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How mobile app developers conceive of dyslexia and what it means for mobile app users

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Abstract. This study surveys the landscape of 531 apps identified in a search for mobile apps for dyslexia and examines how their developers conceive of dyslexia. Results suggest most developers use the word dyslexia to increase the visibility of their apps within digital distribution platforms but do not intentionally design with dyslexics in mind. Those developers intentionally designing for dyslexics often have accurate but simplistic and one-dimensional conceptions of dyslexia and, unfortunately, some also have misconceptions especially as related to the myth that dyslexia can be cured or outgrown. Although a small number of developers are collaborating with dyslexia experts to design their apps, the onus for determining the quality of most apps is left to users. Examples of curated resource repositories and evaluation rubrics for mobile apps are provided to support users in this endeavor.

Keywords: Mobile apps, mobile technologies, dyslexia.

1 Introduction

Smartphones, tablets as well as the more recently introduced smart watches, smart glasses, fitness trackers, body sensors, and smart clothing technologies are quickly transforming human interaction with computing technologies. Mobile technologies like smartphones and tablets specifically have long moved past the early adopter stage in the 21st century society and in 21st century education. The desktop and laptop computer "programs" of the 1980's and 1990's have been replaced by online and mobile "apps" that are more portable, lightweight, customizable, and personalizable.

This is one reason that although computer technology has been recognized for at least three decades as a viable tool for supporting students with learning disabilities (LD) in a variety of ways including learning content, increasing motivation to learn, focusing attention, increasing time on task and supporting independence in the learning process [1], its adoption has been slow until the recent advent of mobile technologies [2]. Mobile technologies and the associated downloadable and often inexpensive apps designed for them have the ability to support students with LD [3] because of their "unlimited potential for individualizing teaching, learning and communication" [2, p.175].

Mobile technologies and apps have been shown to yield positive outcomes for a range of learners including preschool learners [4], K-12 learners with LD [5] and adult learners with special needs [6]. Recent studies also suggest the effectiveness of particular apps for learners with specific disabilities [7, 8]. However, teachers and parents are often hampered in using apps for students with LD because of the shear number and varying quality of the apps available [1, 2].

A case in point relates to our quest to find apps related to dyslexia. A search for mobile apps for dyslexia in the two most common digital distribution platforms for apps (Google Play for Android systems and The App Store for OS systems) yielded 531 apps; some of which did not seem closely related to dyslexia, some of which seemed to misrepresent what is known about it and some of which looked to have great potential. Given that dyslexia is the most commonly identified learning disability across all literate countries [9, 10] that the pace of app development continues to increase [11] and that there are no formal vetting processes to evaluate the quality of apps especially as it relates to content accuracy [12], we were motivated to take a closer look at these 531 apps, how their developers represent of dyslexia and what this means for mobile app users

2 Literature Review

2.1 Dyslexia

Dyslexia is a developmental language disorder that often runs in families and is characterized by primary deficits in word-level reading, decoding, spelling, and oral reading fluency. These deficits interfere with reading comprehension and other domains of academic achievement in spite of adequate listening comprehension, intelligence, and literacy learning opportunities [13, 14]. It is the most commonly identified learning disability and affects 10-20% of the population in all literate countries [9, 10]. Using models of speaking and writing deficits in individuals with acquired brain injury, researchers have associated dyslexia with dysfunctions in neural processing since it was first identified in the late 1800s. A convergence of data from recent advances in the disciplines of cognitive science, neuroscience, genetics, and education has supported unequivocally the neurobiological basis of dyslexia [15]. While dyslexia has been recognized as a specific developmental reading disability in medically oriented disciplines for over a century [16, 17, 18] the translation of basic science research into improved methods for the educational instruction of individuals with dyslexia is limited [9, 19] and particularly limited when it comes to using technology to support dyslexic learners [20].

2.2 Dyslexia and Technology

Technologies for dyslexic individuals are used for a variety of purposes including to support content area learning and skills practice and to enable users to perform functions that are normally challenging [21]. A widely researched area relates to computer-based programs that help younger students learn to read and most research

suggests computer-based interventions that take a more holistic approach to reading yield better results [22]. Other research suggests that technologies such as text-to-speech and speech-to-text technologies and features such as spell check and word prediction can support dyslexic learners in the learning process as well as support metacognitive development, dialogue and collaboration, self-efficacy and self-advocacy [23, 24]. Some studies have also looked at the intersection of dyslexia and technology from a design perspective considering how text features [25], media attributes [26], human-computer interaction [27], e-learning designs [28], texting [29], and social media designs [30, 31] influence dyslexic learners.

