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A Survey of Autism Spectrum Disorder Friendly Websites

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Abstract People with Autism Spectrum Disorder (ASD) have unique challenges making it difficult to interface with information on websites. In this paper, we evaluate six hundred websites for autism friendliness across four primary categories including: (Autism Focused, U.S. Federal, Google Autism Search, and Alexa Rating). Autism user requirements are linked to 29 HTML style properties and 1 image property to develop 25 novel parameterized metric components. These metric components are uniquely matched to three themes – image, animation, and font. A new Website ASD Rating score is created and applied to each website reviewed. The four website categories are comparatively evaluated based on the new Website ASD Rating score. We show that font and animation are significant features with respect to the Website ASD Rating score. The mean ASD Value score is not significant across the web site categories.

1 Introduction

The Internet has become an essential interface for many people. Digital spending is eclipsing brick and mortar commerce. Schools are rapidly moving to paperless systems requiring computerized devices and electronic media. For some, the Internet seamlessly integrates into their everyday lives. Yet, others perceive an entirely different view emanating from the World Wide Web - a cacophony of data accosting their senses.

People with Autism Spectrum Disorder (ASD), a developmental disability that causes social, communication, and behavioral challenges [1], have unique issues when interfacing with websites. Information or sensory overload can cause challenging behaviors or meltdowns [2]. Web content that is blinking, flickering or flashing can be a serious distraction and considered inaccessible by this type of user [3]. Accessing information on the web could be a daunting endeavor for a person with this type of cognitive disorder. The Centers for Disease Control (CDC) reports a staggering 1 in 68 U.S. children with ASD in 2012 [4] while the 2014 National Health Institute Survey reports 1 in 45 with ASD [5]. Website data may need to be uniquely presented to accommodate for some of these difficulties. Developing nations have responded by enacting laws, policies, and standards to ensure the Internet is accessible for people with disabilities. Web accessibility allows disabled people to perceive, understand, navigate, and interact with the information on the web [6]. U.S. agencies which receive

federal funding and use websites are required to comply with accessibility requirements.

Although laws and guidelines have been established for website designs to help people with disabilities [13], [18], including people with ASD, translating ASD user requirements to website design requirements is still very challenging. Without knowing the most influential website design features and how to configure those features, web designers may inadvertently create websites which are unfriendly to people with ASD. This makes it hard for someone to know if they are visiting a potentially unfriendly site. Certain sensory inputs related to auditory and visual processing can negatively impact a person with ASD and either make the website inaccessible or unusable. Furthermore, websites have not been programmatically evaluated and compared for autism friendly characteristics directly related to the graphical user interface (GUI).

Special website accommodations can be implemented for people with disabilities. There are many web plugin tools that have been created to aid users with physical and cognitive disabilities [7]. Tools which facilitate reading comprehension and mitigate sensory overload is an area of special interest for people with ASD. BeeLine Reader is a Google Chrome web extension that generates a more comprehensible rendition of a web page by expelling advertisement, remarks, and other distractions. The tool applies a color gradient to the web page content to guide a user's eyes from line to line [7]. However, certain colors can distract a person with ASD [8]. Replacing one set of color features on the website with a different set may not be conducive to people who specifically have ASD. Krishnakumar and Narayana proposed an adaptive e-learning web tool based on individual user characteristics that can assist in learning for people with Autism [9]. However, these tools do not initially provide a way to identify areas of difficulty for the ASD user on a website. Therefore, there is a need for a metric or grading system to alert designers and users alike as to the ASD friendliness of a site.

Surveying the website feature space across different domain websites such as federal websites and autism-focused websites will improve our understanding about ASD friendly characteristics. Objective metrics are applied to ASD-friendly features to characterize the features themselves and websites for comparison. The feature source is derived from the cascading style sheets (CSS) properties which describe the hypertext markup language (HTML) document and how elements should be displayed. Another feature source is the homepage image data of the website. Both sources are connected to the ASD-friendly metrics. Identifying the most important features contributing to an ASD-friendly website are important aspects to the solution. Since people with ASD have different sensory sensitivities, identifying significant features pertaining to an ASD-friendly metric will be a useful consideration when designing website or tools for specific purposes.

The next sections include a brief history of ASD along with an overview of current website standards and best practices in sections 2 and 3 respectively. A deeper dive into the Website ASD Rating development is detailed in section 4. The website data collection process in section 5 covers the website domains, web scraping, and data preprocessing steps to create the final dataset. Section 6 Survey and Analysis expounds upon the data analysis approach and results. An examination of ethical considerations as it relates to this topic is provided in Section 7 with the conclusion in section 8.

2 History of ASD

In 1943, the first psychiatric clinician to portray autism through case studies was Leo Kanner, a psychiatrist at John Hopkins Medical Center [10]. Two underlying features he believed all patients had in common were "autistic aloneness" and an "obsessive insistence on the preservation of sameness" [10]. Historically people with autism have been mistakenly diagnosed with schizophrenia and mental retardation caused by a cold and uncaring mother [10] but research has continued to learn more about this type of disability. In contrast to historical medical conclusions, approximately half the people with autism have either average or above average intelligence despite the cognitive challenges of this disability [11].

Today, the Diagnostic and Statistical Manual, Fifth Edition (DSM-V) has combined Autism, Pervasive Development Disorder, and Asperger's under one umbrella called Autism Spectrum Disorder(ASD) [12]. The manual defines ASD as persistent deficits in social communication and social interaction across multiple contexts and restricted, repetitive patterns of behavior, interests, or activities [11]. One manifestation is the hyper- or hypo reactivity to sensory input such as the adverse response to certain types of sounds, lights, or movement. Other signs may include a highly fixated and obsessive personalized interest or difficulties with transitions [11]. Current risk factors and causes of ASD listed by the Center for Disease Control include genetics, children born to older parents, certain prescription drugs taken during pregnancy, and occurrence with other chromosomal conditions such as Fragile X Syndrome [1]. Since ASD is a disability, there is no cure. Treatment plans to reduce the symptoms can dramatically differ from one individual to another related to the spectrum, severity, and divergent manifestations.

3 Website Standards and Best Practice

Since the Internet is an essential interface for providing public and private services, developing nations have enacted laws, policies, and standards to ensure people with disabilities can access information. For instance, the United States *§* 508 of the US Rehabilitation Act of 1973 requires accessibility of the web for disabled federal employees or the public users of federal websites [13]. The World Wide Web Consortium (W3C), an international organization promoting "Web for All" design principles [14], informs many of the laws and guidelines in existence today for people with disabilities. Other relevant considerations that accessibility does not guarantee are usability and inclusion. Covering human-computer interactions, the International Standards Organization (ISO) defines usability in ISO 9241-11:1998 in the context of effective task completion, task time, and user satisfaction [15]. Furthermore, inclusive websites encompass a universal design for all without the need for accommodations [16].

