths of the two groups showed that web users with autism and neurotypical users do not follow completely different strategies for obtaining information, however web users with autism would require more time and more cognitive effort compared to neurotypical people. This implies that future accessibility initiatives for users with high-functioning autism should focus on reducing time and effort rather than providing different means for obtaining the information such as additional media (e.g. videos or sound), which may be distracting.

Finally, while the two groups were generally able to locate the required information within the web pages, the group with autism had lower mean and median values for their numbers of correct answers within the given time limit. In practical terms, this suggests that demos, tutorials and automatic previews should allow extra time between changing their slides/visuals. This also applies to academic exams and supports the strategy for allowing extra time for students on the spectrum.

(3) Generalisability of the results to other cognitive disabilities: It is also important to discuss whether the search patterns of people with autism could be generalised to other people with other types of cognitive disabilities. This is because the WCAG guidelines list the requirements of web users with autism under the umbrella term "cognitive disabilities". Our results regarding the possible differences in attention between the two groups can be explained by the WCCT theory and the stimulus overselectivity phenomenon, presented in our related work. However, these phenomena are typical to autism in particular and are not shared by other cognitive disabilities such as intellectual disability or Alzheimer's disease. This means that if our results are indeed underpinned by differences in cognitive processing described by these two theories, then our results cannot be generalised to participants with other types of cognitive disabilities. Comparative studies between various types of cognitive disabilities are thus very much needed in order to not only gain a better understanding of the needs of various user groups, but also to assess the commonalities and differences in their requirements. A good example of such comparison, albeit without empirical data, is the Cognitive Accessibility User Research (Seeman and Cooper 2015). Experimental research comparing the challenges experienced by different groups could induce cognitive accessibility guidelines which give priorities to those elements, whose features are shared between a higher number of user groups.

5.5. *Further Analysis with Bootstrapping*

In terms of our dependent variables, even though the descriptive analysis (the mean and median values) showed that these two groups tend to have differences while they are interacting with web pages, our statistical analysis showed that the ASD and control groups were not significantly different from each other on all the pages. When we conducted a power analysis with G*Power[5], we recognised that we were under powered because of our sample size and this could cause a Type II error (i.e., failure to detect a significant difference) (Gravetter and Wallnau 2008). To achieve at least 95% statistical power, we needed to have more participants, and therefore the sample size should have been larger. To investigate how more participants could affect our statistical analysis,

[5]http://www.gpower.hhu.de/

we decided to use the bootstrapping technique (i.e., sampling with replacement) to increase our sample size for each group (Hesterberg 2015). We estimated the required sample size by using G*Power with its default settings (Effect size d= 0.5, α err prob = 0.05, Power = 0.95, Allocation Ratio N2/N1 = 1). To deal with the possible effects of the selection of the participants with the bootstrapping technique, we generated 1000 different samples with the required same size and then calculated the mean of the p values as shown in Table 9. We then recognised a significant difference ($p < 0.05$) in the most of the cases with all the dependent variables as highlighted in bold in Table 9. Therefore, these further analyses with bootstrapping suggest that it would be worthwhile to conduct the same study with more participants as there is a strong signal that there are significant differences between these two groups in searching on web pages.

Table 9.: The mean p values from the further analysis with the bootstrapping

Metric	Pages	Sample Size	Average p-value
Transitions Between Elements	Apple	92	**0.000**
	Babylon	92	**0.000**
	AVG	92	**0.001**
	Yahoo	92	0.087
	Godaddy	92	0.065
	BBC	92	**0.000**
Scanpath Lengths	Apple	92	**0.000**
	Babylon	92	**0.000**
	AVG	92	**0.009**
	Yahoo	92	**0.000**
	Godaddy	92	**0.022**
	BBC	92	**0.000**
Fixation Durations	Apple	92	**0.029**
	Babylon	92	**0.003**
	AVG	92	**0.002**
	Yahoo	92	**0.001**
	Godaddy	92	**0.000**
	BBC	92	**0.018**
Irrelevant Objects	Apple	92	**0.001**
	Babylon	92	**0.000**
	AVG	92	0.251
	Yahoo	92	**0.017**
	Godaddy	92	**0.004**
	BBC	92	**0.000**

6. Limitations

In this section we discuss the limitations of this work and factors which may have influenced the accuracy of the results.

