

Practical Magic: Applying Guidelines to Serious Game Accessibility

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ABSTRACT

Federal agencies (DoD see FAR Subpart 39.2) are Congressionally mandated to provide electronic and information technology accessible to people with disabilities. Exemption is allowed if accommodation would cause undue burden, would lessen the overall experience for most users, or if no conforming options exist, and exceptions hold for some national security procurements. Prior authors have shared guidance for implementing accessible web-delivered courseware, but actionable creation guidance for accessible learning games has not previously been discussed.

Many serious games provide basic in-game accommodations and with exemption offer alternate, non-game content to meet disabled users' needs. Our community should challenge ourselves to provide serious game experiences to a wider learner audience, accommodating disabled users through the assistive technologies they routinely utilize. While this sounds easily agreeable, in practice barriers to providing inclusive gameplay are prevalent. The most used development engines render games inaccessible to assistive technologies, budgets are often lower than developers request even without accounting for accessibility requirements, and the community lacks design guidance.

The widely recognized Web Content Accessibility Guidelines (WCAG), originally developed for traditional web content, can be adapted to address accessibility in interactive games. Applied in this way, WCAG offers generalized themes useful for developers to extend and interpret as guidance for complex, dynamic user experiences. By designing to WCAG, developers can ensure that their games will be accessible to a wide range of users and create a foundation to communicate the accessibility level of products using a generally understood lexicon.

This paper offers the serious games community a practical guide to accessibility. Topics include: an overview of regulations, requirements, and consumer expectations for accessibility, WCAG introduction with concepts anchored by learning game examples, a comparison of implementing in-game versus assistive technology accommodations with lessons learned, and design challenge highlights from efforts to provide engaging gameplay for all in browser-based serious games.

ABOUT THE AUTHORS

Jenn McNamara is VP of Serious Games and Strategic Products for BreakAway Games, Jenn acts as an advocate and liaison between market leaders, clients, and the BreakAway creation team driving strategic product direction. Specific to this paper, Jenn has been overseeing development of accessible games for over two years.

Starting on the DARPA DARWARS Training Superiority program and continuing through 20 years of game production and research collaborations, Jenn's work has contributed significantly to the body of knowledge of what games offer for learning, training, practice, and assessment. She's worked with clients across defense, healthcare, homeland security, education, and corporate organizations.

Jenn is a strong advocate for the serious applications of games. She is a frequent speaker at industry conferences including Serious Play, the Society for Industrial and Organizational Psychology, I/ITSEC, Game Developers' Conference, Games for Change Festival, and ATP Innovations in Testing. She serves the conference committees of I/ITSEC as the director of the Serious Games Showcase & Challenge and ATP Innovations in Testing.

Jenn holds a B. S. in cognitive psychology from The Pennoni Honors College at Drexel University and M.Ed. from the Pennsylvania State University. She is an adjunct professor of learning game design at Harrisburg University.

Michael Brooks is a leader in Educational Technology and Digital Accessibility with 15 years of experience leading teams through complex projects, implementing solutions, advocating for accessible use of technology by all, and working with clients to strike a balance between usability and innovation. He brings a user-centric approach to solving complex digital problems focused on achieving organizational goals and end-user functionality. Mike is the Assistant Director of Educational Technology at the Pennsylvania State University's World Campus. Among his responsibilities is evaluating candidate educational technology for accessibility readiness, affording him an understanding of organizational requirements.

Mike works with agencies on the accessibility of information and communications technologies, reviewing and developing Voluntary Product Accessibility Templates (VPATs), and consulting on the practical application of policy and standards to complex solutions. He applies user experience-driven information gathering, develops a purposeful understanding of challenges, and guides unique solution design.

Mike holds a B. S. in Design and Development of Information, Science, and Technology from the Pennsylvania State University, and is a Certified Professional in Accessibility Core Competencies from the International Association of Accessibility Professionals. Mike consults on select accessible design projects through UsableWeb Consulting LLC, in this capacity he became a trusted advisor to BreakAway Games.

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CAUGHT OFF GUARD

This paper is based upon the experience of a serious game development company that found itself faced with a simple inquiry from an end user, “why can’t I access this product using JAWS [a widely used screen reader]?””. That question launched our journey to define what it means to provide an accessible serious game. We ultimately met the challenge of transforming an existing web-delivered, game-based learning and assessment product to be compliant with Web Content Accessibility Guidelines (WCAG) 2.1 AA, the most widely recognized current in-use standard for digital accessibility. Our goal is to share the requirements, recommendations, standards, and tools we discovered through our research and development, along with lessons learned in creating three different accessible serious game products built using commercial game engines. We met our co-author after the first two products were created, and he supported our design and development team in deciphering and addressing WCAG 2.1 AA requirements in our most recent accessible serious game product. In this paper, his expertise grounds our experiential narrative with digital accessibility information, including forward-looking insight based upon the recently released WCAG 2.2 and drafts of the next increment guidelines WCAG 3.0 (Spellman et al., 2021). Together, the authors share our experience to help future serious game creators rise to and more readily navigate the challenge of providing accessible serious games.

