

# Improving the web browsing environment for dyslexics by elaborating the viewing and reading functionalities

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## **Abstract**

Dyslexia is a disability in the brain's processing. It is characterized by difficulties in reading, writing, and retaining information in short-term memory, though it does not affect vision, hearing, or intelligence. The number of people who experience dyslexia may be around 6-10% of the population. It varies from language to language, but, in English-speaking countries according to one estimate, around 20 percent of the population suffers from related difficulties.

Assistive technology (AT) based on information technology (IT) can offer effective support for such people, but there are few studies on which kinds of support are useful for people with dyslexia when they are browsing the Web.

In this paper, we investigate effective support functions for Web browsing for people with dyslexia. We interviewed people with dyslexia about the usefulness of these functions while testing a prototype system. We identified several patterns of support for Web browsing and found specific kinds of supporting functions that are the most useful depending on the specific forms of dyslexia.

## **Introduction**

Dyslexia is characterized by difficulties in reading written text caused by information processing problems in the brain. It is not related to problems in hearing or comprehension. Although the number of people with dyslexia may be 6% to 10%<sup>1</sup> of the world's population, in Japan, the rate is estimated at 5% to 7% for written Japanese including kanji<sup>2</sup>. There have been few studies of what kinds of assistance are useful for people with dyslexia who are reading documents on computer monitors, such as when browsing the Web.

People with dyslexia use various kinds of supporting techniques to read printed documents. For example, they may put a ruler under a line where they are reading, cover the rest of the document with a mask that has a one-line opening, or add separator lines drawn with a red pencil between the words (this is effective because written Japanese does not separate the words)<sup>3 4</sup>. Even with these supporting techniques, it still can be difficult for them to read.

Some studies have reported on brain behaviors of people with dyslexia while they are reading printed documents. However, there have been few attempts to examine the brain's behavior while reading computer monitors.

General research suggests that there are many differences between reading printed documents and documents that are displayed on a monitor. What are the difficulties in reading information displayed on monitors, and what are the most effective support techniques for dyslexic readers using computers?

People with dyslexia use a wide variety of computer-related hardware and software. There is general

purpose hardware (such as desktop or laptop computers) and software (such as the Windows® operating system). There is also special purpose hardware (such as handheld electronic dictionaries) and software (such as text-to-speech programs). Especially in the English-speaking countries that are leading in research on dyslexia, AT is available and there are financial aid programs (such as DSA (Disabled Students' Allowance) in the UK). Because of this combination of technical availability and financial support, the opportunities for people with dyslexia are increasing, thus allowing them to fill more active roles in society<sup>5</sup>.

Nevertheless, research on the adequacy of various kinds of AT or on the efficacy of the support services is scarce. We believe there is a need for studies about more effective functions to support people with dyslexia who are seeking information from Websites because we are working on making Web browsing easier for these people.

## ***IBM Easy Web Browsing***

### **What is Easy Web Browsing™?**

The Accessibility Center, a part of the Tokyo Research Laboratory, is working to improve IT accessibility. One of our leading accessibility tools is software to support easier Web browsing—IBM Easy Web Browsing (EWB). The target users of EWB are novice IT users, second-language learners, people with limited vision, and senior citizens. EWB has various functions such as a screen magnification, reading out loud, line spacing controls, and color combination controls to make Web browsing easier by considering the users' special requirements, based on the underlying concepts of "easy-to-read, easy-to-use, and easy-to-understand."

We wondered if, by extending the functions of EWB, we could improve the Web browsing environment for people with dyslexia. The EWB functions are designed to offer flexibility in controlling the Web-browsing experience, so many of the EWB functions might be expected to apply to people with dyslexia, going beyond the original EWB target users.

Through the interviews with dyslexic people, we found that their preferences and requirements are quite different from those of seniors and novice users, the original target users of EWB. Customizability of functions appears to be one of the most important features for such people because they have a wide variety of symptoms.

In this study, we used EWB as a baseline tool for Web browsing by people with dyslexia, and we added some new, experimental functions specifically useful for dyslexics, working towards a prototype of "EWB for LDs," as dyslexia is generally classified as a kind of learning disability (LD).

### **Enhancement to IBM Easy Web Browsing for LDs**

We began by considering which functions could be improved to make EWB more suitable for people with dyslexia. Recent brain research indicates that there are some dysfunctions in processing linguistic and phonological information by people with dyslexia. In general, it seems that dyslexia is not associated with impaired intelligence, but that it causes various kinds of difficulties in reading. Such research indicates that dyslexic readers can overcome many of the barriers with suitable support.

