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Human-Computer Interaction: Influences on Autistic Users

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Abstract

This paper presents a systematic analysis of the existing studies in two research areas: (1) effects that animated objects might have on users, and (2) HCI studies with autistic users. The aim of this work is to broaden current knowledge of the effect of animation on user interface usability. We systematically analysed the state of the art in the related research areas and identified many gaps that should be addressed, as well as proposed the solution to cover these gaps. Our goal is to analyse the performance variance between neurotypical users and autistic individuals in order to gauge task achievement, webpage navigability, and ability to focus.

Keywords: Software Engineering, Usability, Autism, Autistic Users

1. Introduction

As technology becomes more central to everyday life, it is therefore vital to ensure that the interfaces required to access it are usable and accessible to all populations, including autistic people. The usability and accessibility of interfaces have attracted attention from Human-Computer Interaction (HCI) researchers for over two decades now, since well before the end of the twentieth century, based on the fact that usable and accessible interfaces tend to enhance overall system performance as well as user acceptance and satisfaction. Usability in this context refers to how effective, efficient, and satisfactory a website or product is for its users, while effectiveness refers to the ease with which a user can complete tasks within a system, and efficiency refers to how quickly a user can complete such tasks and achieve their goals. Satisfaction, in turn, refers to the users' emotional response to the user interface [1]. The complex resulting from these factors, interface usability, is particularly important for autistic people due to the number of challenges they may face while navigating the web; however, little attention has been paid by the HCI community to the specific challenges posed by digital technology for autistic people.

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Autism spectrum disorder (ASD) prevalence is significantly increasing across the world. ASD as a term refers to permanent neurological disorders generally noted initially in early childhood. People on the autism spectrum tend to be prone to sensory overload and to demonstrate an atypical pattern of attention deficiency [2, 3]. They sometimes also suffer from a condition known as Stimulus *Overselectivity*, whereby individuals respond only to a subset of task or environmental stimuli, resulting in limited cognitive function [4]. These characteristics may lead to them experiencing additional challenges when browsing the web. In 2012, the Centers for Disease Control and Prevention in the USA reported an ASD prevalence of approximately one in every 88 eight-year-olds, while in 2018, the Autism and Developmental Disabilities Monitoring (ADDM) Network estimated that 1 in 59 or 2% of all eight-year-olds had ASD, a distinct increase from the 1 in 68 identified in previous ADDM studies in 2014 and 2016. These studies reflect the numbers of people with official diagnoses; however, many people do not get such official diagnoses for several reasons, suggesting that the actual numbers of people affected may be much higher. As ASD thus affects a significant number of individuals worldwide, there is a growing need for services and goods for such people across all stages of their lives, which makes it crucial to develop usable and accessible websites or applications for this community to ensure they have full access to modern life tools.

Computer technology has been used as an assisting tool for caregivers, physicians, educators, and autistic individuals for at least two decades [5, 6], and much of the emergent research has shown that autistic individuals are also personally interested in technology [7]. Numerous studies have also illustrated the effectiveness and beneficial effects of using computing technology to assist autistic users in their everyday lives by means of simplifying communication with other individuals, coordinating daily tasks, and strengthening relationships with family and friends [5]. This makes it essential to understand the needs of autistic people using online technology in order to ensure that they are not unnecessarily disadvantaged by the interfaces presented to them.

While there have been numerous research studies dedicated to autism-targeted technology, comparatively few have attempted to empirically analyse web usability, and accessibility for autistic individuals. For example, the W3C issued the Cognitive Accessibility User research which is the latest, most comprehensive resource in exploring the needs of persons with cognitive disabilities [8]. However, its findings for autistic people's accessibility difficulties emanate from the subjective outcome of a single interview carried out on an anonymous individual, and the ASD diagnostic criteria. Furthermore, of the web accessibility articles on autistic individuals reviewed in the literature section, few empirical studies conducted on ASD and web accessibility, which is mostly based on even further limited data sources. Similarly, of all other studies on the subject, Deering's research [9] includes empirical data on just four autistic individuals. Moreover, while subjective data proposes that autistic people face challenges in web browsing activities [8], there exists scant objective evidence to support the claim. Therefore, there is a need for extensive empirical research analysis backed by large samples to explore autistic people's interactions with web interfaces.

