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App Factory: A flexible approach to rehabilitation engineering in an era of rapid technology advancement

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ABSTRACT
This article describes a flexible and effective approach to research and development in an era of rapid technological advancement. The approach relies on secondary dispersal of grant funds to commercial developers through a competitive selection process. This "App Factory" model balances the practical reliance on multi-year funding needed to sustain a rehabilitation engineering research center (RERC), with the need for agility and adaptability of development efforts undertaken in a rapidly changing technology environment. This approach also allows us to take advantage of technical expertise needed to accomplish a particular development task, and provides incentives to deliver successful products in a cost-effective manner. In this article, we describe the App Factory structure, process, and results achieved to date; and we discuss the lessons learned and the potential relevance of this approach for other grant-funded research and development efforts. Data presented on the direct costs and number of downloads of the 16 app development projects funded in the App Factory's first 3 years show that it can be an effective means for supporting focused, short-term assistive technology development projects.

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KEYWORDS
emerging trends; information technology and telecommunications; knowledge translation; universal design; usability

Introduction

The Rehabilitation Engineering Research Center for Wireless Technologies (Wireless RERC) was established in 2001 to promote universal access to mobile wireless technologies and explore innovative applications of these technologies to address the needs of people with disabilities. At that time a revolution in mobile wireless technology was underway. The introduction of mobile two-way text messaging in the late 1990s by pioneers like Research in Motion (RIM, now Blackberry), and later Danger, Inc., opened new opportunities for people with disabilities—especially deaf individuals (DeSalvo, 2014), people with complex communication needs (Bryen & Pecunas, 2004), and people with physical disabilities (Nguyen, Garrett, Downing, Walker, & Hobbs, 2007). In 2003, Nokia phones running the Symbian operating system became the first to allow the installation of third-party accessibility screen readers and screen magnifiers—Nuance's Talks software and Code Factory's Mobile Speak (Burton, 2011). Microsoft's Windows Mobile 5.0 operating system, launched in 2005, allowed installation of these popular mobile screen readers by users (Burton, 2011). By 2005 67% of people with disabilities responding to a national survey reported owning or having access to a cell phone (Mueller, Jones, Broderick, & Haberman, 2005).

A second revolution in mobile wireless technology was sparked in June 2007 with Apple's launch of the original iPhone. Google's Android operating system became available soon thereafter in the G1 smartphone launched in October 2008. Undergirding these new mobile technologies are "ecosystems" of software applications for mobile devices (mobile apps), produced by third-party developers, that can be rapidly and easily downloaded on-the-go. Importantly for developers, these mobile apps could be "published" using established and efficient sales channels, or app marketplaces. Mobile apps have proliferated around each of the major operating systems, with each of the two dominant marketplaces Apple App Store and Google Play store now offering over 1 million mobile apps (Statista, 2015). By 2013, 91% of adults with disabilities reported owning or having access to either a cell phone or tablet device (Morris, Mueller, Jones, & Lippincott, 2014).

Challenges to producing assistive mobile apps

Mobile apps vary in sophistication, from extremely simple to very complex. Many offer functionality that is useful to wireless consumers with and without disabilities. For instance, text-to-speech and speech recognition applications are useful to both visually impaired users and users with limited language skills. Native and third-party apps have also been developed to promote the accessibility and utility of wireless devices and services for people with disabilities, including those with limitations in vision, hearing, dexterity and upper extremity control, speech, and cognitive abilities. These efforts have focused mainly on smartphones and tablets, with growing interest in wearables (e.g., Gips, Zhang, & Anderson, 2015; Wallace, Morris, & Bradshaw, 2015), smart watches, and other wrist-worn monitors (e.g., Ahanathapillai, Amor, Goodwin, & James, 2015; Bhatlawande et al., 2014; Fardoun, Mashat, & Ramirez Castillo, 2015).