The difficulties experienced by dyslexics differ depending on the affected areas of the brain. Some of the symptoms they may experience:

1. Though their vision is unimpaired, they may see individual characters as collapsed, distorted, wiggling, or reversed.
2. Their phonological processing can be relatively weak, making it hard for them to associate words with phonemes.
3. They can follow conversations, but have difficulties understanding written sentences.

To address such symptoms, we enhanced several of the basic EWB functions to create EWB for LD.

We gave a version of EWB for LD to a group of people with dyslexia. After they tried out the prototype system, we conducted aural interviews asking about the usefulness of the new functions. Based on the results of the interviews, we analyzed the effectiveness of all the functions provided in the prototype. We then incorporated some of their suggestions as additional new functions to EWB for LD and interviewed them a second time after they tried the newly enhanced, or second version of EWB for LD.

In the following sections, we explain the functions in detail and the reason why the functions are suitable for people with learning disabilities.

#### (1) Reading text out loud

People with dyslexia tend to have weak phonemic recognition and are known to have trouble understanding the meaning conveyed by text. In this case, “reading out” the sentences can help their understanding by associating characters within the phonemic process. Reading the Web site text using synthesized speech (e.g., text-to-speech like ViaVoice® Outloud) supports this process.

For people with learning disabilities, we developed the “KARAOKE-like indicator.” This function allows a reader to see each letter’s color change as it is read out. We expect this function to be instrumental in raising phonological awareness skills.

#### (2) Adjusting the line height and character spacing

Easy Web Browsing currently offers users the ability to make adjustments in line height and character spacing. In EWB for LD, this function is enhanced and may be especially important for people with visual processing issues.

If their difficulty manifests itself as overlapping or swinging sentences, we thought that the ability to spread out the space between the lines or characters might be helpful. In EWB, a user can adjust the line height by 200% (1line). In the EWB for LD prototype, we enhanced the adjustment to 300% (2 lines) and 400% (3 lines). In the prototype and in this paper, we called this function “Adjusting the Line Height.”

#### (3) Colored overlay

This function is new to the EWB for LDs prototype.

In the literature, there is evidence that covering a printed document with a colored filter or wearing glasses with colored lenses can help support reading ( a.k.a., Irlen Syndrome<sup>6</sup> ).

To simulate this technique for reading on a computer monitor, we first developed a “strip-shaped” color filter, instead of a “whole screen” filter. Because of comments derived from the 1<sup>st</sup> interview of our users, we decided to change this function so that it can cover the whole screen. We also decided that the filter’s colors should be the same as filters for printed documents. In the prototype and in this paper, we called this function “Colored Overlay.”

#### (4) Ruler

For some, dyslexia manifests itself as issues with eye motion or not being able to recognize the focal point for reading. For a printed document, many people with dyslexia help themselves find the focal point by putting a ruler under the sentence where they want to read. We believed that the same situation occurs when a user is reading text on a computer monitor. EWB currently offers its users a “ruler” function, but for EWB for LDs, we enhanced the function so that users can choose the width of ruler. In the prototype and in this paper, we called this function, “Ruler.”

#### (5) Page layout map

This is a new function in the EWB for LDs prototype.

In order to help people with short-term memory issues or attention deficit disorder not lose their place on a long page of text, and help them to not forget an area they have already read, we developed a small window which can display the whole page view and can indicate the part of the page which they are reading now.

In the prototype and in this paper, we called this function “Map.”

The following functions already exist in EWB and we did not enhance them. However, we mention them because they may be suitable for people with dyslexia.

#### (6) Screen Magnification

In the same way as the function “adjusting the line height,” screen magnification is suitable for the people who have visual perception issues. When they perceive that sentences are overlapping or collapsing, this function will be helpful.

In this paper and in EWB and EWB for LDs, we call this function “Magnification.”

In addition, we improved the magnification feature. In EWB for LDs, it works like a hand-held magnifying glass. We call this function “Image zoom.” Image zoom cuts off the part of the Web page at the point located by mouse pointer, and shows the magnified image around the mouse pointer in another window. In this paper, these magnification functions are same.

#### (7) Highlight

This function enables a user to invert color of the part of sentences where the TTS is reading. This feature may help people with dyslexia to recognize where they are reading and associate it with the phonological process or it may help them track the text as they move their line of sight.