Several websites and published papers discuss recommendations and best practices for designing ASD-friendly websites [2, 17:19]. Dattolo, A. and Luccio, F.L. proposed 18 ASD-focused guidelines for web designers and developer [18]. The guidelines were generated and filtered from recent publications authored by the Cognitive and Learning

Disabilities Accessibility Task Force (COGA), Web Content Accessibility Guidelines (WCAG), and the U.S. Department of Health & Human Services. Furthermore, Dattolo et al. [18] systematically compared 21 autism related websites to check compliance against the ASD-focused guidelines. Eighteen criteria are quantified as ordinal values – guidelines have been respected, guidelines have been partially respected, guidelines have not been respected.

Another researcher, Nikolay Pavlov, has been pushing to increase user-interface (UI) design research [19]. Pavlov closely follows some of the Web Content Accessibility Guidelines (WCAG) organized by the W3C's Web Access Initiative (WAI) to develop a user interface for a tool, Open Book, that is used to assist people with ASD with written documents [17]. Pavlov assessed numerous design standards for users with attention deficit hyperactivity disorder (ADHD), and reviewed existing research on reading comprehension improvement, and gathered feedback from ASD users and clinical professional. Collectively from this review, Pavlov filtered and listed specific do's and don'ts to follow when designing a website with accessibility for autistic individuals in the areas of presentation; navigation and page loading; and interaction [17].

Jamie Knight offers a unique perspective on website design since he is both a professional web designer and autistic. He has been referenced by websites and literature due to this unique perspective [20]. Based on his experience, Jamie Knight discusses cognition and accessibility along with realistic design guidelines [21-22].

4 Website Data Collection

4.1 Website Data Collection

Four website categories are created – Autism Focused, U.S. Federal, Google Autism Search, and Alexa Ratings. Table 1 represents an aggregate count of websites for each of the four categories. The Gross URL Count reflected in Table 1 is the initial count of websites scraped which is 718. The Net URL Count of 600 represents the number of successful websites scraped. A successful web scrape consists of obtaining the relevant HTML style data from the website.

Table 1. Summary of website categories.

Website Category Name	Category Description	Gross URL Count	Net URL Count
Autism Focused	Dattolo and Luccio's study for autism compatible websites	21	15
U.S. Federal	Federal websites that meet minimum regulatory requirements for disabled	297	287
Google Autism Search	Google keyword search "autism friendly websites"	200	120

Alexa Rating	Top 200 U.S. websites based on Alexa web traffic	200	178
Total		718	600

Autism Focused category encompasses the 15 websites that Antonina Dattolo and Flaminia Luccio evaluated based on their best-practice autism guidelines [18]. The U.S Federal category consists of 287 of the most popular federal websites based on Alan McQueen's and Daniel Castro's scoring [23]. Castro and McQuinn compiled a list of federal websites using Alexa to rank by popularity based on web traffic data in November 2016. This category was selected because federal websites are required to adhere to the United States *§* 508 of the US Rehabilitation Act of 1973. Google Autism Search category is defined as the top websites based on a Google engine key-phrase search, "Autism friendly websites" resulting in 120 final websites; There are numerous references that have proposed similar guidelines and tips on autistic design criteria, mainly from keyword searches on Google. Alexa Rating is defined as the top 200 websites in the U.S. based on highest Alexa traffic data gathered on October 2017. The Alexa Rating category is used as the control for our analysis. We hypothesize that the most ASD friendly to the least unfriendly will be in the following order - Autism Focused, U.S. Federal, Google, Autism Search, and Alexa Rating based on the average Website ASD Rating for each group. In short, the total sample size of websites used for the study is 600 websites. Figure 1 shows a pie chart with the number of websites and percentage by category.

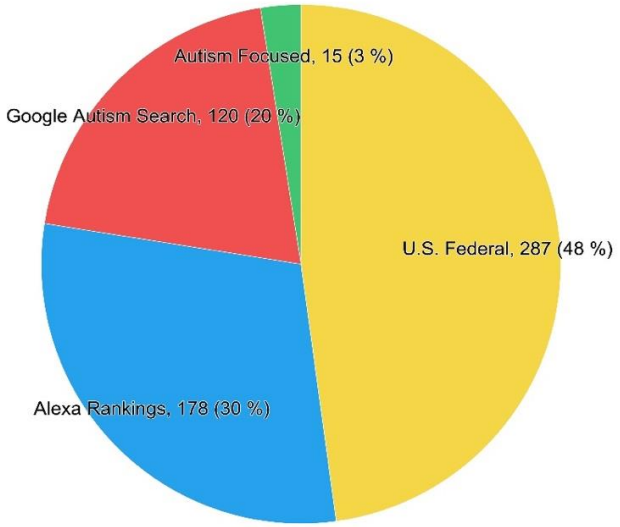


Fig. 1. Pie chart grouped by website category and corresponding percentages.

4.2 Web Scraping

Our data collection method focused on the scraping of the websites. We started with a small sample and scraped every element on the web page. This was a time intensive task, so we investigated which properties and attributes would be important to include for all metrics we may want to consider in our study. As a result, we dropped several properties that had uniform responses over the initial sample. A script was written in Python version 2.7.13 that uses Selenium web driver version 3.6.0, and the Google Chrome webdriver version 2.34. The websites from each domain were listed in a text file, another text file listed all CSS properties found in w3schools.com's online CSS reference [24], and the final text file that lists some attributes of HTML tags that we decided to capture as well. The script simply gathers each of the properties and attributes from every element on each of these websites. Only the first page of each website is used. The data is collected from all CSS properties, attributes, tag names, and text of each element and is mostly text data. Timestamps of when the page was retrieved were collected as well as two screenshots of the web pages at 0 and 5 seconds which is meant to capture changes in the image due to any distracting animation such as blinking images. The home page and the 5 second delay are meant to emulate a user's initial experience with the website. The properties and attributes collected were determined by our own inspection to have either direct or indirect relevance to our metrics.

4.3 Data Preprocessing

An intermediate dataset was created that had 544,137 rows and 163 columns. The rows contained data from the elements of 689 websites and each website had between 3 and 8,114 elements. The processing was originally collaborated over in a Jupyter Notebook using Python version 2.7.13. The only non-standard package used was Pandas 0.19.2 which allowed us to take advantage of the tabular orientation of each dataset and typical summarization methods that can be used with such structure. The summarized data was then used to create metrics for each of the three categories: images, animation, or text metrics.

The first step in processing removed unwanted rows and columns. The unwanted rows were any that corresponded to a stale element or had a CSS visibility property equal to "collapse". The "collapse" property both renders an element invisible and collapses the area where it would occupy. The unwanted columns are those that were both not identified as being relevant to the metrics and displayed little to no variability (99 to 100% of elements report the same value).

The second step was to process some of the relevant properties; some tasks include processing colors into a standard red green blue (RGB) color format, mapping font family values into friendly or not friendly groups, and standardizing animation duration lengths. Most of the properties processed in step 2 were directly relevant to our metrics.