These and other mobile app-based assistive technology solutions represent only a very small portion of available

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apps today. Assistive apps were probably an even smaller portion of all apps when the Wireless RERC launched the App Factory project in 2011. Furthermore, the solutions referenced above were funded by research and development grants, and as such are not typical of apps produced by commercial developers for the mainstream marketplace. The app developer community in general is broad and diverse, comprising large and small companies, as well as many individual developers or very small virtual teams that form and dissolve on a project-by-project basis. As a consequence, understanding of the unique usability and assistive technology needs of customers with cognitive, physical, sensory, and/or speech limitations likely varies widely in this community. Among the smallest developers, any acquired understanding may be the result of designing for a single user (the stereotypical hobbyist developing a solution for a loved one), with the hope that others will also find the application useful. Assistive technologies used by many of these customers in conjunction with their mainstream wireless technologies can compound this problem. Moreover, accessibility gained can be lost as mainstream technology platforms are updated, requiring continued re-investment in assistive and accessibility solutions.

The fast moving and highly competitive business environment of the app developer community also makes it difficult for commercial developers to meet the needs of people with disabilities. In 2011 it was reported that one third of mobile app developers lose money (Marek, 2011). A 2013 report by Gartner predicted that through 2018, less than 0.01% of consumer mobile apps will be considered a financial success by their developers (2013). The Wireless RERC's own survey data on mobile technology use in 2013 showed that almost half (48%) of respondents with disabilities had paid at most $2.00 for any single app, with another 12% paying between $2.00 and $5.00 for their most expensive apps (Morris, 2013). These trends do not favor the development of specialized mobile applications for relatively small segments of the population with specific disabilities and assistive technology needs. Indeed, some subsets of the population of persons with disabilities, e.g., deaf-blind customers, may be considered far too small to address cost-effectively within the highly competitive app developer community.

App ecosystems, in summary, provide both opportunity for assistive technology solutions (relatively short development cycles, established and efficient channels of distribution, and easy deployment), as well as challenges to developing solutions for small, specialized segments of the population (uneven assistive technology expertise, high turnover of developers, lack of profitability, and need for alternative sources of funding for specialized apps for small markets).

App Factory—a model for rapid development and transfer of assistive technology

Recognizing the growing importance of mobile apps to enhance the accessibility and usability of wireless products, in 2011 the Wireless RERC established an "open shop" App Factory project to promote rapid development, validation, and technology transfer of mobile apps designed for people with disabilities. Opening development opportunities to any app developer, whether internal or external to the RERC, was intended to achieve two primary goals: (1) bring highly talented and prolific commercial developers into the process of designing apps that address the needs of people with disabilities, but who may have limited mass market appeal and thus profitability and (2) establish a "pay for performance" mechanism whereby developers are paid upon meeting contractual milestones leading to commercialization of the app. This approach allows one to take advantage of design and development expertise that may not exist within the RERC, and also establishes incentives to deliver successful apps cost effectively.

A complementary objective was creation of a practical model for consumer participation in the development process in order to optimize the usefulness and usability of apps. As a requirement for funding by the App Factory, developers must demonstrate engagement of the community of people with disabilities throughout the conceptualization, design, testing, refinement, and dissemination of new apps. Some developers recruited their own network of consumer advisors while others relied on the RERC to connect with consumers. Consumer advisors help identify and explore new app ideas and facilitate beta testing of funded apps. Integration with industry and consumer outreach efforts also helps identify effective app distribution channels, facilitate user feedback, and promote universal design practice. This approach is consistent with accepted knowledge-transfer practices. As Leahy (2011) noted, "researchers need to involve consumers early in the process to understand their specific needs" (p. 2).

Management of apps development

To ensure consistency in approach and successful deployment of completed apps, a systematic process was established to guide the App Factory project, from setting priorities for app development through deployment and evaluation of their success. The project is guided by an "Apps Council" composed of members of the RERC staff, content experts from academia and industry, and outside stakeholders, including app developers and consumer representatives. With input from consumer advisors, the Apps Council sets priorities for app development, reviews, and approves app development proposals and budgets, and monitors app development, testing, and deployment. Members of the Apps Council are allowed to submit proposals for app development but must recuse themselves from deliberations about these proposals in order to avoid conflicts of interest.