In this paper and in EWB and EWB for LDs, we call this function “Highlight.”

The following functions are now only implemented for the Japanese version of EWB for LDs, though we hope these functions may prove to be effective with other languages.

#### (8) Furigana

When a person has phonological dyslexia, his association of written characters with the corresponding phonemes is weak. We believe that users recognition of the words in the sentence will increase by showing the hiragana printed beside each kanji character. In English, we hope this new function can be used to help with abbreviations and acronyms such as EC, OPEC, and so on. These abbreviations and acronyms can be spelled out – in essence, given the equivalent of a hiragana.

In this paper and in the prototype, this function is called “Furigana.”

When a person has surface dyslexia, she has a weakness at grasping the shape of the letters or words. In this case, giving the pronunciation is important. This function is enhanced in the Japanese version. We believe that this concept could be effective for English speakers—especially for those who mispronounce word. A good example of this would be “Bushisms.” The former US President Bush is known for his unique pronunciations such as:

sar-KO-zee

## Sarkozy

Using this function, correct pronunciations are indicated near the words. This function could prove to be effective and helpful for people who have learning disabilities.

### (9) Spacing between words

Specific to Japanese, adding spaces between words (because standard Japanese does not use spaces) may be effective in displaying the words as the familiar shape. In the paper and in the Japanese version of EWB for LDs, we call this “Spacing between words.”



**Figure 1. As shown at the top of the figure, in Japanese, there are no spaces between words. After putting some space between the words as shown in the bottom part of the figure, many people with learning disabilities can read and grasp the meaning easily.**

### (10) Change color

This function enables a user who needs contrast between the foreground and background colors, such as a person with low vision or a senior, to change the color combination of text color and background color for low vision or the senior. We think that this function is equivalent to the colored overlay.

## ***Pilot study***

### **Interview and comments**

In August, 2008 and again in November of 2008, we interviewed 10 adults with dyslexia (mainly exhibiting symptoms of learning disabilities, but some having been diagnosed with ADHD). These participants were recruited by NPO EDGE, which is the most widely-known dyslexia support organization in Japan<sup>7</sup>

Because each participant exhibited different symptoms, it was difficult to determine what functions or settings were effective for all. However, note that all participants agreed that there was a need for efficient support/additional help while they were browsing the Web.

In the end, we asked each participant to choose 3 functions he or she felt were effective in supporting their Web browsing. We then calculated the result with a weighting coefficient as follows: 1<sup>st</sup> choice was worth 8 points, 2<sup>nd</sup> was worth 4 points, and 3<sup>rd</sup> was worth 2 points. The results are shown in table 1.

	Function	1 <sup>st</sup> prototype	2 <sup>nd</sup> prototype
1	“Reading text outloud”	38	34
2	“Colored Overlay”	20	28
3	“Adjusting the Line Height”	20	24
4	“Ruler”	8	10
5	“Highlight”	16	4
6	“Furigana”	12	2
7	“Spacing between words”	12	2
8	“Change Color”	4	0
9	“Page Map”	4	4
10	“Magnification/Image Zoom”	4	0

**Table 1. Ranking score of the favorable functions which participants selected.**

### **Objective assessment**

The participants commented that, by using the functions in the prototype EWB for LDs, they were able to read more easily than before. But, we wondered if the functions in EWB for LDs were truly effective. We set out to discover the answer to this question.

To assess the improvements in reading, we provided some sentences each of the same length. We measured the participants’ reading speed with and without the EWB for LDs functions. We considered the level of the difficulty of the sentences, e.g., topics are the same, same reading level of words, and the same numbers of the complex words and so on.

The results, shown in the following table clearly demonstrate that all the participants were able to read faster using the EWB for LDs functions even though there is a wide variation in the improvement ratios.