The third step binarizes the fields that were processed in step 2 and produces proportions where indicated as appropriate.

The fourth step begins to clean up by binarizing and producing proportions for properties not processed in step 2 and 3. All properties processed in step 4 were not directly relevant to our metrics.

The images of the webpages were also processed to detect 5-second delay pixel changes. This was done asynchronously but before step five and processed the webpage images by calculating their pixel-wise difference to determine if there was a change in the webpage in the first 5 seconds; the output of this process included a Boolean value indicating a change or no change and a value between 0 and 1 indicating the proportion of the webpage that changed.

Step five does some final clean up and coordination by producing all the final counts, sums, and proportions, then incorporating the website domain categories mentioned in the previous section, including 5-second delay pixel change data, and finally summarizing each website into a single row.

5 Website ASD Rating Component Metrics

Pavlov's comprehensive review and detailed guidelines provides the basis for the 10 selected ASD user requirements for websites that underpin the Website ASD Rating. Some of the user requirements point toward simple images; no visual distractions like animations; and clear, readable fonts. A hierarchical structure of the Website ASD Rating creation is provided in Figure 2.

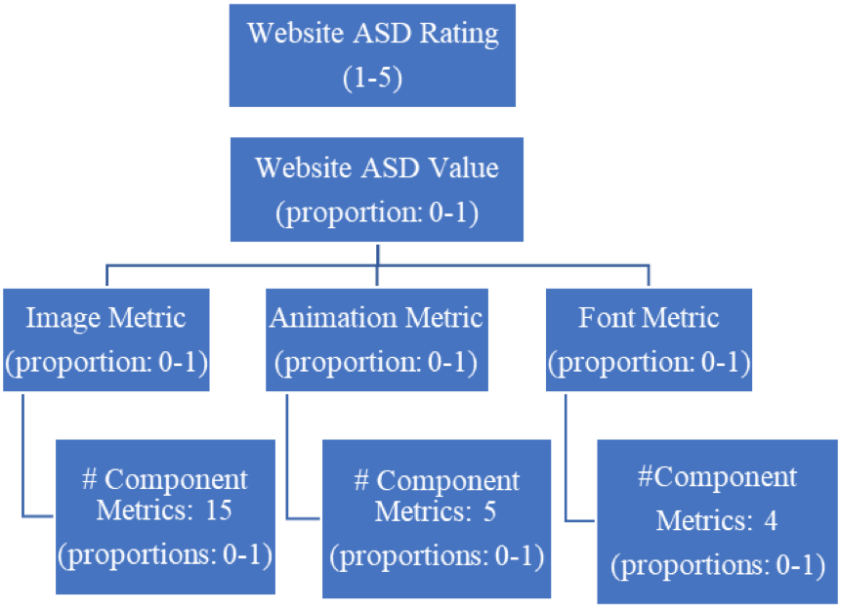


Fig 2: Hierarchical structure of the Website ASD Rating.

The user requirements are grouped into three main categories which are Image Metric, Animation Metric, and Font Value. These three metric scores are the equally weighted average of their associated Component Metrics. The Component Metrics measure the proportion of unfriendliness of a property with scores ranging from 0 to 1. The most-friendly score is 0 and the least-friendly score is 1. An overall ASD Value is calculated for a website by averaging the Image Metric, Animation Metric, and Font Value as seen in Formula 1.

$$\text{ASD Value} = \frac{1}{3}\text{Image Value} + \frac{1}{3}\text{Animation Value} + \frac{1}{3}\text{Font Value}. \quad (1)$$

The final ASD Website Rating is created by binning the ASD Value scores into 5 intervals, 1 through 5, as seen in Table 2. At the extreme ends, an ASD Website Rating score of 1 represents the friendliest ASD website and a score of 5 represents the least ASD friendly website. This is in-line with all the lower level scoring – the higher the score the more unfriendly the website.

Table 2. The Website ASD Rating score from 1 through 5 representing the most and least friendly websites.

	Most Friendly ----------> Least Friendly				
ASD Website Rating	**1**	**2**	**3**	**4**	**5**
ASD Proportion	0.0–0.19	0.20-0.39	0.40-0.59	0.60-0.79	0.80-1.00

5.1. Metric Components

Creating a crucial bridge, the Metric Components connect the 10 selected ASD user requirements from Pavlov to website design features such as HTML's CSS properties, HTML text attribute, or screenshot homepage image data. The image, animation, and font metric categories have 6, 1, and 2 unique user requirements respectively.

The first source of information used for the metric component are the 21 HTML's CSS properties which provide the display and style measurements of a website. This type also uses the text attribute which is a text string. A website contains many HTML elements (rows) with various CSS properties along with the text feature. Roughly 400 elements on average were downloaded for each homepage. For example, the title of a website is defined in one element whereas an icon is defined in another element. The text or object can be styled based on the CSS properties that control image position, animation, or font size. In addition, each of these CSS properties are defined by functions and configured using several parameters. For example, font size can be set with the "font-size" function using the different parameters such as "large" or "length" (font-size: medium | xx-small | x-small | small | large | x-large | xxlarge | smaller | larger | *length* | initial | inherit) The criteria that is used to determine whether an element or attribute of a website is friendly or unfriendly is set using a combination of the parameter settings. These criteria are defined in detail for each Component Metric in

Appendix: ASD User Requirements and Component Metric Calculation Tables. Only elements which were visible on the website are used related to the CSS property, "visibility" with a "visible" parameter setting. The criteria for twenty-one unique CSS properties are used to create 23 of 25 Component Metrics. On the other hand, a second source for the metric components is the homepage image data in the form of 2 screenshots that are captured 5 seconds apart; these images are used to create 2 of 25 component metrics. The change in the pixel count attribute is used in this case.

Two types of Metric Component calculations are used. The first type of scoring calculation applies to the majority (23 of 25) Component Metrics. This score results in a range of proportions from 0 to 1; the higher the score the more unfriendly. The first type is calculated as the number of elements or attributes that contain the unfriendly characteristic divided by the total number of elements or attributes for website.

$$\text{Metric Component Type I} = \frac{\text{\# of elements with unfriendly attribute}}{\text{total \# of elements for webpage}} \quad . \tag{2}$$

The second type of Component Metric derivation is binary in nature, 0 or 1. If the unfriendly condition exists at the website level, the Component Metric is 1. On the other hand, if the unfriendly attribute does not exist the Component Metric is 0 indicating a friendly score.

$$\text{Metric Component Type II} = \begin{cases} 1: \text{ unfriendly} \\ 0: \text{friendly} \end{cases} \quad . \tag{3}$$