CURRENT ACCESSIBILITY REGULATIONS FOR SERIOUS GAMES

The Americans with Disabilities Act (ADA) requirements that paved the way to current end-user expectations for accessible serious games are not new. Since 2001, the United States Congress 1998 amendment of Section 508 of the Rehabilitation Act (29 U.S.C. 794d) has required Federal agencies to ensure all electronic information and communication technology (ICT) is accessible to people with disabilities. Review Section 508 (US GSA, 2023a) and Federal Acquisition Regulation (FAR) Subpart 39.2 (US GSA, 2023b) for the requirements. The requirement for agencies to give disabled employees and members of the public access to information comparable to that available to those without disabilities is not new to the training community. Prior authors have shared regulation overviews and developer guidance for eLearning, mobile apps, and computer-based assessments (Ambrose & Ibáñez, 2002; Bandrowski & Clark, 2010; Deibler et al., 2015; McCullough & Vartuli, 2002; Twitchell, Bandrowski & Clark, 2012).

Developers of advanced training and assessment games and simulations have long been allowed exception or exemption to accessibility regulations. According to Section 508 policy and relevant FARs, exemption from providing fully accessible ICT is allowable for legacy systems not altered since January 2018, when accommodations would cause undue burden defined as “significant difficulty or expense” relative to the budget and timeline, when accommodations would fundamentally alter the nature of the application lessening the overall experience for most users, or if no conforming commercial options exist. Exceptions hold for some military procurements including national security systems, ICT used in-house by the contractor, or ICT used for maintenance, repair, or occasional monitoring of equipment in maintenance or monitoring spaces. These accessibility exemption and exception allowances remain in place today. To limit requirements for accessibility regulation compliance, training application procurements most often claim undue burden, fundamental alteration of experience, or exclusion of certain user disabilities in the target training audience given job related task requirements.

So why, with most game-based training applications eligible to claim exception or exemption from accessibility regulation compliance, do we believe it is time for the development community to take accessibility more seriously?

NOW IS THE TIME FOR CHANGE

Convergence of the following market and industry factors will increasingly compel game-based learning and assessment developers to create accessible serious game experiences rather than exercise exemptions:

1. Expanded organizational commitments to diversity and inclusion.
2. Increased disabled consumer expectations and demands for improved access.
3. Continually advancing technology opening new approaches to delivering accessible training and assessment products, as well as presenting new accessibility challenges.
4. Availability of existing and evolving accessibility design and implementation guidance that can be extrapolated to game-based training and assessment products.

As accessible products become the norm and training and assessment game technology advancements and design recommendations become more robust, exemptions will no longer be a justifiable option.

Global Commitment to Inclusion

Broad organizational investments in accessible digital products are commonplace. This focus is likely fueled by an increased emphasis on organizational citizenship and social responsibility driving Diversity, Equity, Inclusion, and Accessibility (DEIA) initiatives (Biden, 2021) alongside organizations' fears of or involvement in one of the many accessibility related lawsuits waged against federal and corporate organizations for failing to meet individual needs (Vu, Launey & Egan, 2022; Shaw, 2023). A Gartner market guide on digital accessibility (Stewart et al., 2023) well positions the current state of accessible ICT, "Digital accessibility is no longer a choice; it's a requirement." Supporting evidence for this claim includes factors aligned with those mentioned above. The report indicates that major contracts require accessible technology for government organizations, most educational institutions, major companies, and nonprofits. Together these factors have culminated in a global commitment to increase support for users with disabilities – resetting user expectations of what is achievable. Including accessibility in your product will broaden your potential user base and create a marketing opportunity for progressive practices in the DEIA space.

Protecting the Future Impacts of Serious Games and Other Advanced Modeling & Simulation Products

In a disturbing trend, as cited by Twitchell, Bandrowski, and Clark (2012) and continuing today, many agencies simply eschew interactive and advanced training applications choosing simple solutions readily in compliance with accessibility regulations. They note that designers have abandoned innovative instructional strategies favoring "least common denominator experiences" that will support accessibility, providing a more uniform experience for more users but at the same time lessening overall quality. This trend is something developers of interactive learning and assessment products need to push against by creating accessible advanced training applications wherever practical, to not only allow learners the rich and engaging learning experiences our community can offer via serious games but to pave the way for future applications including extended reality, artificial intelligence, and future novel approaches.

LEARNING AND ASSESSMENT GAME EXAMPLES

We appreciate the ability to share lessons learned from our experiences creating accessible game products supported by several clients. The clients are respectfully held confidential, and games described abstractly, sharing only details necessary to differentiate among our experiences applying different guidelines and tools for accessibility. Our first accessible design request came up during development, allowing us to pause, research, and redesign from an inclusive perspective. Two other products were retrofitted. The games were built in Unity (Unity, 2023) or GDevelop (GDevelop, 2023) and do not require 3D environment navigation. They utilize menu-driven selections for casual game or simulation interactions using animations to convey story, carry out player actions, and stimulate decision-making.

ACCESSIBILITY DESIGN STANDARDS, GUIDELINES, AND RECOMMENDATIONS

There are no established criteria to assess accessibility compliance for a learning or assessment game. Our search for actionable design guidance produced no standards, guidelines, or development toolsets to specifically support the creation of accessible serious games. However, since learning and assessment game design borrows principles from instructional design, entertainment game design, and web design we expanded our search to include accessible design

recommendations for these domains. Examined collectively, this body of guidance formed a useful foundation to inform our accessible design challenge but still fell short of meeting our complete accessible learning game design needs. Here we briefly discuss how the accessible design guidelines from instruction and entertainment games informed our team. Accessible web guidelines will be discussed later.