Despite the diversity of these studies in terms of focus area, participant population (dyslexic learners from K-12 through post-secondary) and research methods, they have yielded many common results. First, the technology needs of dyslexic and non-dyslexic learners are different and strategies that work for non-dyslexic learners can hinder learning for dyslexic learners and, at times, result in "insurmountable barriers" [28, p. 703]. Second, dyslexic learners' experiences with and preferences for technologies vary. Different combinations of media and strategies work for different dyslexic learners; likely due the wide range of cognitive profiles among dyslexic individuals [32]. Third, everyone experiences dyslexia differently and, thus, individual choice as related to technology trumps one-size-fits-all interventions [23].

The individual nature of mobile technologies aligns with the personal nature of dyslexia. In fact, mobile technologies are among the "dynamic and disruptive forces" that are rapidly reshaping the intersection of dyslexia and technology [33, p. 7]. A recent special issue of *Perspectives on Language and Literacy* published by the International Dyslexia Association (IDA) gives considerable attention to mobile technologies and apps with articles identifying apps to support dyslexics with disciplinary literacy [34], writing [35], executive functioning [36] and reading [37]. Similarly, special educators are beginning to write about "mobile technology toolkits" that include apps to support dyslexic learners with reading, writing, notetaking, organizational skills and metacogntive skills [2, p. 117] with the end goals of making curriculum accessible in inclusive classrooms, encouraging independent learning and increasing the confidence of learners with dyslexia.

Some developers from academia are also beginning to publish design and evaluation studies related to mobile apps for dyslexia [38, 39, 40]. Although such studies and design papers are emerging related to mobile apps for dyslexics, little is known about how most developers conceive of and understand dyslexia. And, as discussed in the next section, the mobile app development scene includes limited checks and balances to ensure developers are designing appropriately for their intended audiences.

2.3 Mobile App Development

Mobile technologies have numerous advantages over previous technologies including portability, lightweight and small sizes, lack of mandatory peripherals, the ability to transmit and sync data wirelessly, features that automatically update apps and operating systems and the ever increasing number of apps available for inexpensive and easy downloading [21]. These features and the ubiquity of mobile technologies have escalated demand for associated software or apps. The high demand for software

for mobile technologies on the one hand and the relative ease of developing and sharing mobile apps via mobile app marketplaces like The App Store or Google Play Store on the other hand have resulted in an explosion of a variety of applications for mobile platforms. The relative ease of using mobile app development tools and frameworks such as XCode, Apple's integrated development environment, and Android Studio, the development environment for the Android platform, has expanded the number of app developers allowing individuals even with minimal expertise in software development to enter the app development area. One-person mobile app development projects are becoming more and more common, the line between user experience designers, coders, and project managers is becoming thinner and thinner, and the field has even developed a term for a "jack-of-all-trades" type software developer – full-stack developer [41].

In order to keep up with the growing demand for mobile applications, app development enterprises have drastically shorted the development lifecycles [11] and reduced the timeframe between ideation and launch. The traditional application development lifecycle, including the popular agile software development model that allows more flexibility and adaptivity in the design and development processes, typically consists of a number of phases including preliminary needs-affordances analysis, user research, competitive audit, requirements definition, development of the design framework and interaction schemes and metaphors, interface design, coding, integration and testing, acceptance, deployment, evaluation, and maintenance [42]. While it is recognized that not every software development project will undergo each phase, adequate analysis of the need, users, and competition is expected for the application to be viable [43].

An important (and unfortunate) consequence of the mobile app development trends described above is that in the race for the mobile app customer in the dynamic marketplace of the 21st century much of the application development has been driven by the considerations of what *can* be developed using the existing tools and developer expertise rather than what *should* be developed given the needs and goals of the application users [44]. To us, educational technology designers, researchers and practitioners, this problem seems particularly evident in the mobile educational app arena. The sheer number of educational mobile apps available to teachers, parents, and their children is overwhelming, however few guidelines and tools exist to assist educational app users in determining the quality and potential appropriateness and usefulness of an application given the user's needs and goals [12]. Educators and learners generally rely on the "top 10 apps for …" type blog posts and the scarce app rankings by professional organizations such as the American Association of School Librarians or the International Reading Association.