Image Value. The first metric category is image. The image metric category has three main subcategories which are image complexity, image quality, and unique colors. Image complexity is evaluated in terms of the simplicity of the elements on the page and the number of background images. Some parameters of simple elements can be measured related to the CSS properties for text-shadow, column-rule-style, perspective, border-bottom-style, border-left-style, border-right-style, border-type-style, box-shadow, position, and text-decoration-style. Simple website elements with minimum embellishments such as solid lines are considered more friendly than complex elements such as dashes or images which are sticky and move with page scrolling. The second component of image complexity is evaluated in terms of the number of background images the webpage contains. Pavlov does not recommend the use of background images. The related CSS property is background-image. The second main subcategory is image quality and can be quantified using the CSS properties background-size and filter. Parameters which distort the image such as resizing the object without maintaining its original form or using blurring effects are considered unfriendly while images which are maintained in the original form or grayscale are scored as friendly. The third main subcategory for image is color which focuses on the proportion of different colors used on the homepage. Nine CSS properties are evaluated which are background-color, border-bottom-color, border-left-color, border-right-color, border-top-color, color, column-rule-color, outline-color, and text-decoration-color. Each of these properties contain RGB integer parameters which define the color for an element

on the webpage. Different combinations of RGB represent different colors. The total number of unique colors are calculated for each website and divided by the total number of unique colors for all websites. Finally, this proportion is divided by 9 since 9 color CSS color properties were used. Pavlov recommends minimizing the use of many colored icons. A lower proportion of colors is friendlier than a higher proportion of colors. See Table 3 for a summary review of the ASD user requirements and the corresponding metric components for the Image Metric Category.

Table 3. Image Metric ASD user requirements with associated component metrics.

Metric Category	ASD User Requirements	Component Metrics
Image Value	Use simple graphics.	text_shadow_binary_Prop column_rule_style_binary_Prop perspective_binary_Prop border_bottom_style_binary_Prop border_left_style_binary_Prop border_right_style_binary_Prop border_top_style_binary_Prop box_shadow_binary_Prop position_binary_Prop text_decoration_style_binary_Prop background_attachment_binary_Prop
Image Value	Do not use background images.	background_image_binary_Prop
Image Value	Make sure the illustrations are in sharp focus.	background_size_binary_Prop filter_binary_Prop object_fit_binary_Prop
	Do not use many colors.	NumUniqueColors_Prop

Animation Metric. The second main metric category is animation. Pavlov does not recommend the use of pop-up elements or distractions. This metric derives from three CSS properties; animation-delay, animation-duration, and animation-name. Like the image-related metrics, all three CSS properties are binarized for all elements, where 1 indicates the presence of an animation and 0 indicates no presence of an animation. In addition, two further animation metrics are used which are not CSS properties. Both correspond to detect image changes after 5 seconds. The first one is change_5_sec_Prop which is the proportion of pixels that changed. The second metric is a binary metric which can either be a 0 for no change or a 1 for change. The overall website metric for animation presence is the average of these five proportions for each website. See Table 4 for a summary review of the ASD user requirements and the corresponding metric components for the Animation Metric Category.

Table 4. Animation Metric ASD user requirements with associated component metrics.

Metric Category	ASD User Requirements	Component Metrics
Animation Value	Do not use pop up elements and distractions.	animation_delay_binary_Prop animation_duration_binary_Prop animation_name_binary_Prop change_5_sec_Prop change_5_sec_Bin

Font Value. The third main metric category is font. The first subcategory is "font size" which is the count of all text characters at size 14-point or larger divided by the count of all text characters in the web page. We use the conversion chart given by Mike Foskett to convert from pixels to point [25]. This metric returns a ratio value between 0 and 1. Only elements with CSS-property "visibility" set to "visible" are considered in this metric. The second subcategory is "clear font" which is the count of all text characters in a clear font divided by the count of all text characters in the web page. The scale will be a decimal value from 0 to 1. For our purposes, the following fonts are considered clear: Times New Roman, Verdana, Arial, Tahoma, Helvetica, and Calibri [26]. The third subcategory is "max of two typefaces" which specifies that a maximum of two typefaces should be used, one in heading and one in the main text. This metric returns a value of 1 if more than two typefaces were detected and a value of 0 if two or less were detected. A risk involved here is not specifically delineating header text and non-header text. See Table 5 for a summary review of the ASD user requirements and the corresponding metric components for the Font Value Category.

Table 5. Font Value ASD user requirements with associated component metrics.

Metric Category	ASD User Requirements	Component Metrics
Font Value	Font sizes should not be smaller than 19 pixels/ 14 pt. for easy readability.	font_size_binary_Prop text_rate_Prop
	Use a maximum of two typefaces	unique_font_gt_2_Bool
	Text should be written using clear fonts.	mod_font_family_binary_Prop

6 Results

6.1 Data Exploration and Visualization Results

The distribution of Website ASD Ratings (scaled) for all 600 websites is shown in Figure 4. The distribution is right-skewed with 37% of websites yielding a Website ASD Rating 4 to 5, which is considered less ASD friendly. Only 20% of websites fall between a Website ASD Rating of 1 to 2; these ratings are considered more ASD friendly.