Accessibility Guidance for Instruction

Universal Design for Learning (UDL) provides guidelines for inclusive learning. UDL targets overall course design with high-level accessibility recommendations for specific course elements including syllabi, presentations, activities, etc. Example guidelines include “optimize access to assistive technology” and “use alternates for visual information” (CAST, 2018). UDL encourages the use of learner options to perceive, comprehend, and express their learning. Followed to an extreme, this guidance might result in meeting disabled learners’ needs through addressing key considerations. For our team, UDL helped reinforce a mindset for accommodating learner preferences, providing options, and supporting standard tools, but in general did not provide actionable recommendations to guide our creation nor retrofitting of a learning game.

Accessibility Guidance for Game Designers

Accessible game design guidance aimed at entertainment products focused the team on critical design considerations as we sought an initial understanding of accessible games. The AbleGamers Design Patterns (AbleGamers Foundation, 2018) and the Game Accessibility Guidelines (Ellis et al., 2023) each approach accessible game design uniquely, and they each served their own role as we scoped and designed our first accessible learning game. From the guidelines, our team created a list of reasonable and necessary accommodations to provide as part of the product.

AbleGamers Design Patterns

The AbleGamers Design Patterns (AbleGamers Foundation, 2018) aim to help designers create Accessible Player Experiences (APX). The design patterns include 12 foundational Access Patterns and 10 Challenge Patterns. Access patterns help designers create game worlds that players with disabilities can access. Challenge Patterns focus on engaging all players in game narrative and play experiences. Each pattern is presented as a design problem matched with a design solution and expanded APX design drivers that explain how players with different types of disabilities may be impacted by the problem (see Table 1 for an example expanded design pattern). Descriptions and images of examples from entertainment games that have met the design challenge in some way are included. The design patterns can be accessed for free online or purchased as a set of cards. Additionally, formal training courses are available to train individuals or teams in their application.

Table 1. Example Expanded Design Pattern

| Design Pattern | Design Problem | Design Solution | Expanded APX Design Drivers |
|----------------|--|---|---|
| Clear Text | Players cannot reliably read the text in the game or its interfaces. | Players can change how text is presented to them in the game or its interfaces so that it can be read reliably. | Players with color vision deficiencies may need to change the foreground and background color of a text to ensure it is readable. Players with learning disabilities such as dyslexia may prefer a different font for text in the game (e.g., serif vs. sans serif). |

The patterns are not presented as an exhaustive inventory of all issues a user could encounter with a game, nor are they a checklist one can complete to claim a game accessible. Rather, our design team found these patterns useful to help in initial consideration and expanding our thinking about the different ways a range of disabilities might impact a user’s experience playing a game. For our team, the patterns were helpful in thinking through design elements, mechanics, and user interface options more mindfully in the process of designing accessible serious game experiences.

Game Accessibility Guidelines

The Game Accessibility Guidelines (Ellis et al., 2023) provide a useful list of recommendations for game design grouped into three levels determined by the reach (number of people who benefit), impact (the difference made to those people), and value (cost to implement). Basic guidelines are simple considerations that apply to most game

mechanics, benefit large numbers of users, and are easy to implement during design. Intermediate guidelines don't necessarily apply to all game mechanics but still benefit many people, generally foster good game design improving the experience for all users and are harder and more resource intensive to implement. Advanced guidelines are complex adaptations that provide high value for specific niche users and require more budget and specialist knowledge to implement. Within each level the guidelines are further organized by disability category: Motor, Cognitive, Vision, Hearing, Speech, and General. Each guideline is presented as a goal statement, for example, "Ensure no essential information is conveyed by a fixed color alone". Each guideline is supported by quotes from game designers or end users related to the issue, an explanation of the guideline, advice and links to images or videos illustrating best practice examples, links to information about associated disabilities, and related tools that help convey the experience or issue.

The guidelines are presented on a website and a Microsoft Excel downloadable checklist is available to facilitate use. Our team found exploring the guidelines and then downloading the checklist helpful to initiate a table to track all the elements of our design that might need to be considered with respect to potential disabled users. We used the table as we reviewed each component of the in-development game's design against each guideline, indicated any potential issues, and listed possible mitigation strategies. We used this expanded checklist to communicate options to our client, scope the effort, and represent the tasks to be completed in our statement of work. As useful as the guidelines were in helping us determine the universe of possible design issues for accessibility and providing examples of how other games achieved accessibility, they left the design team to determine if and how to address each issue versus providing standard solutions. There was also no sense of holistic coordination among the guidelines or the example solutions.

TECHNOLOGY DRIVERS, TOOLSETS, AND PREFERENCES FOR SERIOUS GAME ACCESSIBILITY

HTML5 Provides Opportunity and Challenge for Accessibility

Modern web technologies greatly advanced learning and assessment game access by enabling their presentation in a browser without additional plugins or executable downloads, simplifying delivery for learners. To provide dynamic and interactive graphics content beyond what the traditional static web provides and without requiring additional plugins or downloads, game developers use HTML5 with WebGL rendering to a canvas container element via scripting. This is true of games created with the most prevalent cross-platform commercial-off-the-shelf (COTS) game engines – Unity (Unity, 2023) or Unreal Engine through UE4 (Epic Games, 2023) and smaller engines. Anything drawn to a canvas may be inaccessible to user agents, the software which "retrieves, renders and facilitates end-user interaction with Web content" (W3C, 2011), that provide accessibility accommodations. To meet the challenges of interacting with a range of assistive technologies, web game developers need to find or create an accessibility solution.