	Without support (sec) (a)	With support (sec) (b)	Improvement ratio (%) $= (a-b)/a$	Time lag (s) $= a-b$	Selected EWB for LDs function
A	56.4	42.2	25%	14.2	Colored Overlay (yellow)
B	86.0	65.0	24%	21.0	Adjusting Line Height
C	43.6	36.1	17%	7.5	Colored Overlay (yellow)
D	36.8	29.1	21%	7.7	Ruler
E	30.8	28.1	9%	2.7	Adjusting Line Height
F	37.3	36.3	3%	1.0	Colored Overlay (yellow)
G	43.3	34.6	20%	8.7	Magnify & Furigana
J	71.3	63.1	11%	8.2	Colored Overlay
average	50.7	41.8	16%	8.9	

**Table 2. Results of the reading speed and improvement ratio**

## ***Summary and considerations of the pilot study***

### **Reading speed progress with the EWB for LDs functions**

Extrapolating from the results shown in Table1, we believe that there are 3 main types of functions that are most effective in shaping the reading progress model<sup>8,9</sup>. These are to support the user's ability to:

- (1) Comprehend the shape of characters and recognize them visually.
- (2) Grasp the phonology of the characters.
- (3) Understand the meaning of the characters.

Based on these three functions for effective reading, we enhanced current EWB functions and added new features to EWB for LDs.

### **EWB for LDs functions that support visual/perceptual clarity (helping users to comprehend character shape)**

This category includes:

- Color Overlay
- Ruler
- Adjusting the Line Height
- Magnification

Almost all participants agreed that adjusting the line height is an effective technique. We were surprised at the amount of adjustment with which they were comfortable—300 or 400 percent. This was much

larger than we had expected.

From this evidence, we became aware that magnify the characters is a good feature, but allowing the user to adjust the space between the lines was a necessity. Based on anecdotal evidence from participant's comments, we also realized that spacing between words is effective. In addition, we recognized that the settings for height of lines or characters spacing can vary widely according to each person's symptom. If the spacing is too wide or too high, people with dyslexia cannot grasp the meaning of the sentences because of the decrease in the amount of text information.

Participants liked the colored overlay that was a small strip. However, their comments led us to enable the user to cover the full screen. In the testing of the second prototype where the color overlay can be used to cover the full screen, the users rated it as more effective than the smaller band filter.

Interestingly, one participant, male, age 30, no cataracts, told us that he had never tried to cover the screen or a printed document with a color overlay even though he knew that it might be an effective technique for him.

In our testing, we found that the participants preferred yellow, with light blue as their second choice. This bears out the findings of an earlier study showing that, with a printed document, people with dyslexia preferred a color overlay with a long wave length like orange, yellow, rose<sup>10</sup>.

We hypothesized that our participants preferred color on the screen would be the same as their preferred color for printed documents. We obtained evidence that this conjecture was true by trying different colored overlays on the monitors.

Some of the participants said that they preferred different color overlays with different Web pages. This is inconsistent with the way people generally use color overlays with printed materials – they generally do not change the color of the overlay when they read printed documents. In future work, we plan to research the correlation between “the colors of the overlay” and “the colors of the Web pages.”



**Figure 2. EWB for LD changes the Web site using the colored overlay (red color) and adjusting the line height.**

Our participants found the functions, “Ruler” and “Highlight” to be useful and helpful. We theorize that these functions can clarify where people with dyslexia are reading and can help them discriminate where they do not want to read.

One note on supporting visual/perceptual clarity: We provided an option for vertical writing for older Japanese-speaking people because they are familiar with vertical writing. This option may support people with dyslexia too because vertical writing is easier for the eye motions of the people who do not have good control of horizontal eye motion.

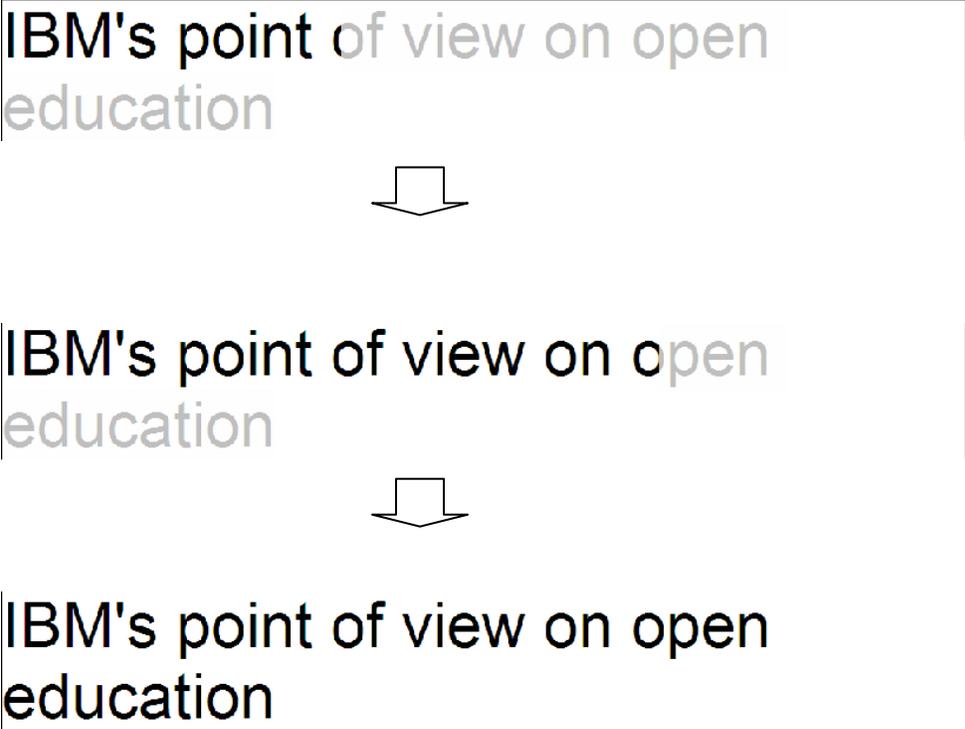
**EWB for LDs functions that supports users grasp of character phonology**