Therefore, our research focuses on the usability of an interface —- especially the influence of an interface's animations —- on autistic users. A minor distraction to others can be excessive for an autistic individual. Animation may affect them more than other groups, as the animation on websites may have contrasting elements or a flashy design, which can potentially capture the attention of an autistic user and negatively impact them [10].

Contributions: In this paper, we provide a systematic analysis of the existing studies in two research areas: (1) effects that animated objects might have on users, and (2) HCI studies with autistic users. Our aim is to broaden current knowledge of the effect of animation on user interface usability. The core research goal is to analyse the performance variance between neurotypical users and autistic individuals in order to gauge task achievement, webpage navigability, and ability to focus.

Outline: The rest of the paper is organised as follows. Section 2 introduces the studies that examined effects that animated objects might have on users. Section 3 discusses the existing HCI studies that focused on autistic users, as well as limitations of these studies. Finally, in Section 4, we analyse the results of the literature review, summarise the paper and introduce directions of our future work.

2. How do animated objects affect users?

Zhang [11] proposed to define animation as motion of any type which is featured on websites. When the worldwide web was in its infancy, there was an emphasis on presenting information on a web page without imagery. With the adoption of new technology and innovation, web design has been revolutionised, producing high-quality sites

with integrated animations. The tools aim to improve communication and attract users to click, view, or purchase from, a website [12, 13, 14]. According to Hong et al. [15], animation is also implemented in information systems for the visualisation of information in order to enhance the users' understanding of the information. This method of transmission inspires a novel or amusing impression in users. It also serves to draw the audiences' attention to particular screen-based informational elements. In addition, it is used for decision making [16], information retrieval [17], process visualisation [18], multimedia training [19], and domain knowledge visualisation [20].

Banner ads (banner advertisements) are a very popular type of web animation, see [21]. Thus, the current studies on animation can be organised into two categories, depending on whether they are dealing with advertisements:

- *Advertisement-focused studies on animation*. In these studies, the researchers are seeking to ascertain whether animations can assist in drawing the users' attention to banner advertising, improve click-through rates, and increase their knowledge of an advertised brand [13, 14, 12, 22, 23, 24, 25].
- *General studies on animation*. McCrickard et al. [26] studied three various forms of animation which are applied in notification systems when users are browsing Web pages. Zhang [11] investigated the impacts of peripheral text and cartoon animation on the users' ability to seek information. Hong et al. [15] examined animation that is a primary element in the content of a website (that is, a product on a shopping website). Non-advertisement animation has even been investigated in other ways, such as menu animation technology in online support systems and animated characters (for example, virtual teachers or Web chauffeurs) to assist users through online materials [27, 28].

The effectiveness of animation in banner advertisements, as well as non-banner advertisements was analysed by researchers from a variety of fields, including the human-computer interaction [12], information systems [29, 30, 31, 32], marketing [33], and communications [23]. Many of these studies have focused solely on animated banner advertisements rather than web animation [34]. However, the conclusions from the results of these studies are very diverse, from strictly positive to strictly-negative. We can group the studies by their results as follows:

- *Positive effect.* Some researchers have found that animation has a positive effect on web advertisements by attracting the audience's attention which results in greater click-through rates or improved recall of the animated content, see [35, 36, 37, 32].
- *No effect / minor effect.* Other researchers, in opposition, have concluded that animation has no apparent impact, see [14, 38, 24, 33, 39].
- *Negative effect.* Some studies have demonstrated clearly that animation has adverse influences on attitudes toward the advertisements or the website itself, the recalling of animated content, visual search performance, see [40, 12, 41, 31, 42, 15]. Other studies have also found that animation has significant impact on task performance and distracting users from the main task [41, 43, 34, 42, 11, 44].

In general, most of the relevant studies identified negative effects of animation, and these effects may be significant. For example, it could have a serious impact on how users interact with the user interface. In addition, animations may be tiresome and distracting for users [45] resulting in difficulties completing the main activity provided by the website [46].