Game Engine Plugins for Accessible Game Development

Given a lack of prescriptive guidance in the AbleGamer patterns and Game Accessibility Guidelines, our team sought out accessibility software developer tools. Hoping to find more specific design or implementation direction, we utilized an open-source Unity plugin created to ease the burden on developers creating accessible games.

UI Accessibility Plugin (UAP)

To explore building an accessible game user interface (UI), we added accessibility features for the vision impaired to an existing mobile game using the UI Accessibility Plugin (UAP) for Unity (MetalPop Games, 2021). UAP provides a native solution path to make Unity-generated game UI accessible to visually impaired users. UAP does this by systematically allowing developers to classify and label elements in their UI. The labeling allows native mimicking of how screen readers work. The end user may have the UI read aloud to them using text-to-speech (TTS). At the same time, when keyboard navigation is used on screen elements are also highlighted. These features benefit users by providing access to what are normally indistinguishable pixels on a screen transitioning them to objects and elements that can be accessed through means other than a visual mouse. UAP is noted to be designed for 2D UIs and not for 3D game environments, which may limit some developers in the ways they must design their games and interactions.

The mobile game we instrumented with UAP had a very specific target user population and use case, exposing users to preview a potentially stressful environment to help them gain comfort through exploring the space, equipment, and activities that would be encountered in the real world through playful casual games set in a cartoon-styled replica. The client was satisfied by the accessibility gains possible through the UAP accessibility accommodation provided.

Later, we used UAP as part of our design and development planning for a more complex web-delivered, game-based continuing competency product. This product required that the screen reader functionality be provided by standard assistive technology; in this case, COTS screen readers [JAWS and NVDA]. Mimicking a real screen reader would not be an acceptable solution. The team needed to build a custom solution to meet this challenge, while it was being developed, other team members used UAP to explore the design for additional accessibility elements. Using UAP to instrument the existing game provided concrete scenarios to discuss accessible design. This practice enabled our team to reconsider some non-standard interaction elements to determine how to classify and label them appropriately and to allow them to function appropriately with keyboard controls. We also completed an overhaul of the game UI, and UAP experimentation helped us think through design elements. For instance, a drag-and-drop interaction was changed to allow an item to be selected and sorted via buttons. Working through this experiential discovery process guided by the plugin structure informed later design decisions made by the team in other game modules. Using UAP allowed our team to create a quick accessible game prototype to share with our client, accessibility consultants, and disabled testers for quick design feedback to inform the under-development custom solution.

Apple Accessibility Plug-in

While not utilized by the team on the efforts reported here, Apple released an open-source package of accessibility plugins for Unity. Like the UAP, Apple's plugins allow users to identify element types and provide them with labels, but unlike the UAP, it is developed to provide a link for Apple's native screen reader, VoiceOver, to access the content in the game. The benefit of this approach is that users can continue using their familiar and preferred screen reader without interruptions or the possibility of missing important content. They are not required to dive into the settings to enable an in-game screen reader. It works more seamlessly for Apple VoiceOver users on all Apple devices but does not provide a solution for non-Apple platforms and devices. Developers would need to duplicate the work of identifying and labeling objects in both the Apple Unity Plug-ins and the UAP. Developers must choose between the universal but less ideal UAP solution or duplicating effort for a great Apple user experience.

Bring Your Own Assistive Technology

To build the best solutions for users, developers build use cases to drive design decisions. In the case of assistive technologies, it is important to remember that you are designing to support people with unique needs, strengths, and preferences. The preferred solution to providing accessibility assistance is to develop a method to allow the vast range of assistive technology hardware and software users bring to their web interactions (i.e., screen readers, voice recognizers, switch devices, and reading assistants) vs mimicking the behavior of those devices natively in game.

While UAP is a step in the right direction, it does not allow assistive technologies access to your game. Instead, it mimics the expected behavior of those technologies. To illustrate this more concretely, the UAP approach could be likened to how a closed system Automated Teller Machine (ATM) traditionally manages accessibility; developers mimic the functionality of assistive technology within the programming of the software rather than interfacing with assistive technology. In the ATM, the physical hardware makes use of braille, and there is a headphone port to connect and receive the built-in audio instructions. While this is beneficial in completing very specific functions rapidly, it funnels the user into a one-size-fits-all interaction. Alternatively, when non-proprietary hardware and computing are involved, users expect to bring their chosen assistive technologies configured to their needs to use your product. Carrying the banking example forward, the same bank with the ATM at their physical location does not employ the same accessibility methodology for their browser-based online banking portal, as the user brings their own hardware, software, and user settings to the experience.