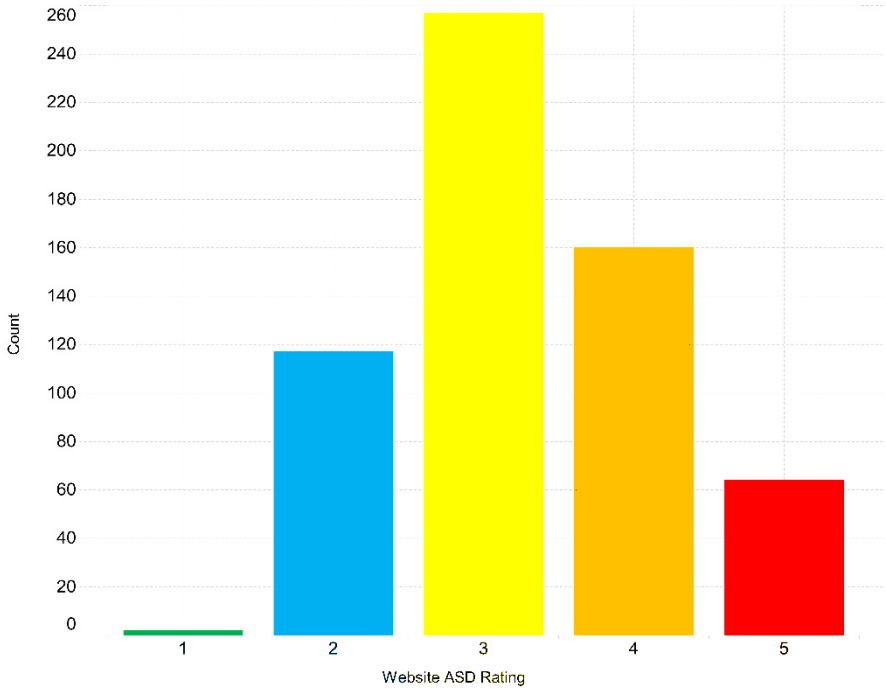
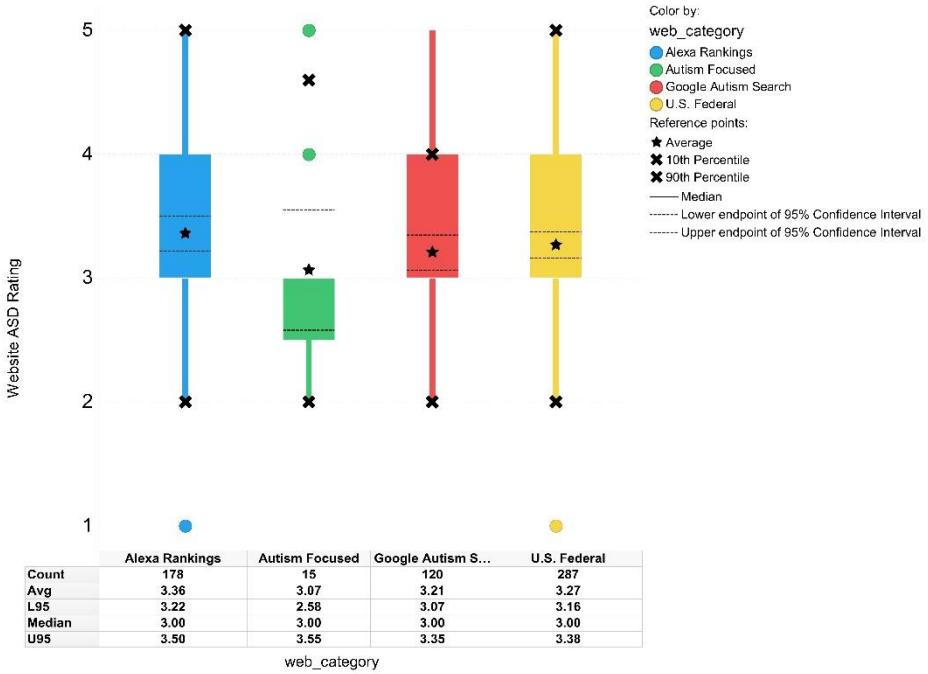


Fig. 4. Histogram for the 600 websites based on the scaled website ASD rating.

Grouping by website category, Figure 5 illustrates a boxplot comparing the Website ASD Rating by website category. On average, the Autism Focused websites has the lowest Website ASD Rating (3.07) with a 95% confidence interval falling between ratings of 2 to 3; the other three website categories have a 95% confidence interval within a Website ASD Rating of 3. However, in Section 6.3, Table 6 shows that the relationship between website categories and Website ASD Rating is not statistically significant.



	Alexa Rankings	Autism Focused	Google Autism S...	U.S. Federal
Count	178	15	120	287
Avg	3.36	3.07	3.21	3.27
L95	3.22	2.58	3.07	3.16
Median	3.00	3.00	3.00	3.00
U95	3.50	3.55	3.35	3.38

Fig. 5. Boxplot of Website ASD Ratings and summary statistics grouped by website category.

In general, the Website ASD Rating supports Pavlov's recommendation on ASD accommodation. Figure 6 shows the homepage of a website with an ASD rating of 2 (www.autsmnz.org.nzh). The low rating (more ASD friendly) is attributed to the following direct measurements: higher proportion of friendly font, no background image and animation, lower number of unique colors compared to the sample mean, less than 3 type face usage, and the text boxes are clearly separated. In contrast, Figure 7 shows a website with an ASD rating of 4 (www.parenting.com/gallery/autism-apps). This website contains a higher proportion of unfriendly fonts, presence of animation, greater than 2 type face, higher proportion of smaller fonts compared to the sample mean, and the presence of advertisement.

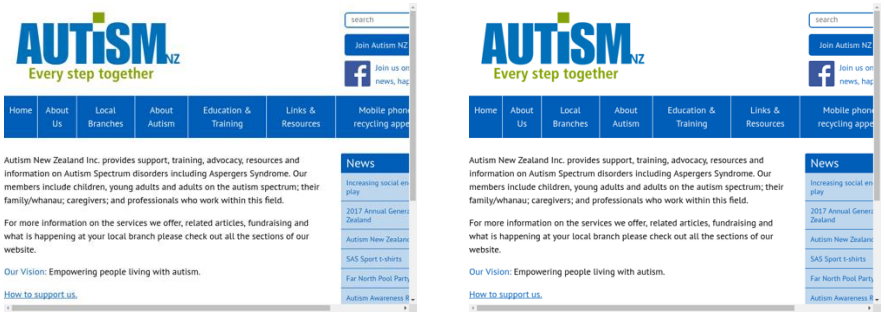


Fig. 6. Homepage image with a Website ASD Rating of 2 illustrating a friendlier website.

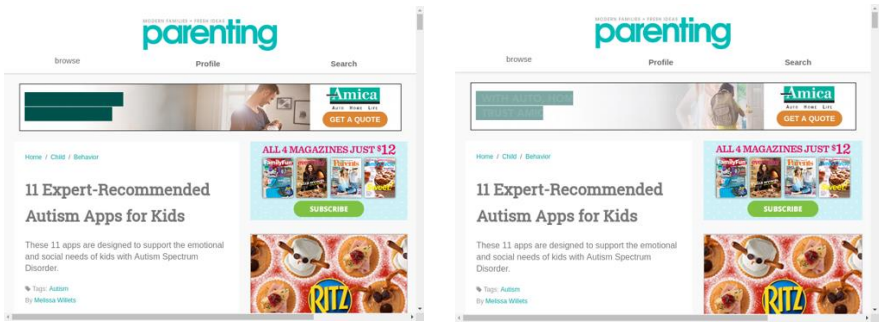


Fig. 7. Homepage image with a Website ASD Rating of 4 illustrating a less friendly website.

6.2 Feature Importance Results

From a linear regression model of the component metrics used to create the Website ASD Rating, the top feature importance is displayed in Figure 10. Font and animation metrics are the top drivers for the Website ASD Rating. This is because of the way the Website ASD Rating is calculated. Referencing Appendix 1, the Website ASD Rating is comprised of three over-arching categories totaling 25 variables. By variable counts per category, the animation and font comprise of 9 features. In contrast, the image category is an average aggregation of 16 variables. The Website ASD Rating averages all three categories. The font and animation subcomponent metrics have some binary scores (0 or 1) whereas the image metric is only composed of proportion scores ranging from 0 to 1. Therefore, the animation and font have a higher impact than the image category.