Animations have the effect of attracting users' attention, click rate and task performance. Hong et al. [34] investigated user interaction with non-banner advertisement animation across browsing and searching tasks. They concluded that animations are effective at capturing users' attention. Recent research [29] studied how users' attention was concentrated when viewing animated and non-animated features using eye tracking method. It was found that animated features resulted in improved visual attention to all elements of a web page. In addition, the allocation of attention was affected by animation, which raised perceptual attention on the animated object, at the cost of non-animated objects on the same website. Further, it was found that users were more likely to click on an animated feature, which led to purchases.

Thus, animated non-banner advertisements are an effective tool for companies as they attract users' attention to their products and services. However, non-advertisement animations were also found to negatively affect the performance of tasks; this was particularly prominent during browsing [34, 29]. There is a limited amount of research into the

effects of animation on different internet based tasks, other than searching and browsing. Furthermore, the studies are limited in that the participants were mostly university students. The research would be more widely applicable if the samples were varied with users of different cognitive styles to better represent website users in general. Given that autistic users have different needs to the general population, this study can assist in determining methods through which research on HCI can be utilised to address issues faced by autistic people to reduce distraction and increase site usability for all users.

Animation in banner advertisements can become anathematic to users and affect their perceived workload. As asserted in the studies of Brajnikand and Gabrielli [47] and Burke et al. [12], Animated advertisements can have a negative effect on users' experience of a website. They can also hamper users' searching and increase their workload. Several studies have found that animation in a banner tends to reduce users' focus. Additionally, it was found that animation did not affect users' ability to recall an advertisement. While animation in an advertisement improved user attitudes toward the advertisement itself, it was found to negatively affect user attitudes towards the product. Finally, they found that properly designed interactive features on a website increased its usability. However, the users in this study were general users. For autistic users, interactive features "like web content that is blinking, flickering, or flashing can be a serious distraction and considered inaccessible" [48].

The attention that a user gives to animated banner advertisements is affected by multiple factors. Lapa [49] used questionnaires and eye tracking analysis. They discovered that the background colour of a banner has no significant effect on how likely it was to be viewed by users. Similarly, the relevance of the banner content does not impact the likelihood of it being viewed by users. Furthermore, visual attention given to banners appears to be higher when a user first visits a website, but once the user learns the structure of the page, visual attention to the banner declines. However, the study did not analyse the content of the animated banner in-depth and did not mention the animation features (only briefly considering the effects of an animated banner). Moreover, the size and position of the advertisement remained constant; all banners were the same size and in the same location on the website. Finally, the participants may have all had the same concentration ability. Therefore, it is essential to consider usability before placing advertisements on a website due to the wide range of different users who may visit it. This emphasises the need for software developers to consider autistic users when designing user interfaces.

Further studies on animation are summarised in Table 1. Two observations were made from the studies, namely on the features of the animation used and the task condition(s) examined. Firstly, animation can be implemented in different ways, which may have various effects on the user. Thereby, it is more difficult to evaluate results relating to different forms of animation. Some studies lack a description of the design and the features of the animation and therefore it is difficult to know the effects of each feature. Screenshots of the animation are provided for some studies; however, it is impossible to ascertain the features of the animation from a still image. Furthermore, animated advertisements usually incorporate multiple animation features and so researchers are unable to separate their effects in the analysis. This means that each feature of the animation can contribute to the overall effect in a different way. Consequently, it is not possible to generalise the results of these studies. In brief, determining the primary characteristics of the animation is essential for consistency when investigating multiple animation characteristics.

Finally, it is important to identify the effects of the animation based on task conditions. The experiment tasks were classified into searching, browsing tasks and other tasks employed across the studies. When searching and browsing conditions are studied together in one study, the findings usually show that animation has greater effects during browsing tasks than during searching conditions (such as [34, 29, 50]). As such, one animation feature could have a significant effect on a specific task, and it could have a different effect on another task. It is therefore crucial to investigate the effects of the same animation feature on various tasks in order to better understand its effects. Most of the studies discuss the effect of animation on searching tasks. However, a user typically undertakes multiple tasks on the website or when using Internet. This study will examine the effects across six tasks: searching, purchasing a product, emailing, reading a paragraph, selecting a particular option, and solving puzzles. We will specify the features of animation cases to black and white image, colour image, rotating animation with different speeds, and small size rotating image with slow speed.

All of the studies fail to consider the effects of images and animation on autistic users. Unfortunately, there are very few HCI studies that consider autistic users. We discuss this point in the next section in more detail.