To think about how developers are unwittingly complicating users' access, consider what happens when a user employing assistive technologies encounters a game that provides screen reading accommodations but does not allow their preferred screen reader. Upon launching the game, the screen readers may overlap and talk over one another before the user can turn off their primary agent, potentially causing them to miss important information at the game start, such as instructions for using the in-game screen reader. The user must swap their screen reader for whatever is supported for the duration of the gameplay and then switch back to their preferred screen reader after they are finished. This could require a restart of the game if instructions were missed with the user trial and error troubleshooting what is going on. To play the game, the user is required to learn a different screen reader from the one they are familiar with and comfortable using, often with different or less flexible control of the experience. They cannot switch tasks from playing your serious game in one browser window/tab to performing other tasks without re-enabling their

preferred screen reader. Users may struggle to relaunch their primary screen reader or to reset their desired settings. These actions are performed by a user without full sight, already navigating the environment in a more complex way.

Separate But Equal? – Historical Mode of Operation for Development and Retrofitting

A common approach that we see for meeting accessibility requirements is to create a separate accessible version of the interaction or environment. There are many reasons that teams will generate a separate experience, including the complexity of retrofitting, technical limitations of the core experience, and a gap in knowledge for how to create the same experiences accessibly. A separate experience can make users feel segregated and excluded. Maintaining two separate products increases support and maintenance costs, often resulting in the accessible experience getting less attention, falling behind, and further deviating from the main experience. Users familiar with "separate but equal" will wonder if what they consume is accurate and relevant, even if you just launched your product. This erosion of confidence will impact their experience and place your company in a less favorable light for them.

THE STANDARD FOR WEB ACCESSIBILITY

While helpful in informing the accessible design of serious games, the tools discussed thus far do not provide a standard to assess and communicate the level of accessibility provided by a specific serious game nor a mechanism to ensure conformance with an overall corporate digital accessibility strategy. For this, the universal design principles of the WCAG (Henry, 2023) and the use of a Voluntary Product Accessibility Template (VPAT) (ITIC, 2023) for reporting how a product meets the accessibility requirements specified in the applicable standards are recommended.

Web Content Accessibility Guidelines (WCAG)

The WCAG is a set of guidelines developed by the Web Accessibility Initiative (WAI) of the World Wide Web Consortium (W3C) (Henry, 2023). WCAG 2 is the current version most prevalent in use, its primary purpose is to ensure that web content is perceivable, operable, understandable, and robust (referred to as the POUR principles) for all users, including those with disabilities. The guidelines cover various accessibility considerations, including visual, auditory, physical, speech, cognitive, and neurological disabilities, organized around the POUR principles with component guidelines for each category organized into levels. Level A includes the most basic and critical requirements, while levels AA and AAA increase the degree of accessibility, often moving more toward usability for people with disabilities. The guidelines provide specific success criteria for web developers and content creators to implement in websites and web applications to achieve an accessible outcome. These criteria include providing text alternatives for visual content, color contrast conformance, enabling keyboard accessibility, and beyond.

User Agent Accessibility Guidelines (UAAG)

The WAI provides the User Agent Accessibility Guidelines (UAAG) specifying how to develop an accessible user agent (Spellman, 2016). Serious games are classified in a space between web content and user agents presented in the browser. Increasing the accessible design challenge, serious games are developed for a user agent that the development team has limited control over. Thus, developers cannot directly apply the UAAG to their development.

Voluntary Product Accessibility Template (VPAT)

Where organizations must comply with governmental and/or international laws, such as Section 508 of the Rehabilitation Act in the United States, EN 301 549 in Europe, and JIS X 8341-3 in Japan, or ISO/IEC 40500 (identical to WCAG 2.0) they often require evidence of conformance in adopting new technology or developments of new content and products to be used in their organization. For this reason, the VPAT checklist template is used for reporting detailed information on how a specific product or service meets the accessibility requirements specified in these standards. It is currently organized with flexibility for the reporter or agency to only include the relevant applications to their distribution market. The VPAT uses a standardized classification methodology to report on the degree to which each guideline is met. It also includes areas to detail testing methods used and for the document author to provide notes for each guideline for how it does or does not meet the guideline. The rationale behind exemptions, partial or full failures should be explained in the VPAT. Procuring organizations will review a VPAT when making purchasing decisions to determine if the product meets their DEIA standards.

MAKING ACCESSIBLE SERIOUS GAMES

Applying accessible design and development guidelines in your projects will impact time and budget. Extra time will be necessary to include accessibility in planning and design conversations, as well as in the writing and testing of code deliverables. When explaining the need to comply with accessibility standards to a client or executive team, it is important to position it as a priority and to gain support for the increased effort required. When done as a practiced part of the design and development process, this additional time will be minimal when compared to having to retrofit a product for accessibility.

In a retrofit, decisions may have been made along the way that makes the challenge of adding accessibility far more difficult than if accessibility influenced the design in the first place. Entire code libraries could need to be reworked, possibly including fundamental functions of the product. The time and cost incurred for a retrofit would be a duplication of effort and often results in the attempt to salvage as much of the existing product as possible, which leads to less-than-ideal compromises for all users. Attention to accessibility in the initial product development allows you to consider a more universal design model where user choice and preference are at the forefront of the experience. Retrofitting occurs because of accessibility not being included in the design and development of the product, which may have resulted from a lack of time, budget, or knowledge of regulations or solution implementation options.