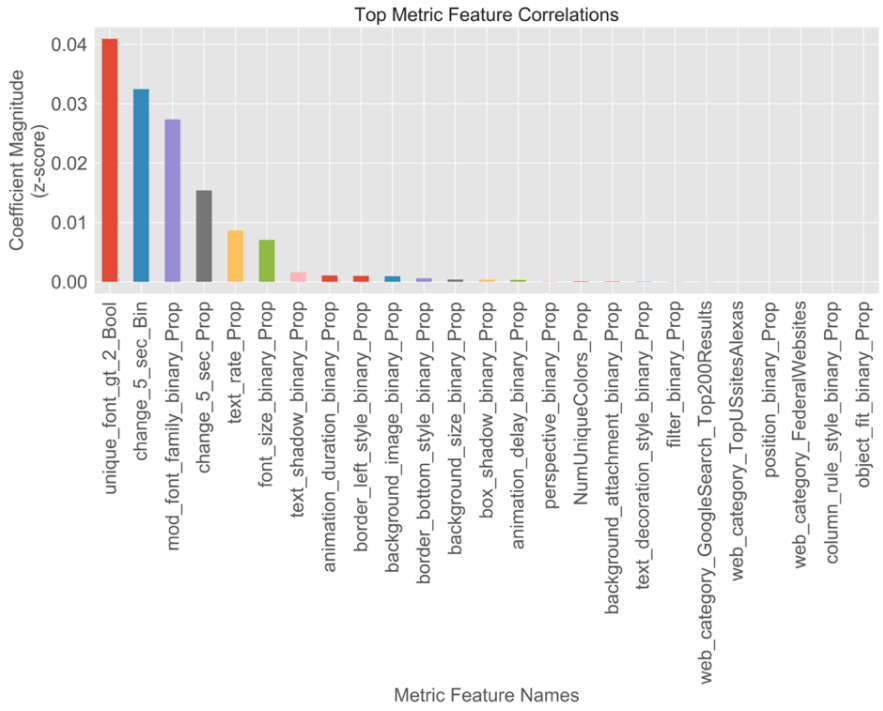


Fig. 10. Feature importance bar chart of direct metrics.

6.3 Significance Test Results

Table 6 displays the results of a fitting an ordinary least square multiple linear regression model based on website domain category. Only the intercept had p-value indicating that it was significantly different than 0, the coefficient estimates for each website domain were not found to be significantly different than 0. The p-value of 0.5981 for the model from the overall F-test indicates that there is no evidence that the model using these independent variables is a better fit than a model without these variables.

Table 6. Summary from multiple linear regression testing of website categories to the Website ASD Rating.

Parameter	Estimate	Std. Error	t value	Pr (> | t |)
(Intercept)	0.26789	0.01692	15.834	<2e -16
Alexa Rating	0.01983	0.01762	1.126	0.261

U.S. Federal	0.01618	0.01735	0.933	0.351
Google Autism Search	0.01233	0.01794	0.687	0.492
Autism Focused	NA	NA	NA	NA

Residual standard error: 0.06552 on 596 degrees of freedom
Multiple R-squared: 0.003143
Adjusted R-squared: -0.001874
F-statistics: 0.6265 pm 3 and 596 DF
p-value: 0.5981

7 Analysis

A primary difference between our analyses compared to Dattolo, A. and Luccio, F.L. is in the metric data collection step. Dattolo, A. and Luccio, F.L. measures each criterion by subjectively assessing qualities [18]. We analyze websites by extracting the top-level domain data to evaluate against our Website ASD Rating. We examine relations between the rating and their corresponding variables, with the intent of finding the main drivers. Distinguishing CSS properties and metrics that highly impact the Website ASD Rating can aid web developers. The base analysis is a two-fold step; analyze all websites and then by website categories understand ASD friendly characteristics across different website groups. Analysis 1 is a descriptive study based on visual analysis. Analysis 2 focuses on the top feature importance determined from linear regression. Analysis 3 is fitting a linear regression model to testing significance to the Website ASD Ratings by the four website categories.

7.1 Data Exploration and Visualization Analysis

Data exploration commences through generation of univariate statistics and visualizations histograms, to gain an understanding of the features. To assess if our defined Website ASD Rating generally holds, the homepages of the websites with higher rating and lower ratings are visually analyzed.

7.2 Feature Importance Analysis

The objective is to determine the top driving features. This analysis consists of a multiple linear regression model using the component metrics for the dependent variables and the Website ASD Rating as the independent variable. No transforms to the explanatory variables were made, and explanatory features that were correlated greater than 90% were removed.

7.3 Significance Test Analysis

This analysis answers the following question of interest: Is there a statistically significant difference in the group means of Website ASD Rating between the website domain categories? A multiple linear regression model was fit with an intercept and using the domain categories as the regressors. As previously mentioned, there was no significant difference between the group means.

8 Ethics

Designing websites for users with physical and cognitive disabilities is being trail blazed by several organizations such as the W3C® leading the Web Accessibility Initiative. These initiatives have had a direct impact on influencing the creation and modifications of laws that support people with disabilities on the Internet. Voice recognition, captions, and visual contrast are just a few requirements that have been integrated into web designs to aid people with physical and auditory needs.

But, establishing objective website design requirements geared toward people with ASD is still a relatively untapped arena. Moral considerations related to discrimination are a key concern if certain design criteria significantly reduce or eliminates access to information or usability of a website for this group of individuals. These inequities can have a substantial impact on autistic individuals. For example, certain websites with blinking and flickering distractive content could possibly deter or eliminate the use of the website. If the website is critical for their school or work, this could mean the difference between success and failure.

Current treatments for ASD published by the Center of Disease Control are rooted in providing structure, direction, and organization [27]. In addition, sensory integration therapies are often deployed to combat over sensitive responses to light, sound, and visual stimulus. Since communication skills are often a problem, visual pictures and symbols can also aid in closing communication gaps [27].

However, translating these autism therapy recommendations to website designs is still under exploration along with the effectiveness of those designs. Competing requirements and priorities from numerous stakeholders can drown out the needs for the disabled. Lead generation and sales are key economic drivers that remain at the forefront of web design projects. Yet, people with ASD make up a considerable portion of the population - 1 in 68. In addition, other reports confirm an average prevalence of 1% - 2% in Asia, Europe and North America. High functioning autistic people are prolific users of the Internet which helps to close the social isolation barriers they experience when interacting face-to-face with others [28]. Creating awareness of the potential impact among business and service providers along with website design architects is an important first step to bringing critical stakeholders that directly impact website designs into the picture.

In an ideal world, everyone would have equal access to information and usability from technology. Clear strides have been made to protect the rights of the disabled by researchers, advocate organizations, and governments alike. Furthermore, business economic drivers will continue to uncover discrepancies among users and website

designs to optimize their results. These initiatives, whether purposefully or organically propelled, will drive changes in website designs bringing visibility to the needs of these unique individuals.