During both stages of prototype testing, most participants ranked “Reading the text out loud,” as necessary and effective for them. In fact, five of 10 participants chose ranked the ability to hear text read out loud as the most important and effective feature, while only two participants felt that audio and text was too much information for them.

One participant summed it up best by saying: “Reading the text out loud—that combination of the phonetic and the characters—helps provide the meaning of the sentences and it helps me to avoid reading sentences more than once.”

Along with reading the text out loud, we have provided the following functions that help users grasp characters: inverted color of the magnified part of sentences while the text is being reading out loud. Most of the test participants mentioned that the having the dual inputs of both hearing the text read out loud and seeing the text magnified was helpful.

We added the “Karaoke function” in the second test of the prototype and received many favorable comments. This function pinpoints the exact letter that is being read, honing in from the function that indicates the whole sentence. Figure 3 shows the karaoke function. The sentences that are being read out loud are indicated with the letters changing color from gray to black.



**Figure 3. The color changing sequence as speaking progresses (Karaoke function)**

Because of evidence in the literature<sup>11</sup> indicating that people with dyslexia tend to have phonological deficits when reading Chinese characters, we believe this function will be especially helpful to these users.

## **EWB for LDs features that help users to understand the meaning of text**

Currently, the EWB for LDs features “Furigana” and “Spacing between the words” are intended to help users understand the meaning of the Web content they are reading. Because the pronunciation or sound of the word and shape of the characters are needed to understand the sentence meaning, this combination of these functions in EWB for LDs is helpful. “Furigana” supports both the pronunciation of the word and shape of the characters). “Spacing between the words” can support the user’s grasp of the shape of the characters and words—it can help people who see the words as picture. When users are able to recognize the shape of the word, they can easily remember the phoneme. So they can understand the sentences.

We feel that we have to add more functions and improve our current functions in order to bolster the ability of users to understand the meaning of the content they read. One idea we have is to develop functions that can show the meanings of words or show an image associated with the word.

## **Test conclusions regarding reading speed improvements**

Our participants all agree that they have a great need for assistance when they are browsing the Web. Because their symptoms differ from each other, there are few functions or settings which are effective for all, but most of the functions worked for some part of the population represented by the participants. Thus, we found that when the participants used EWB for LDs, both their reading speed and the ease with which they were able to read improved.

While the variations in the improvement ratio could be attributed to variations in the dyslexic symptoms exhibited by our participants, we did not analyze the data from that perspective. In the future, we plan to adjust our testing method to include both non-verbal test sentences and analysis of the data about the fluency of reading with the voice spectrum.

We found, also, that complex words are especially difficult to read. In future investigations, we would like to factor such things as word complexity into the testing and data analysis.

## **But, what about reading comprehension?**

We felt that we had proven that EWB for LDs helped improve reading speed and ease. We wondered, though: “Do the functions in EWB for LDs contribute to a better understanding of the meaning of Web content?”

In trying to determine the answer, we showed our test participants some sentences and we asked them to choose the correct sentence that would convey the answer to some corresponding questions. Our results were inconclusive, maybe because of our test methodology or because of the divergent symptoms exhibited by our test participants.

We would also like to ascertain whether improvements in reading speed and ease contribute to the improvement of reading comprehension?”