Oftentimes, even with good intentions and organizational support, a gap in knowledge for how to apply accessibility guidelines plays a role in how high of a priority it will become. The lack of knowledge will lead to "kicking the can down the road" for all involved in accessibility. The investment often comes late in the development process and is frequently a collateral assignment for an existing team member with little interest or expertise in the topic. If you are waiting until the project kickoff to consider product accessibility, you have already waited too long to have the most beneficial impact with the lowest cost. Accessibility planning should start when building your team. Select team members with skills, knowledge, and interest in making accessible products, and invest in their continuous learning.

A Reasonable Accessibility Target: “Complying” with WCAG 2.1 AA

Most organizations currently strive to achieve WCAG 2.1 AA compliance across their websites. If a learning or assessment game is part of an organization's web suite, the developing team will be asked to have their game comply with WCAG 2.1 AA, which does not offer particularly strong recommendations for achieving the standards with interactive content. The application of WCAG to serious games presents many challenges due to the technology used for development and deployment and the design and interaction complexity that goes well beyond standard web content. These can easily lead to the "separate but equal" treatment we discussed previously. Accepting exemption via an alternate experience will not allow a disabled user to gain a learning or assessment experience equivalent to that of a non-disabled user even if it provides equivalent content. Furthermore, it will not get your learning and assessment game used broadly by institutions intending to deliver on their DEIA goals.

The WAI acknowledges that criteria may not be able to be met with some technologies and notes the importance for developers to understand the limitations of each technology. Currently, the supporting material and supplemental guidance documents focus predominantly on the most common web content and web programming languages. WCAG is an evolving standard with active draft revisions available for review and comment from the public. WCAG 2.2 published October 3, 2023 (Abou-Zahra, 2023) was available in draft form throughout this work, and the WCAG 3 (Spellman et al., 2021) draft remains available for review. With each new revision of the WCAG, the language is shifting from being prescriptive and specific toward offering generalized principles for content creators to follow. While this will broaden WCAG's applicability to more interactive, dynamic, and niche applications, designers lose specific guidance for achieving content accessibility within WCAG. By doing this, the argument for the WCAG not applying to the more interactive web applications and simulations is beginning to be eroded. However, prescriptive guidance for advanced developers is not yet available.

The organization that owns the serious game is responsible for the claims it will make about WCAG compliance. If the developer is not the owner, a collaborative effort is necessary to determine how an organization desires to define compliance with WCAG and how the design can meet those goals. The VPAT then needs clear documentation of the approach implemented to communicate product accessibility affordances and weaknesses to end users and governing bodies clearly. Ultimately any procuring organization and end users will review the VPAT to determine if the method to achieve accessibility for your learning or assessment game meets their requirements.

Meeting the Guidelines

We recommend reviewing WCAG 2 (Henry, 2023) for an overview of the standards. For ease of reference, in the following discussion any guidelines introduced will be indicated by their associated WCAG 2 name and number.

Some of the WCAG standards are straightforward, and our team found them reasonable to address without exemption. For example, addressing 1.4.1 Use of Color was relatively straightforward. This discussion will not cover guidelines such as this to instead focus on the guidelines that proved more challenging for serious games to address. There are several reasons for a serious game to claim an exemption from meeting the WCAG standards. The HTML5 canvas is not impacted by many user agent functions, such as text resizing, window resizing, high-contrast modes, and reader modes found in browsers, nor do they have native playback functions like speed controls, volume controls, and captioning found in video players. Serious games are neither standard web content nor are they video content. In many cases where serious games cannot comply with the standard as recommended, alternatives can be implemented to meet the intended outcomes of the standards. This is the approach we took with our most complex accessible game implementation. The discussion here will primarily focus on standards for which our team designed and implemented alternatives to meet the intention of the standard, versus complying as recommended. These standards are primarily Level A and AA but may include AAA standards where commonly applicable to serious games.

Allowing Preferred User Agents Through Middleware

As we have covered, there are many challenges in the technology that displays content developed in commonly used game engines that prevent standard accessibility solutions and practices from being applied. The preferred method of support is to allow the full range of assistive technology user agents to interact with a product. For this reason, we must extend game functionality to allow all users to engage with the environment and information. To achieve this, our team undertook the development of a middleware communication and interpretation layer between technologies drawing to the canvas element in HTML5 and the user agents. We anticipate that eventually canvas and game technologies will evolve to directly enable the necessary support for developers to include accessible practices. Until then, middleware can be used to capture information and simultaneously write it to the page, hidden from visible view, in standard HTML, CSS, and JS, where we can make use of all the guidelines and standards provided by the W3C WCAG, UAAG, and WAI-ARIA Accessible Rich Internet Applications (W3C, 2023). This middleware needs to enable interaction back with the environment, allowing users to not only consume output and content updates but also engage with the content and elements. Providing the ability to translate a wide range of hardware inputs to navigate and perform actions should be handled through the middleware, allowing the standard web development languages to manage the interpretation and mapping of controls for common, but varying hardware. Doing this will help future-proof hardware and interactions that are yet to be developed or reach mainstream use.