Table 1. Studies on web animation (P denotes the number of participants on the study)

Study	Tasks	p	Animation features	Measure	Results
[14]	Search	66	Motion Flashing	Recall	Animation does not affect recall.
[51]	Browse	751	Not mentioned.	Click through rate	Animation rises click through rate in customers who have lower product involvement.
[38]	Search	12	Motion	Search time	It does not rise search time.
[24]	Search	807	Not mentioned	Trademark recognition Trademark awareness Advertisement recall.	It does not impact trademark recognition awareness and ad recall.
[43]	Count and detect changes.	12	Motion	The number of changes The direction of length.	It does not distract users from the main task.
[52]	Search& Browse	292	Motion Changing size.	Recall	It increases ad recognition. Increasing animated advertisements size results in an improvement in greater advertisement recognition than animated advertisements that decline in size.
[53]	Search	54	Rotation from left to right	The number and duration of fixations using eye tracking data Recall advertisements.	It improves number of fixations. It has no effect on duration of fixations. It increases advertisement recall.
[33]	Browse	28	Not mentioned	Percentage of fixation by Eye tracking. Recognition.	It increases recall. It does not have crucial influence on the percentage of fixations.
[31]	Browse	118	Not mentioned	The number and duration of fixations using Eye tracking data. Recall. Brand attitude.	Animation decreases number of fixations to advertisement. It results in shorter duration of fixations. Duration of fixation decline brand attitude but enhance recall it.
[42]	Searching	70	Floating animations	Accuracy. Search Time. Recall. Satisfaction.	Animation increases search time. It significantly affects user satisfaction.
[11]	Searching	24	Motion Changing size	Accuracy. Search Time.	It has a negative effect on main task efficiency, and it has a greater impact on basic tasks than on complex tasks.
[44]	Searching	25	Changing the time that the animation appears during searching tasks.	Accuracy. Search Time.	Animation effect that is noticeable in the middle or the end of the task is more significant than one that appears at the beginning of the task.

3. HCI studies with autistic users

This section will highlight the characteristics of autistic individuals and how those characteristics can be barriers when using websites, particularly in terms of the user interface of a website and application. This study also investigates the reasons for the lack of usability studies focusing on autistic users.

3.1. ASD

ASD is a category of neurodevelopmental disorders, usually diagnosed by the age of three. It is considered to be a spectrum disorder with three different areas of dysfunction. These are framed as the triad of impairments, namely socialisation, communication and restricted and repetitive behaviours and interests. It can be accompanied by cognitive and language difficulties [54]. It impacts each individual to differing degrees. The Diagnostic and Statistical Manual of Mental Disorders DSM-5 [54] states that the term *Autism spectrum disorders* describes three of the five pervasive developmental disorders, namely autistic disorder, Asperger's syndrome and pervasive developmental disorder – not otherwise specified (PDD- NOS).

Individuals are mentally affected by ASD in varying ways. Some have a severe intellectual disability while others have a normal or very high level of intelligence. Further, about 50% of autistic individuals do not develop language skills. Although some of them can adequately develop their language abilities, their linguistic milestones can be

significantly delayed. For example, two-year-olds do not speak single words and three-year-olds do not verbalise communicative sentences [7].

The most recent version of DSM-5 divided ASD into three levels based on severity (i.e. ASD level 1, ASD level 2, and ASD level 3). People considered to be at Autism Spectrum Condition (ASC) level 1 have normal to high levels of intelligence, but still have difficulties associated with, for example, social situations and sensory sensitivity [54].

Autistic people at each level of autism diagnosis may have problems with sensory integration and attention span to differing degrees. Sensory issues may include hypersensitivity or hyposensitivity to specific colours, lights, textures, sounds and smells. It is estimated that 80-90 % of autistic children suffer from sensory processing problems [55]. Additionally, the attention patterns of those who have been diagnosed with ASD differ from those of non-autistic people [55]. One of the major theories concerned with the understanding of autism is the Weak Central Coherence Theory (WCCT). WCCT states that autistic people exhibit a cognitive profile with a preference for processing local sensory information instead of global, contextual, and semantic information [56]. Therefore, those diagnosed with autism are more likely to concentrate on the finer details. This inhibits their ability to visualise a broader perspective. The WCCT aligns with the sensory over-selectivity phenomenon of autism, in which a portion of the sensory information is overlooked. This causes *tunnel vision* with a focus on particular details while neglecting to engage with the larger picture [57]. Thus, those issues can make specific devices and input methods more challenging to use for autistic people.