Certain sets of guidelines do exist for mobile app developers through the Android Developers portal as well as the Apple Developer Tools and Guides. Application review guidelines that are used to screen mobile apps before that are posted to the marketplace focus primarily on the technical aspects of app development such as susceptibility to crashes, conformance with device resolution, app size, and so on, as well as metadata, advertising, legal requirements, and user privacy considerations. The guidelines that deal with the content of the apps generally focus on "objectionable content" (e.g., apps designed to upset or disgust users) or "media content" (e.g., specifications for streaming audio and video content). The actual

educational content of the applications is not curated because apps are developed for thousands of different purposes and contexts, and screening them for content quality would require an army of experts in these various content areas. What this means for the end users of mobile applications, however, is that the responsibility for determining the quality and appropriateness of apps rests on their shoulders. In the case of mobile apps for dyslexic learners, this would mean developing some understanding regarding the attributes and misconceptions of dyslexia to evaluate what might be considered as promising approaches for supporting dyslexic learners.

3 Design and Methods

The purpose of this study is twofold: (1) to survey the landscape of apps marketed for dyslexia and (2) examine how developers represent dyslexia in their app descriptions.

3.1 Data Sources

A search for mobile apps for dyslexia in the two most common digital distribution platforms for apps (Google Play for Android systems and The App Store for OS systems) yielded 531 apps. These apps form the basis of our analysis.

3.2 Data Analysis

Survey the landscape of apps marketed for dyslexia. We first identified which of the 531 apps used the word "dyslexia" in their descriptions to ensure that the apps we analyzed were, indeed, targeting dyslexic users in some way as it is possible to have keywords used in searching algorithms that are not germane to the app. We then aggregated data from these apps using five categories available within the digital distribution platforms: (1) content area, (2) genre, (3) age group, (4) price, and (5) release/update date. Frequency counts and percentages were used to describe apps targeting dyslexia.

Examine how developers represent dyslexia in their app descriptions. Content analysis [45] was used to examine the descriptions provided by developers within the digital distribution platforms. An a priori codebook [46] of research-based attributes and misconceptions of dyslexia guided analysis (See Table 1). To establish interrater agreement or whether analyses among researchers were concordant [47], three researchers (2 educational technologists and 1 dyslexia researcher) used the codebook to independently analyze the descriptions of ten randomly selected apps. The researchers then met, compared how each person analyzed each app and found nearly 100% agreement in our use of the codebook. Periodic check-ins to ensure interrater agreement was maintained with the third researcher analyzing the majority of the apps.

Table 1: Attributes and misconceptions codebook

Attributes of dyslexia*	**Present (Y/N)**	**Notes/Comments**
A gap between intelligence and academic performance		
Difficulty learning letters and letter sounds (phonemic awareness)		
Difficulty reading single words (decoding)		
Difficulty learning to read		
Slow reading		
Difficulty with spelling		
Poor visual coding (orthographic coding)		
Misconceptions about dyslexia*	**Present (Y/N)**	**Notes/Comments**
People with dyslexia cannot read		
Dyslexia is only about seeing things backwards		
Children will outgrow dyslexia		
Dyslexia can be cured		
All struggling readers have dyslexia		
Dyslexia is primarily about attention or behavior		
Dyslexia is primarily about poor vision or hearing		
Other Comments/Insights:		

*[9, 48]

4 Discussion

4.1 Purpose 1: Survey the landscape of apps marketed for dyslexia

From within these 531 apps, only 234 apps (44%) included the word “dyslexia” in the app descriptions. Given that keywords used in searching algorithms can be

misleading, data presented for this section includes the 234 apps using the word "dyslexia" in their descriptions. It should also be noted that these data represent a snapshot in time (apps available on June 1, 2015) as available apps change frequently.

Genres. The majority of apps are designed for educational purposes although a large number of apps provided no information in this category (See Table 2).