Using Settings In-Game

In-game options and settings can be used where the user agent does not provide a means for meeting a guideline. Our team addressed several standards by building options into global settings to allow users to retain their options and go beyond the guidelines to improve the universal design. As our team chose, designing your game with a default state but also providing adjustability options for alternative color patterns/high-contrast mode, text-sizing, volume, layouts, playback speed, or text alternative and caption display can meet the spirit of the following guidelines:

- 1.2.2 Captions
- 1.2.3 Audio Description or Media Alternative
- 1.4.2 Audio Control (partially)
- 1.4.3 Contrast
- 1.4.4 Resize Text

Everything is Machine Readable

Machine-readable means that the element is provided semantically with recognizable text and attributes to classify it so that it can be programmatically parsed and interpreted back to the user in a way that makes clear to them what the element is and how to interact with it. Our games have instances where this information is conveyed visually or using audio, so we needed to supply a text alternative for our non-visual / non-hearing users but did not want those to be present for all users. We also needed to determine which visual images or sounds are merely decorative and thus do not require a text alternative. We had design and content experts collaborate with significant thought behind the text alternatives to be provided. Text alternatives should not be auto generated. It is also important to remember that these text alternatives are output to a variety of assistive technologies. Impacted guidelines are 1.1 Text Alternatives and 1.1.1 Non-text Content.

Pre-Recorded Content

Guidelines concerning pre-recorded content extend to the handling of audio elements, animations, and predetermined sequences. WCAG standards focus on captioning and providing text alternatives such as transcripts, and it is a good idea to have these elements developed within the game contextually where they occur. Even with in-game accommodations, most organizations want transcripts to hold as a fallback and post in case a user is unable to make other assistive technologies deliver the serious game experience. Our team provided both in-game and transcripts.

Time-sequenced text is common in game platforms and meets the captioning criteria needs, but less common are audio descriptions. Audio descriptions to supplement important visual content in a scene are typically provided in the dialogue gaps for video content. These are provided as a separate audio track in a few varying ways, but applying these can be simpler by design for an interactive game because, when enabled, they can be triggered wherever the developer chooses. For our time-based content, we pause delay time-based actions for the audio description file to play, and for interactions that wait for user input, we simply trigger them immediately after an animation or dialogue, and the user has the freedom to wait for their next action. We also implemented a play/pause, rewind, or replay feature that affects content playback to help to satisfy the remainder of criterion 1.4.2 Audio Control. At times, we chose a replay function to satisfy that spirit without implementing a rewind feature for shorter intervals, such as the opportunity to replay sequences back from the last point of interaction. This benefits users with hearing or cognition disabilities.

Full Keyboard Operability

At its basic core intent, WCAG requires that each element on the page can be reached and interacted with using keyboard controls. Arrow keys are used to navigate all content, while the TAB key moves between interactable elements. As with many games, you must define selection keys, and assistive technology users have a common understanding that the SPACE BAR is used for selection while the RETURN/ENTER key is used to execute an action. Our team learned to ensure you keep these keys available to the assistive technologies vs. gameplay interactions.

As important as navigating a page using a keyboard only is, knowing where you are in the page's context is also crucial. Both operability and predictability play a role in this. Our team spent significant effort ensuring the user would have the ability to move linearly with the intended navigation order through the content while maintaining a visual indication of their current position in the environment satisfying criteria within 2.4 Navigable and 3.2 Predictable. Going further would be to segment the UI by defining common blocks of the UI into regions. Typically, this is done with region tags, headings, and other HTML elements; however, other methods to satisfy a criterion such as 2.4.1 Bypass Blocks, would be to implement a quick jump menu with an assigned quick shortcut. Just be mindful of compliance with 2.1.4 Character Key Shortcuts to not interfere with standard conventions for mappings.

Other considerations should be given to functions that are typically pointer-based interactions, such as the case with 2.5.7 Dragging Movements (WCAG 2.2). Designing these activities with a target selection that persists upon keyboard selection until either canceled or the location target is subsequently selected, which executes the action or move, will satisfy the criterion without changing the mouse-based drag-and-drop functionality.

Exemptions and Considerations for Maintaining the Intended Goals and Experience

When considering the alternatives and meeting the spirit of the guidelines, when creating learning and assessment games we must consider areas where this detracts from the spirit of the goals or outcomes. These discussions should always come up in the design phase to ensure that we are not detracting from the goals or providing an advantage or disadvantage to any group of users. One example of this would be in an assessment where we have the user observe and report findings. If we are testing their knowledge, we cannot create text alternatives to visual indicators that they need to identify as a part of the evaluation. You must be careful to describe the visual content without undermining the assessment while providing enough information for the user to reach the intended conclusion on their own.

We do not want to implement our design in a way that detracts from the core purpose of ensuring accessibility for all. Universal design provides enough flexibility for the user to maintain the experience that best matches their preferences. Creating all content as text because that is the ultimate common denominator places users who learn best and feel the most engaged through interaction and visual content at a disadvantage. We wish to provide instead a thoughtfully designed and implemented solution that users can engage with in the way that meets their needs best.

Timed-based simulations where users are being trained for real-world situations in which an accommodation cannot be provided, such as diffusing a bomb, should not be adjusted for the purpose of meeting the WCAG standards. This is a true case of an exemption by way of fundamentally altering the experience. Even so, these decisions with rationale should be noted in the VPAT for an evaluator to understand why an exemption is appropriate.