In conclusion, this section presented an overview of several important characteristics of individuals with ASD. They experience difficulties with social situations, communication and attention. Those characteristics can lead to difficulties when interacting with a system. However, those diagnosed with autism tend to have a keen interest in using technology [7], particularly for improving their skills [58], or supporting their daily life [59]. In the following sections, accessibility usability studies for autistic users are discussed.

3.2. Lack of user interface usability and accessibility studies

The HCI community has not sufficiently considered the challenges posed to those diagnosed with ASD by website usability or accessibility. The Web Content Accessibility Guidelines (WCAG) 2.1 by the World Wide Web Consortium (W3C) is considered to be the most significant guideline for web accessibility. While the guidelines were created to accommodate all disabled users' needs, it concentrates less on the difficulties faced by cognitively-disabled users [60]. In attempting to identify the reasons for this paucity of usability research in the context of autistic users, two studies are discussed. Corlu et al. [61] examined 89 studies of the user experience of autistic individuals. They investigated the problems encountered by researchers studying autistic users, and the reasons for these problems using a combination of qualitative and quantitative research methods. Their investigation concluded that, as the user base is quite sensitive and HCI researchers lack experience with a diverse user base, researchers find it difficult to conduct experiments and report user studies on autistic people. This has led to a research gap, with a shortage of research that focuses on the user experience, usability and accessibility for autistic users.

The majority of research on the autistic population is in relation to specific technologies or has a focus on children only. Although models have been created during the design process to include autistic users in studies, they tend to focus on children [62, 63]. Valencia et al. [64] reviewed 94 studies that mentioned three aspects relating to autistic people and technology. These studies illustrate how to support ASD children in using different technologies, which can be used to develop a great number of skills and assist in their education. The authors concluded that some studies mention the importance of the user interface, usability, and accessibility to support the autistic population. However, Valencia et al. found that problems identified in relation to user experience in previous studies were not combated or substantiated in the research that followed. Therefore, autistic individuals have participated in many studies, but those studies tended to concentrate on the evaluation of specific tools or applications for autistic users [6, 59, 65, 66]. As a result they offer little or no advice on usability and accessibility issues.

3.3. Lack of empirical research

Empirical studies of the difficulties experienced by autistic web users are rare. Britto and Piz-zolato gathered and analysed 107 guidelines relevant to ASD and grouped them into ten categories: *Visual and textual vocabulary*, *engagement*, *redundant representation*, *multimedia*, *customisation*, *feedback*, *system status*, *navigability*, *affordance*, and *interaction with a touch screen*. The research was chosen from nine countries: the United Kingdom, Israel, Brazil,

Hong Kong, Chile, India, Malaysia, Italy and the United States. However, not all of the guidelines are based on empirical studies of autistic users; 22 guidelines for autistic users are proposed from a literature review for cognitive disabilities by Friedman and Bryen [67]. ASD-relevant guidelines are developed based on guidelines established for low literacy people by Darejeh and Singh [68]. Putnam and Chong [7] conducted a survey of parents and teachers to propose guidelines for autistic users, which is a relatively empirical study. However, their paper does not identify web design guidelines and doesn't engage directly with the user base, but it does emphasise aspects that may help to build tools for autistic users.

As far as the writers are aware, there are only two empirical studies on the difficulties faced by autistic web users and the differences that exist between their experiences and non-autistic users. Deering's Masters research [9] examined the differences between autistic and non-autistic users in web page processing. However, it lacks statistical viability due to it only including four participants. It concludes that there are no variances between autistic and non-autistic users. The potential for further study [10] will be explored in the following section.

3.4. Effect of an irrelevant web element on autistic users

Eraslan et al. [10] studied the differences in web processing between autistic users and other user groups. They concluded that an autistic user looked at irrelevant elements of a website more often, and their scan paths were longer than those of non-autistic users. However, their fixation duration was shorter compared to that of others. Therefore, autistic people may be less likely to complete their searching task without becoming distracted.