9 Conclusions

Assessing websites for ASD friendliness using HTML style properties along with image data as the objective criteria can provide a comparison for websites. Websites receiving higher scores (unfriendly) versus lower scores (friendly) usually had less animation, fewer font types and sizes, and less complex images. The two most important metric categories which explained the website score in the multiple linear regression model are font and animation. The average Website ASD Rating for the website categories are not significantly different. Nevertheless, these website categories, Autism Focused; U.S. Federal; Google Autism Search; and Alexa Rating, ranked from most friendly to least friendly respectively.

Future work could entail exploration of the website rating scores relating to the weighting criteria and component parameterization. Other HTML style properties should be examined more closely to determine if these features should be incorporated into the metric model. Developing a website add-on to automatically calculate the Website ASD Rating along with the underlying metric category scores could facilitate the exploration of more websites and provide feedback to web designers on possible HTML style properties or image criteria that are impacting the ASD friendliness of the site. To move towards the ideal world an application of this research will take the method of extracting data and applying the transformations to enable an instant assessment of other websites not initially surveyed. Again, a browser extension or simple web application can be made to allow this analysis to be done ad hoc when users may need that security. The final solution brings together the website owners with an understanding of their ASD Website Rating related to what features are driving their score. Actionable changes are possible from these feature scores that directly tie back to the parameters of the website properties which can be modified. As a result, a more ASD friendly website is possible. Lastly, a human studies trial with autistic people to rate the websites in the dataset would provide a gold standard in which to improve on the model.

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Appendix: ASD User Requirements and Metric Calculations Tables

There are eight ASD friendly user requirements. Tables are created below that represent a unique ASD friendly user requirement corresponding to a specific Metric Category (Image, Animation, Font) with the associated component metrics. In addition, the tables also include component metric's name, description, formula, source information, and criteria for friendly and unfriendly.

Table 7. Use simple graphics.

ASD Friendly Requirement	use simple graphics
Metric Category Metric Name, Description, and Formula (proportion of unfriendliness from 0 to 1) Unfriendly (1); Friendly (0)	Image Metric Source and Criteria (friendly and unfriendly)
Metric Name: text_shadow_binary_Prop, Description: The proportion of elements with a text shadow. Formula: Number of elements with a text shadow / total number of elements	Source: - css Property Function and Parameters: text-shadow: h-shadow v-shadow blur-radius color|none|initial|inherit; Criteria: if "none" then element is friendly (0) else element is not friendly (1)
Name: column_rule_style_ binary_Prop Description: Proportion of unfriendly elements do not have a simple style of the rule between columns. Formula: # of elements with an unfriendly style of the rule between columns/ total # of elements	Source: - css Property Function and Parameters: column-rule-style: none|hidden|dotted|dashed|solid|double| groove|ridge|inset|outset|initial|inherit; - specifies the style of the rule between columns Criteria: If element is "none", "hidden", "solid" then friendly (0) else unfriendly (1)
Name: perspective_binary_ Prop Description: The unfriendly proportion of all elements that have 3D. Formula: # of elements that have 3D / total # of elements	Source: - css Property Function and Parameters: perspective: length|none - specifies the perspective on how 3D elements are viewed Criteria: If element is "none" then friendly (0) else unfriendly (1)

Name(s): border_bottom_style_ binary_Prop border_top_style_ binary_Prop border_left_style_ binary_Prop border_right_style_ binary_Prop Description: The unfriendly proportion of all elements that have more complex borders styles. Formula: # of elements with unfriendly border style/ total # of elements	Source: - css Property Function(s): border-bottom-style: border-top-style: border-right-style: border-left-style: Parameter Settings: none|hidden|dotted|dashed|solid|double| groove|ridge|inset|outset|initial|inherit - sets the style of the bottom, top, left and right borders respectively Criteria: If element is "dotted", dashed","double", "groove", "ridge", "inset", or "outset" then unfriendly (1) else friendly (0)
Name: box_shadow_ binary_Prop Description: Unfriendly proportion of elements that have shadows on boxes. Formula: # of elements that have shadows / total # of elements	Source: - css Property Function(s): box-shadow: none|h-shadow v-shadow blur spread color |inset|initial|inherit; - attaches one or more drop-shadows to the box Criteria: If parameter is "none" then element is friendly (0) else unfriendly (1)
Name: position_binary_Prop Description Unfriendly proportion of elements that do not scroll with the scroll bar. Formula: # of elements that the objects are sticky / total # of elements	Source: - css Property Function(s): position: static|absolute|fixed|relative|sticky| initial|inherit; - specifies the type of positioning method used for an element. Criteria: If parameter is “sticky” then element is unfriendly (1) else friendly (0)

Name: text_decoration_style_ binary_Prop Description Unfriendly proportion of elements that the line style is not solid. Formula: # of elements that the line style is not solid / total number of elements	Source: - css Property Function(s): text-decoration-style: solid|double|dotted|dashed|wavy| initial|inherit - specifies the style of the line in a text decoration - Criteria: If parameter is "solid" then element is friendly (0) else unfriendly (1)
Name: background_attachment_bina ry_Prop Description Unfriendly proportion of elements that have background attachments that are not scrolling. Formula: # of elements that the background attachments are not scrolling / total number of elements	Source: - css Property Function(s): background-attachment: scroll|fixed|local|initial|inherit; - sets whether a background image is fixed or scrolls with the rest of the page. Criteria: If parameter is "scroll" then element is friendly (0) else unfriendly (1)

Table 8. Do not use background images.

ASD Friendly Requirement	Do not use background images.
Metric Category Metric Name, Description, and Formula (proportion of unfriendliness from 0 to 1) Unfriendly (1); Friendly (0)	Image Metric Source and Criteria (friendly and unfriendly)
Name: background_image_ binary_prop Description: Unfriendly proportion of background images Formula: # of elements that have background images / total # of elements	Source: - css Property Function and Parameters: background-image: url|none|initial|inherit; - Specifies one or more background images for an element Criteria: If parameter equal to "none" then friendly (0) else unfriendly (1)

Table 9. Make sure illustrations are in sharp focus.

ASD Friendly Requirement	Make sure the illustrations are in sharp focus.
Metric Category Metric Name, Description, and Formula (proportion of unfriendliness from 0 to 1) Unfriendly (1); Friendly (0)	Image Metric Source and Criteria (friendly and unfriendly)
Name: background_size_binary_Prop Description: Unfriendly proportion of elements that images are resized which create distortion. Formula: # of elements that images are not displayed in their original size / total # of elements	Source: - css Property Function and Parameters: background-size: auto|length|cover|contain|initial|inherit; - Specifies the size of the background image(s) Criteria: If parameter equal to "auto" then friendly (0) else unfriendly (1) "auto" maintains original size of image.
Name: filter_binary_Prop Description Unfriendly proportion of elements that images have filters which create distortion. Formula: # of elements that images have filters / total # of elements	Source: - css Property Function and Parameters: filter: none | blur() | brightness() | contrast() | drop-shadow() | grayscale() | hue-rotate() | invert() | opacity() | saturate() | sepia() | url(); - defines effects (e.g. blurring or color shifting on an element is displayed. Criteria: If parameter equal to "none" then friendly (0) else unfriendly (1)
Name: object_fit_binary_Prop Description: Unfriendly proportion of elements that have resized elements which may create distortion. Formula: # of elements that have contents that have been resized / total # of elements	Source: - css Property Function and Parameters: object-fit: fill|contain|cover|scale-down|none|initial|inherit; - specifies how the contents of a replaced element should be fitted to the box established by its used height and width. Criteria: If parameter equal to "none" then friendly (0) else unfriendly (1)

Table 10. Do not use many colors.