The primary mechanism for engaging developers is an annual request for proposals (RFP). The RFP includes a list of priority areas for development, but also encourages "field-initiated" app proposals that address needs identified and substantiated by the applicant. The RFP is distributed widely via the RERC website, newsletters, social media channels, and other developer networks. Proposals received in response to the RFP are initially screened by RERC staff to sort out projects that do not meet program criteria or are determined to be obviously not feasible, too expensive, or inadequately resourced. Projects making the first cut are then reviewed more closely by the Apps Council. Ad-hoc reviewers with technical or domain-specific knowledge are added as needed. Proposals are reviewed according to the following criteria:

(1) app addresses an important accessibility or assistive technology need;
(2) app is unlikely to be developed in the commercial marketplace;
(3) app is technically feasible;
(4) technical capacity required for development is readily demonstrable by the developer;
(5) projected "lifetime" of the app justifies the investment; and
(6) app complements and does not duplicate other apps in the marketplace or under development.

In addition, all proposals are required to include (1) information about the availability of existing, comparable app solutions, and the unique features and functionality of the proposed app; (2) the potential market for the proposed app (i.e., size of the intended user population); and (3) the importance of the proposed solution to the target user population. The Apps Council may connect developers whose proposals identify promising concepts but who may lack the necessary technical capacity, with skilled developers. The Apps Council may also elect to fund a project with higher (technical or conceptual) risk if the ratio of potential benefit to proposed cost is high.

Most of the App Factory projects to date have been carried out by developers external to the RERC, and in most instances external to academia. For all external developers, a standard contract is used specifying milestones for which some portion of the total value of the contract is to be paid. Paying developers for delivery against mutually determined milestones has proven to be an effective mechanism for immediate accountability that is not always possible in grant-funded development projects. Paying for performance also allows specifying user testing and user acceptance as part of the final milestone for all app development contracts. Final payment is contingent upon the app demonstrating basic accessibility/usability performance and commercialization. In one instance, for example, the beta version of a funded app designed for blind users required that the user press a small button in the middle of the screen to confirm audio output. If active confirmation was indeed needed, the whole screen could have been used rather than requiring a blind user to locate a small button in a specific location. Final payment on this app was withheld until this usability issue was resolved to the satisfaction of the App Factory consumer advisors, and the app was the published on the relevant smartphone marketplace. In most instances, the commercialization milestone is achieved when the app is published on the relevant app marketplace. Publication is contingent upon the app meeting established requirements for apps set by each app marketplace. These requirements are not spelled out in the contract for app development funding, but are an implicit assumption since the final milestone is commercialization.

Proposals are submitted each year by July 31, with notices of acceptance for funding or rejection sent to applicants by the middle of October each year. Shortly thereafter contracts are sent to awardees. Generally, awardees have until August of the following year to complete the final set of milestones, which includes publishing the app on the relevant app marketplace. Some of the funded app projects have required a few additional months to complete, mainly due to unanticipated technical issues like the release of a major new version of the relevant operating system. In these instances, the awarded funds are simply carried over to the new grant year beginning on October 1.

These features of the App Factory model—an "open shop" to leverage and support expertise in the AT community and to build expertise among skilled engineers in the mainstream developer community, internal review and advisory guidance, and pay-for-performance against specific development milestones—address the key challenges to development of assistive apps while ensuring proper oversight and adherence to delivery schedules.

App Factory performance metrics: Outputs, cost, and technology adoption

The Wireless RERC proposed a production goal of four apps per year. Approximately $215,000 was budgeted in the first 3 years of the grant for App Factory projects. In that period a total of 58 proposals were submitted in response to the RFPs and 16 projects were accepted for funding. Of the funded projects, 10 were completed successfully and distributed through commercial app marketplaces (Table 1). One additional app (Citra) was successfully developed, validated in a clinical trial, and just recently published in the marketplace. Of those not successfully completed, one was terminated after exploratory research determined the project to be technically unfeasible.

The four remaining unpublished apps are reported to be still in "beta testing" by the developers but are unlikely to reach commercial distribution. Notably, all four of these apps were developed by university-based developers (and not bound by the pay for performance contract used with external developers). The direct cost per developed app (including the cost for apps that were not completed) averaged $19,535. Direct costs do not include the administrative costs associated with running the App Factory project or overhead charged to the grant.