The study specified a time limit of 30 seconds for each task. While time limitations for tasks are vital in order to capture inter-group differences, it may be a stressor for some participants. A similar experiment to measure task completion times will be utilised by this study. This is required in order to accurately record the processing speeds of autistic users. In addition, the Eraslan et al. study only included 18 participants with high-functioning autism, which may affect the accuracy and generalisability of its findings. Therefore, there is a pressing need for research that utilises a larger sample, and does not create unnecessary restrictions, to increase the accuracy of the results.

Yu et al. [48] record many websites that use tools to support ASD. These tools help autistic users with reading and mitigating sensory overload. An example of one such tool is BeeLine Reader, which removes any distraction from a website, for example, advertisements and comments, making the page more comprehensible for autistic users. However, the authors claim that these tools do not combat the problems posed by advertisements when using a website. Therefore it would be beneficial for web designers and users to have a scheme that identifies the ASD-friendliness of websites, such as a rating system. Thereby, in order to enhance the understanding of how websites can be more ASD-friendly, the feature space of 600 websites have been evaluated in this study. The websites analysed are based on four web categories: Autism Focused, U.S. Federal, Google Autism Search, and Alexa Rating. They characterise ASD-friendly features based on objective metrics, which are image metric, animation metric, and font value [48]. For Pavlov's review and detailed guidelines, these metrics are selected based on ten website requirements of autistic users [69]. It was concluded that font and animation have a more significant effect than images. Moreover, an ASD rating was developed, and a score was assigned to each website. Websites that received high scores were deemed unfriendly to ASD users, while those receiving lower scores were deemed friendly to ASD users. The websites that were deemed unfriendly had more animation, complex images, and a wider variety of font types and sizes.

4. Discussion and conclusions

Many studies examine the effect of animation that is implemented in different ways. They conclude that different features of animation may have different influences on the users. Other research has also demonstrated that animation has a negative effect on task performance and distracts users' attention from the primary task. However, in relation to the autistic population, experimental parameters related to irrelevant animations (such as size, speed and colour), are neglected in terms of usability and task completion. Moreover, the impact of irrelevant animations has not been studied in cohorts likely to be more vulnerable to their presence, such as autistic users.

There are many studies about autism and technology, but they do not cover the HCI and web-application field. There are only very few experimental studies on how autistic individuals interact with websites and the differences between autistic and neurotypical people when accessing websites. We identified only one such study in our literature

review, namely, Eraslan et al. [10]. Furthermore, there is a very limited number of empirical studies that include autistic users on interface usability and accessibility.

A thorough review of the website's usability and accessibility literature found that animation has significant effects on web users. Animation does attract a specific amount of the users' attention and then left fewer attentional resources for the main task on the website. Further, background information on autism and its characteristics were set out. For autistic individuals, there are challenges when using websites or applications due to "limited reading comprehension, complexity, slower learning, limited fine motor control, reduced spatial perception...." [67]. We focused on attention pattern and sensory issues that is common between all three levels of autism and may greatly cause difficulties when interacting with interface. Autistic people are more likely to concentrate on potentially irrelevant elements, distracting them from seeing the bigger picture. Autism attention patterns can cause an effect on the way autistic people use the websites compared on non-autistic people. So, they can be easily distracted by animations, images, and website pop-ups and may spend longer than required performing a particular task or may not complete the task at all.

As result of the literature review, we identified many gaps in the research area, and we are going to cover them in our future work. These gaps are very important to address for the autistic community. In our future work, we aim to address these limitations by conducting a usability experiment. We will analyse the impact of irrelevant elements (including animated objects and images) on usability and task completion by autistic and non-autistic adults. We will especially focus on such parameters as the size, speed, colour, and contrast and specific tasks such as searching and reading. The study will investigate the potential differences between autistic and non-autistic people while using the websites. Importantly, it is a study that has been co-designed with autistic researchers. It is important to investigate whether user interface use among persons diagnosed with autism is similar to that of unaffected individuals. Hong et al. [3] assert that animation increases the time it takes general users to complete tasks. It would be also important to investigate the differences between the two groups in terms of time needed to complete tasks, so as to uncover any issues that may be responsible for the disparities. Thus, we will also examine whether autistic users encounter considerable challenges in using websites compared with other groups.

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