TECHNOLOGY CONSIDERATIONS AND IMPLICATIONS FOR MORE ADVANCED INTERACTIONS

The combinations of hardware and software users can bring to your game can be staggering, and designing for every permutation individually is not practical. This is where standards for design come in. As the developer of web-based learning and assessment games, we will be delivering our experience through a web browser. We will need to inherit the interaction and display output standards that web browsers bring to the experience. For the sake of this topic, we will broadly define browser-based serious games as requiring a web application at a minimum, where we are bound to the browser experience but also must go beyond development in terms of HTML, CSS, and JS.

These games are different from standard HTML web-based content; they are dedicated interactive environments provided through embedded web applications where the content interaction goes beyond 2D, linear experiences. In serious games, developers must apply WCAG to three-dimensional environments where user interactions and choices influence the experience dynamically, making it harder to predict what comes next, even as a developer. A few realities are implicit with the highly immersive and dynamic environments being built upon various engines. 1) The default expectation is to use a coordinate system and a focal point to manipulate the interaction. This focal point maps to a mouse pointer more closely than it does to a keyboard. 2) Each behavior or action is defined at the time of development. While there may be some generally accepted navigation and interaction methods for each input device, there are no standards defining these in the way we have for HTML and web languages accessed via the web browser.

Developers capture events through a wide variety of inputs. Choosing the most robust common denominator, inputs can be narrowed to two main categories: spatial and sequential. Spatial examples with freeform positional pointing devices that use x, y, and z axes in conjunction with the graphical rendering as it falls on those spatial coordinates include a mouse, joystick, or gaze tracking device. Examples of lock-step sequential devices that move linearly from one object or point to the next include keyboards and speech-to-text commands. There are a range of ways to make inputs more efficient. Improvements include providing various ways to skip through the sequence and implementing one input device to resemble another. As examples consider using a controller joystick to toggle through a list of UI tabs sequentially or using a keyboard's arrow keys to manipulate an on-screen cursor. These examples illuminate the importance of how you map the functionality of the input device to the interaction type. Providing a system where the user can bring their own input device and connect to the interaction schema is important. This means untethering hard-coded keyboard inputs to functions. Instead define the action that is connected to the function to allow a user to map their device to that action. Although you want to define a schema that is input device agnostic, you should also provide default mappings for the user that accounts for common hardware.

Providing a robust user feedback system is just as important as providing a robust input system. Information that is important to the understanding of the content or experience should not be limited to a single sense. Instead, there should be multiple ways to perceive the information. When something is visually presented, an audible alternative can also be created to convey the same information, such as an audible tone for when an elevator arrives, and the doors open. Likewise, when something is audibly presented, there also needs to be a visual method to present the information, such as closed captioning on a video. In some cases, it is obvious how to handle alternative outputs, but this is not true in all cases a serious game developer will encounter. The limitations of the technology or standards available require creativity in designing outputs.

Technological advancements have opened more sensory channels for perceiving outputs, offering both additional complexity and more possibilities to adapt. Consider the use of touch haptics. UI button selection output used to only have options of visually changing the state and providing an audible sound cue. In some cases, those are still the only options, but in others, we can introduce haptic output to a touchscreen, touchpad, or even mouse and controller when the hardware supports haptic functionality. The inclusion of haptics provides additional methods to convey information back to the user. More advancements will surely come, but we cannot predict what those will be or when they will be adopted widely enough to rely on. One way to plan for these unknowns is by providing an application interaction interface, to allow new hardware to come in and interface with defined inputs and outputs.

CONCLUSION

Our team achieved varying levels of accessibility support in the example learning games referenced in this paper, each may have a place in your own game-based learning and assessment products. First, in the absence of specific serious game accessibility standards, we worked from instructional and entertainment game accessibility guidelines and design patterns to achieve a mostly conformant serious training game, but we did fail to meet complete WCAG 2.1 AA conformance following this process. Second, for a limited use tablet-based game, we addressed simple to achieve accessibility requirements (e.g., color selection, contrast, captioning) and implemented a native TTS feature, mimicking screen reader functionality, but fell short of supporting end users' preferred assistive technologies. Finally, by starting from the WCAG web-delivery standards aligned with our web-based game delivery mechanism, we were able to deliver a WCAG 2.1 AA conformant serious game. While this was motivated by a requirement from our client, we now recommend this as the best mechanism to provide accessible serious games. The reliance on WCAG provides a standard language to define and communicate the level of accessibility achieved with the resulting serious game enabling clients and users to understand what to expect from the game experience.

We achieved WCAG 2.1 AA conformance with a threefold solution. First, we met basic WCAG guidelines as recommended. Second, for WCAG elements games would normally state an exemption from, through interpretation of the guideline goals, we delivered an alternate solution in support of the underlying guideline intention. And third, to meet the preferred practice of supporting disabled users by allowing a wide range of user agent accessible technologies not supportable with current HTML5 WebGL game delivery practices, we built a custom middleware solution to communicate and interact between the user agent and learning and assessment games. As part of the design, we leveraged entertainment game accessibility guidelines and instructional accessibility guidance informing a more universal design. Our approach will all be explained against the relevant sections in the VPAT checklist prepared and provided by the client and their accessibility consultant to their customers and end users. We believe our success supports the continued consideration of serious games delivered via HTML5 using WebGL developed in commercial game engines as a viable accessible learning and assessment solution. We further see this approach as paving a path for future types of advanced interactive products to offer accessible training and assessment solutions.

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