ASD Friendly Requirement	Do not use many colors.
Metric Category Metric Name, Description, and Formula (proportion of unfriendliness from 0 to 1) Unfriendly (1); Friendly (0)	Image Metric Source and Criteria (friendly and unfriendly)
Name: NumUniqueColors_Prop Description: Formula: 9* (Number of unique colors for website / total unique colors for all websites) Note: multiplied by 9 to weight for each of the 9 css color properties.	Source(s): - css Property Functions background-color: border-bottom-color: border-left-color, border-right-color, border-top-color, column-rule-color, outline-color, text-decoration color, - Parameters: color|transparent|initial|inherit; invert|color|initial|inherit; color|initial|inherit; Criteria: The parameter, "color", consist of RGB (Red, Green, Blue) values. Unique color values are calculated from unique RGB values. The higher proportion of unique colors that a website contains the more unfriendly.

Table 11. Do not use pop up elements and distractions.

ASD Friendly Requirement Metric Category Metric Name, Description, and Formula (proportion of unfriendliness from 0 to 1) Unfriendly (1) Friendly (0)	Do not use pop up elements and distractions. Animation Metric Source and Criteria (friendly and unfriendly)
Name: animation-delay_binary_Prop Description: the proportion of unfriendly elements that have an animation delay. Formula: # of unfriendly elements (1) for website / total # of elements for website	Source: - css Property Function and Parameters: animation-delay: time|initial|inherit - Specifies a delay for the start of an animation Criteria: if time = "0.0" then element is friendly (0) else element is not friendly (1)
Name: animation_name _binary_Prop Description: The proportion of unfriendly elements that have an animation name. Formula: # of unfriendly elements (1) for website / total # of elements for website	Source: - css Property Function and Parameters: animation-name: keyframename| none|initial |inherit - Specifies the name of the @keyframes animation Criteria: if keyframename = "None" then element is friendly (0) else element is not friendly (1)
Name: animation_duration_ binary_Prop Description: The proportion of elements that have an animation time greater than 0. Formula: # of unfriendly elements (1) for website / total # of elements for website	Source: - css Property Function and Parameters: animation-duration: time|initial|inherit; - Specifies how many seconds or milliseconds an animation takes to complete one cycle Criteria: if time = "0.0" then element is friendly (0) else element is not friendly (1)

Name: change_5_sec_Prop Description: # of pixels changed from image 1 to image 2/ total # of pixels Formula: Proportion of changed pixels at 5 seconds due to animation.	*Source:* 2 web site image screen shots. The first screen shot at time = 0 sec. and the second screen shot at time = 5 sec. Criteria: - number of pixel changes - a higher number of pixel changes are more unfriendly than a lower number of pixel changes.
Name: change_5_Bin a binary value (0 or 1) which is based on if the website image changed. Formula change_5_Bin = 0 or change_5_Bin = 0	*Source:* 2 web site image screen shots. The first screen shot at time = 0 sec. and the second screen shot at time = 5 sec. ***Criteria:*** 0: no image change 1: image change

Table 12. Font sizes should not be smaller than 19 pixels/ 14 pt. for easy readability.

ASD Friendly Requirement	Font sizes should not be smaller than 19 pixels/ 14 pt. for easy readability.
Metric Category Metric Name, Description, and Formula (proportion of unfriendliness from 0 to 1) Unfriendly (1); Friendly (0)	Font Metric Source and Criteria (friendly and unfriendly)
Name: font_size_binary_Prop Description: Proportion of unfriendly elements that have at least one character with a pixel < 1 Formula: # of elements that have at least one font character <19 pixels or 14 pt. / total # of elements for website	Source 1: - css Property Function and Parameters: font-size:medium|xx-small|xsmall|small| large|x-large|xxlarge|smaller|larger| *length*|initial|inherit - Specifies the font size of text. Source 2: - "Text" attribute from the element - A string of text displayed on website. Criteria: If character in text <19 pixels: unfriendly (1) else friendly (0)
Name: text_rate_Prop Description: The proportion of characters in text string that are too small (< 19 pixels or 14 pt). Formula: sum of the # of characters in text string that are unfriendly (1) / total text length	Source 1: - css Property Function and Parameters: font-size:medium|xx-small|xsmall|small| large|x-large|xxlarge|smaller|larger| *length*|initial|inherit - Specifies the font size of text. Source 2: - "Text" attribute from the element - A string of text that was displayed on website. Criteria: If character in text <19 pixels: unfriendly (1) else friendly (0)

Table 13. Use a maximum of two typefaces i.e. one for text and the other for headings.

ASD Friendly Requirement	Use a maximum of two typefaces i.e. one for text and the other for headings.
Metric Category Metric Name, Description, and Formula (proportion of unfriendliness from 0 to 1) Unfriendly (1); Friendly (0)	Font Metric Source and Criteria (friendly and unfriendly)
Name: unique_font_gt_2_Bool Description: The proportion of elements with unique typefaces greater than 2. Formula: # of elements with unique typefaces greater than 2 / total # of elements Formula unique_font_gt_2_Bool = 0 or unique_font_gt_2_Bool = 1	Source 1: - css Property Function and Parameters: font-family: family-name|generic family| initial|inherit; - specifies the font family for text Criteria: If the sum of the number of unique “family-name” is greater than 2 for all elements, then unfriendly (1) else friendly (0)

Table 14. Text should be written using clear fonts.

ASD Friendly Requirement	Text should be written using clear fonts.
Metric Category Metric Name, Description, and Formula (proportion of unfriendliness from 0 to 1) Unfriendly (1); Friendly (0)	Font Metric Source and Criteria (friendly and unfriendly)
Name: mod_font_family_binary_Prop (a.k.a clear fonts) Description: The proportion of text string characters that are not clear fonts. Clear fonts are defined as Times New Roman, Verdana, Arial, Tahoma, Helvetica, and Calibri [26]. Formula: (sum (# of characters in text string that are not clear font for all elements)) / (sum (total text string length) for all elements.	Source 1: - css Property Function and Parameters: font-family: family-name|generic family|initial|inherit; - specifies the font family for text Source 2: - "Text" attribute from the element - A string of text that was displayed on website and captured for each element. Criteria: If font-family in element is Times New Roman, Verdana, Arial, Tahoma, Helvetica, or Calibri then text character is friendly (0) else text character is unfriendly (1)