Table 2: Genre of apps identified in a query for reading and dyslexia

Genre	Frequency	Percentage
Education	88	37.61%
No information	40	17.09%
Books	34	14.53%
Lifestyle	27	11.54%
Productivity	23	9.83%
Games	18	7.69%
Entertainment	4	1.71%

Focus areas. The majority of apps focused on reading followed by multisensory experiences, vocabulary development and auditory experiences. In reality, these focus areas are not mutually exclusive and most apps like included more than one area (See Table 3).

Table 3: Focus areas of apps identified in a query for reading and dyslexia

Focus	Frequency	Percentage
Reading	80	34.19%
Multisensory	36	15.38%
Vocabulary	30	12.82%
Auditory	30	12.82%
Visual	12	5.13%
Reference	12	5.13%
Writing	9	3.85%

Age. Apps identified in this query were overwhelming designed for kids although a large number of apps provided no information in this category (See Table 4).

Table 4: Age recommendations for apps identified in a query for reading and dyslexia

Age	Frequency	Percentage
Kids	97	41.45%
Adult	48	20.51%
All	45	19.23%
No info	44	18.80%

Release dates. The majority of apps identified in this query were released in 2014 with very few apps released from 2010-2012 (See Table 5).

Table 5: Release dates for apps identified in a query for reading and dyslexia

Release date	Frequency	Percentage
2010	2	0.85%
2011	13	5.56%
2012	11	4.70%
2013	40	17.09%
2014	108	46.15%
2015	21	8.97%
No information	39	16.67%

Price. The vast majority of apps identified in this query are free while most others cost $5.00 or less (See Table 6).

Table 6: Price of apps identified in a query for reading and dyslexia

Price	Frequency	Percentage
Free	152	64.96%
Under $2.00	24	10.26%
$2.01-$5.00	28	11.97%
$5.01-$10.00	19	8.12%
$10.01-$20.00	7	2.99%
Over $20.00	4	1.71%

Downloads. Information about the number of downloads was not provided for many of the apps, however, very few were downloaded more than 10,000 times. Of the 11

apps with 10,000 or more downloads, four relate to speech-to-text and/or text-to-speech capabilities, three are word games, one provides a downloadable font and three are curricular in nature (learn to read or phonics focused). All 11 apps with more than 10,000 downloads are free.

Table 7: Number of downloads for apps identified in a query for reading and dyslexia

Downloads	Frequency	Percentage
under 10	20	8.55%
11 to 50	16	6.84%
50-100	13	5.56%
100 to 500	39	16.67%
500 to 1000	22	9.40%
1000 to 5000	19	8.12%
5000-10,000	10	4.27%
10,000 - 50,000	6	2.56%
50,000 to 100,000	2	0.85%
1000,000 to 500,000	3	1.28%
No information	84	35.90%

4.2 Purpose 2: Examine how developers represent dyslexia in their app descriptions

When analyzing the 234 apps using the word “dyslexia” in the app description, only 46% or 107 app descriptions actually mention anything related to attributes or misconceptions of dyslexia. The data presented in this section are based on the 107 apps descriptions including attributes or misconceptions in their descriptions.

Attributes. Fifty-eight percent (58%) of the app descriptions mention research-based attributes of dyslexia with the most common being difficulty learning letters and sounds followed by slow reading, difficulty learning to read, difficulty reading single words and difficulty with spelling. Nearly half of these apps are designed to help young children with phonics and sight word recognition while the nearly one-quarter focus on improving reading speed with training programs designed for children or adults.

Misconceptions. Twenty-four percent (24%) of the app descriptions mention common misconceptions of dyslexia with the idea that dyslexia can be cured or outgrown as the most common followed by associating dyslexia only with poor vision, hearing, attention or behavior and dyslexia equating to seeing things backwards.

Other findings. Fifty-seven percent (57%) of the app descriptions mention accommodations built into the apps with auditory accommodations accounting for about seventy-five percent (75%) of these followed by special or customizable fonts

and customizable highlighting features. A small number of app descriptions (11%) also included additional information such as information about research on the app, collaboration with subject matter experts, information about the developer having dyslexia and marketing promises typically related to curing dyslexia or guaranteeing results in a short period of time.