Certainly some of our participants could read faster than ever, but their memory capacity remained the same. We realized that there are two points to consider:

1. Their understanding may have remained the same because their memory capacity also remained the same.

2. Their understanding may have improved because their attention span was optimized by the improved reading fluency.

We were unable to put these hypotheses to the test. We hope that, perhaps, a more specialized research organization will attempt to determine the answers to these follow-up questions and welcome any involvement we would be invited to have.

## **Conclusions**

We improved the functions in the existing program IBM Easy Web Browsing that we felt are suitable for learning disabilities. After developing a prototype application, we wanted to determine if the functions were usable and effective for people with dyslexia and we wanted to focus on which of the functions provided the most benefit for this population.

Our study resulted in both subjective (participant comments) and objective (measurements of reading speed) data that led us to several conclusions—that the functions in EWB for LDs can be effective for people with dyslexia and that work to improve accessibility to IT such as EWB for LDs is important and can have far-reaching implications for both individuals and society.

## **EWB for LDs—an effective tool**

The participants in our study all agreed that they needed assistive technology to help them read Web content. In addition, they asserted that EWB for LDs was an effective tool to be used for that purpose. We did find that each participant preferred a different set of EWB for LDs application features and that those preferences were based on the symptoms of learning disabilities they exhibited.

Other anecdotal data we gathered about EWB for LDs:

1. Many participants remarked that they preferred EWB for LD over other tools because of all of the features they needed were in one “package.” They said that it is an inconvenience to use many tools simultaneously, especially because of any short term memory issues. They also mentioned that they liked being able to try out all of the EWB for LDs functions as it helps give them awareness of what functions are suitable for them.
2. The functions most useful to dyslexics turned out to be reading out loud, the colored overlay, improved line spacing, and the line ruler. Almost all participants mentioned that the colored overlay is effective even for phonological dyslexia. When people read words, there is a specific model that progresses from the visual process to recognizing the word visually, and includes understanding through phonological comprehension<sup>12</sup>.

Before starting our study, we supposed that most people with dyslexia would have weakness in all “thought” processes. However, because of our research into the literature and our experiences with the participants, we became aware that there are different levels of dyslexia including phonological, surface, or deep dyslexia. These variations might depend on the language in which the text is displayed. For example, investigations into people who read Chinese and have dyslexia conclude that there are two types of dyslexia: disability in basic visual perceptual functions and deficit in phonological recognition<sup>13</sup>.

We found it difficult to concentrate our study on one function because of the diversity of symptoms manifested within the disability. At the one point, we separated EWB for LDs functions into three categories in order to simplify our interviews. We would like to use the user model or user scenario to create a more detailed profile for people in order to create a more flexible user interface that gives the user more choice of options on the operation panel. There are few studies of the efficiency of the

technology, and it will be helpful to have guidance from experts in the field dyslexia.

Note too, that some of the EWB for LDs functions are specifically for Japanese, which uses a mixed script including ideographs. However in English, these functions may be useful for people who are reading words as pictures, similar to the process in Japanese. We hope that some of our approaches may be helpful for people with dyslexia who use other languages.

## **Creating accessible IT—benefits for society and business**

At IBM, we feel a responsibility to contribute to society. As a leader in IT, it is reasonable that we focus on ways to use IT to help create a better world for both individuals and for society at large.

Dyslexia can be a “silent” disability - many people do not realize that they have such disabilities. They may come to believe that they are less intelligent than others, become depressed, and succumb to lives of crime and delinquency.<sup>14</sup> Our belief is that if we can provide technologies that support people with learning disabilities early in their lives, we may help avoid these unwelcome outcomes.

On the other hand, there are many people who have special ability, e.g., A. Einstein, A. Christy, R. Bronson ... who have, or have had, dyslexia or LDs<sup>15</sup>. These people stand as an example and a testament that such disabilities can be overcome. While English-speaking countries generally recognize learning disabilities and have begun to focus attention on helping to mitigate them, the rest of the world has not necessarily recognized these disabilities. It is necessary to raise awareness and understanding of dyslexia and learning disabilities throughout the rest of the world.

Lastly, we want to mention the reading/literacy problem. Reading comprehension problems can be an issue for a person’s entire life span. And, many people can have such problems, even though they may have a less severe issue than others. We think that EWB for LDs can be helpful in this area and that it can help people, not just in their lines of work, but in all areas of their lives as well.

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