Participant sample: We had a small group of users, therefore it would be beneficial to replicate this study with a larger and more representative sample to draw stronger conclusions (see Section 5.5). It is also important to note that all participants who took part in our study were at the high end of the autism spectrum, which is why the results of this study should be interpreted with caution when generalised to people with different levels of autism severity.

Stimuli and tasks: We used only six web pages in our eye tracking study in order not to impose heavy cognitive load on the participants with autism and to comply with ethical considerations. Since we observed that all the participants were easily able to cope with this amount of web pages and tasks, we plan to assess a greater number of web pages with a varying content in a new study. One variable that may have influenced the accuracy of our results is the formulation of the tasks. While we have done our best to design simple and uniform tasks which require the identification of a single visual element as the correct answer, it is possible that some participants may have found certain tasks easier than others. In this sense, some within-group differences between the processing of individual pages may be attributed to the perceived task difficulty, in addition to individual differences among the participants.

Time limit: The time limit for the tasks was 30 seconds and this might have caused some pressure on the participants. However, it was important to have a time limit for completing the tasks in order to make the study sensitive enough to capture between-group differences. Furthermore, the timely location of information is important in many real-life situations and this should be a consideration when developing accessibility guidelines. It would nevertheless be interesting to design a different study where we measure the time taken by each participant to complete a given task without any time limit. Such a comparison of task-completion times would perhaps be more informative of the extent to which users with autism have issues related to processing speed.

Technical inaccuracies and defining the areas of interest: When working with eye-tracking data, one should not forget that such data inevitably contains inaccuracies owing to the structure of the eye (Duchowski 2009). As a result, it is possible that a small number of gaze fixations may have been inaccurately attributed to specific locations on the web page and thus diminished the accuracy of the results. However, this type of inaccuracy is small and is typical for all eye-tracking research. Assigning individual fixations to particular locations raises another question of the definitions of the areas of interest. In this study we have used a systematic approach where each area of interest corresponds to a page element but it is possible that defining the areas in a different way (e.g. with more cushioning around the element or to assigning probability to individual fixations) may lead to other interesting findings.

Finally, in our work, we mainly investigated search tasks within web pages as a first step towards a broader investigation of web accessibility for people with autism. In the future, we plan to conduct more studies to investigate the behaviour of these people in search tasks that involve visiting multiple pages and making decisions on returned results. In that case, we may focus on the formulation of queries and the selection of relevant links among the returned results. Our current findings relate to those users with autism who are at the highest end of the spectrum. However, it would be particularly interesting to conduct the same study with a user group with a more severe form of autism.

7. Concluding Remarks

Autism Spectrum Disorder is a condition which affects communication and social interaction (American Psychiatric Association 2013) and whose worldwide prevalence increases at a steady pace (Dave and Fernandez 2014). People with autism have differences in attention, cognitive processing and sensory integration (American Psychiatric Association 2013). As a result, the way they access information from the web would also be different. Many existing works aim to identify the challenges of web users with autism, and propose design guidelines for making the web more accessible for them (see Section 2). However, the vast majority of these works lack empirical evaluation.

In this study, we investigated differences and similarities between web users with and without autism when searching information within web pages and whether certain page elements serve as distractors as suggested by the WC3 Cognitive Accessibility User Research. We also aimed to discuss the implications of our analysis for future web accessibility guidelines. We presented an eye tracking study involving 18 participants with a diagnosis of autism and 18 control group participants. All the participants were asked to view six web pages and find particular information or items on each web page.

According to our analysis, the participants with autism tended to look at more irrelevant visual elements and have longer scanpaths. However, their fixation durations tended to be shorter than those in the control group. Furthermore, the participants from the ASD group had a tendency to make more transitions between the elements of the web pages and have higher within-group variance. When comparing the concatenated scanpaths of the two groups, we found that they were

≈45% similar and ≈55% dissimilar to each other.

These findings mean that people with autism tend to employ different information searching strategies when processing web pages, and that the content of the web pages needs to be improved to better accommodate these differences.

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