5 Discussion

We were somewhat disappointed by our results because we were hoping to gain more insights into how mobile app developers conceive of dyslexia. However, we now suspect that most developers use dyslexia as a keyword for the purpose of app store optimization (ASO) to yield more exposure from searches conducted in digital distribution platforms. Indeed, the developers of more than half of the 531 apps appearing in our search results did not even include the word dyslexia in the app descriptions. This is concerning because recent market research suggests the majority of apps are discovered using searches within digital distribution platforms [49] possibly creating frustration and information overload for those searching for apps designed for dyslexics.

Despite the fact that our pool of app descriptions was whittled down by more than half from 531 to 234 apps, we expected richer data from these descriptions. Of the 234 apps including the word dyslexia in their descriptions only 107 of them included information about dyslexia besides phrases such as “also appropriate for dyslexics” or “also for those with dyslexia.” We suspect these tag-on phrases may have resulted from recent national movements drawing attention to dyslexia among a wider audience (see, for example, Congressional Resolution 456). (In fact, the year in which the most apps were released coincides with the year this congressional resolution was introduced.) Unfortunately, such tag-on phrases do little to help those seeking apps for dyslexics to gauge their appropriateness.

The app descriptions from remaining 107 apps do provide insight into how developers who are intentionally developing for dyslexia conceive of it. In many cases, the developers accurately but simply represent dyslexia. The majority of apps are designed to help children learn letters and letter sounds or to recognize sight words. While these are essential skills for learning to read and challenging skills for most dyslexic learners [48], they also oversimplify the concept of how dyslexics learn to read since a holistic, multisensory approach to teaching reading is recommended [9]. Although many of these apps could be integrated into a more holistic approach, this would be dependent on the expertise of the person using the apps and the appropriateness of the app design for dyslexics (a topic we have begun to undertake in our current work – See [12]). We suspect the large number of apps focused on these skills result from the simplicity of the content and the capabilities of easy-to-use mobile app development platforms.

Developers also appear to have a one-dimensional understanding of the supports appropriate for dyslexics with the majority focusing on providing auditory access to content; sometimes referred to as “ear reading” [50] Auditory access to content is a strategy that works for many dyslexics, however, given the varying cognitive profiles

of those with dyslexia, auditory processing cannot always be assumed a strength and can be a weakness [32]. The focus on auditory access to content within these apps privileges those with auditory processing strengths and disadvantages others. We suspect the large number of apps with an auditory focus relates to the capabilities of easy-to-use mobile app development platforms more than to an understanding of the needs of dyslexics. The auditory focus may also relate to blurring lines between apps for special populations such as those with dyslexia and apps for everyone [33] because many non-dyslexics may prefer auditory access to content. In fact, four of the eleven apps with 10,000 or more downloads related to speech-to-text and/or text-to-speech capabilities which may have advantages for users of all types depending on personal preference.

A concerning finding from our analysis relates to the fact that many app descriptions claim to "cure" or "fix" dyslexia. This is a misconception of detrimental consequences for dyslexics given that dyslexia can adversely affect self-esteem especially if not accepted and understood by the individual and her community of support [9]. The idea that dyslexia can be cured is not only false but contributes to a deficit view of it. It highlights weaknesses without recognizing and supporting strengths.

A promising find from our analysis relates to the very small number of app descriptions that mention collaboration between developers and dyslexia experts. This stands is contrast to the trends of one-person mobile app development projects [41] and shortened development lifecycles that skip or glaze over some design processes [11]. Interestingly, none of these apps have a high number of downloads suggesting his information does not influence users decisions to try out an app. Nonetheless, collaboration between developers and subject matter experts increases the likelihood of a product appropriately designed for the target audience [51].

The most important finding from this study may relate to the fact that results from searches within digital distributions platforms may not result in lists of useful apps designed with an understanding of dyslexia but rather lists of apps in which developers used popular but not necessarily relevant keywords. We cannot confirm this is the case for learning disabilities other than dyslexia but strongly suspect it is. If searches in popular digital distribution platforms are not reliable then it begs the question of where to look for apps designed with an understanding of dyslexia. There are no easy answers here.

We found numerous websites and blog posts (357,000 to be exact) about apps for dyslexia but the qualifications of the individuals or groups recommending the apps was often questionable or unknown. Sites curated by experts on dyslexia were difficult to come by and we found many of the sites suffering from the same misconceptions or simplistic notions found in our analysis of app descriptions. DyslexiaHelp curated at the University of Michigan is one of the most promising resources we found (http://dyslexiahelp.umich.edu/tools/apps). This resource provides "an extensive and meticulously organized list of apps that may be helpful to individuals with dyslexia, parents of dyslexics, or the professionals who work with dyslexics." The site does not provide information on how frequently it is updated but the associated blog is current (http://dyslexiahelp.umich.edu/latest). Another resource includes apps for dyslexia along with apps for other learning disabilities. SpedApps (http://spedapps.kent.edu/index.php), a new initiative developed at Kent State

University, is in the early stages of developing a "searchable website that catalogs high-quality apps for special education, especially those focusing on STEAM." An expert in the particular learning disability reviews each app. Apps are searchable by price, content, audience and learning disability.

Even as we write about these two resources we worry about the accuracy of this information in the future. Only six of ten resources for finding apps related to dyslexia identified in an article published less than three years ago are still functional. Given the ever-changing landscape of digital resources and mobile apps, a more useful discussion may relate to how to analyze the quality of mobile apps. Details about the design and development of several rubrics have been published in recent years and, while none of the rubrics focus explicitly on apps for dyslexia, the underlying principles of the rubrics combined with knowledge of dyslexia can support users in selecting appropriate apps for their needs. Table 7 summarizes the focus of these rubrics for those interested in analyzing the quality of mobile apps for dyslexia.

Table 8: Published app evaluation rubrics

Reference	Target Audience	Rubric Focus
[12]	Developers and users	Designed to assist both designers and users of mobile apps with aligning what the users should be able to do in order to meet a need with how the technology affords and supports such abilities.
[1]	Parents, teachers and other professionals	Considers multiple instructional design variables such as feedback and error correction, practice opportunities, instructional strategies, sequencing, individual customization, motivation and multimodal elements.
[52]	Adults with special needs and those who work with them	Addresses issues such as cost, benefits of use, ease of use, customizability and application as related to adults with special needs
[53]	Practitioners	Considers factors such as curriculum connections, authenticity, feedback, differentiation, user friendliness, and motivation.

5 Summary of Key Findings and Implications

This section provides of a summary of the key findings and implications discussed more thoroughly above.

5.1 Key Findings

Key Finding 1. Developers including dyslexia as a keyword or in their app description often have no particular interest or expertise in dyslexia and these apps are likely not designed for dyslexics. Thus, many searches within digital distributions platforms will likely not yield useful results.

Key Finding 2. Many developers have an accurate but simplistic and one-dimensional understanding of dyslexia. Some developers claim dyslexia can be cured or fixed and thus display a deficit model of thinking when developing apps.

Key Finding 3. A small number of developers collaborate with dyslexia experts when designing and developing apps. This collaboration, while promising, does not seem to influence user perception based on the small number of downloads these apps receive.

5.2 Key Implications

Implications 1. Checks and balances for ensuring developers accurately represent their apps through keywords and app descriptions are essential for users to locate appropriate apps.

Implication 2. Given the continued exponential growth in mobile apps, check and balances related to accuracy of content and appropriateness for intended users are all but impossible. This places the onus of evaluating apps on individual users.

Implication 3. Users interested in finding appropriate apps for dyslexia will likely not have success by searching digital distribution platforms. Some curated resources of mobile apps for dyslexia are viable options but their lifespans, recentness and sometimes accuracy can be uncertain.

Implication 4. Users interested in finding appropriate apps for dyslexia may be best served by evaluating potential apps using rubrics deigned for this purpose.

6 Conclusions

Dyslexia is a learning disability that affects 10-20% of the population through their lifetimes [9]. It is also one of the most misunderstood learning disabilities [10]. When handled poorly, dyslexia can result in serious consequences throughout a person's life with some estimates suggesting up to 50% of prisoners are dyslexic [50]. Conversely, when handled well the strengths and abilities of these learners can lead to very

positive results with nearly 35% of entrepreneurs and a large percentage scientists and inventors being dyslexic [54]. Given the emphasis placed on using mobile apps to support struggling learners [55], our findings about how app developers conceive of dyslexia and often simply use it as a keyword to boost the number of hits their apps receive is concerning. However, the small instances of developers collaborating with dyslexia experts, curated sites of mobile apps for dyslexia and evaluation rubrics for analyzing the quality of mobile apps give us hope that many dyslexics will benefit from mobile apps for learning, working and living.

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