From December 2011 through November 2015, there were 600,160 downloads of published apps. The distribution of these downloads was skewed in favor of three highly popular apps, with the IDEAL Accessible App Installer (a package that automatically downloads and installs 8 accessibility apps sponsored by Sprint) accounting for 535,160 downloads. Average investment per download for all apps was $0.36, with a range of $0.02–$75.00 per download, based on total cost/number of downloads for each app. Excluding the cost and download activity for the IDEAL Accessible App Installer, the average cost per download was $3.15 for 65,000 downloads. New installs continue to be reported for all published apps.

Discussion

The App Factory appears to offer several advantages as a means of promoting rapid development of useful accessibility apps for mobile wireless devices. First, the approach leverages

Table 1. Summary of app development projects funded in first 3 years of App Factory: Cost and number of downloads by app project.

Project Title	Developer	Direct cost (US$)*	Number of Downloads
Year 1			
BrailleTouch	BrailleTouch, Inc/ GA Tech	$16,000	18,616
Georgia Read More ASL	GA Tech/GA Public Television	$9,000	Beta
IDEAL Group Reader	IDEAL Group	$14,500	14,535
IDEAL Group Accessible App Installer	IDEAL Group	$10,000	535,160
Mobile Assistive Listening System	Inclusive Technologies	$3,500	Exploratory
Year 2			
AccessNote	Am. Foundation for the Blind	$19,000	6,050
Citra	Tony Wells Fdn/ Ohio State U.	$15,000	200
IDEAL Currency Identifier	IDEAL Group	$5,000	6,381
IDEAL Group Reader—Mathwriting Recognition	IDEAL Group	$7,500	11,015
Impromptu Upgrade	Ohio State University	$12,973	2,764
PicTalker	Duke University	$11,600	Beta
Smart Steps	Smart Steps, Inc.	$19,742	2,401
Year 3			
Continuous Tongue Drive	GA Tech Bionics Lab	$28,269	Beta
IDEAL Document Knowledge Miner	IDEAL Group	$15,052	259
RheumMate	GA Tech/Emory University	$10,000	Beta
ZyroSky Switch Accessible Game	Zyrobotics	$17,752	2,779

Note. *Direct costs do not include the administrative costs associated with running the App Factory project or overhead charged to the grant.

the rapid development and testing cycle of the mobile app ecosystem. Instead of years, most apps are developed and brought to market in a matter of months. Second, the pay-for-performance contract for deliverables provides incentives to adhere to the rapid development cycle and, by requiring user testing as a milestone in the development process, also helps ensure the usability of final deliverables. This contributes to cost effectiveness by ensuring that only completed and commercially released solutions receive full payment. Our experience is that awardees often contribute additional funds or resources to their projects, making RERC funds go further.

A third advantage is the RFP process, which has been used to encourage development of "orphan" apps that might not otherwise be developed. Consumer input throughout the App Factory process helps identify and prioritize these otherwise limited-interest apps. Many App Factory grantees already have expertise in the disability/accessibility field but may not be interested in pursuing these low-volume (and potentially low/no profit) apps without App Factory funding to cover their up-front development costs. The RFP process also permits the sponsoring agency to exert influence by specifying an invitational priority for app development. This happened in one instance, where the U.S. Department of Treasury wished to make a currency reader app available for blind/low vision users at no cost. Currency reader apps exist but require a fee to download, and few developers would be interested in creating a no-cost app without funding to do so. In this case, Treasury was able to work with NIDRR to provide supplemental funding for the app's development through the App Factory.

Finally, the App Factory leverages existing, highly evolved mobile applications marketplaces (App Store, Google Play, Windows Phone Store, BlackBerry World), which are designed for rapid launch of new and upgraded offerings. These markets have global reach, and provide app developers with real-time information on numbers of installs and usage. The Google Play store also provides data on compatible device brands, and Android operating systems. This allows developers to control availability of their app for specific devices and versions of Android, which helps limit unsatisfactory experiences, maintains higher review ratings, and in turn promotes additional installs. The mobile app marketplaces provide a fully formed channel for marketing and distribution of the App Factory deliverables, and help overcome one of the key obstacles for effective technology transfer in rehabilitation engineering—the lack of a detailed tech transfer plan as an integral part of the overall development plan (Lane, 2008).

One potential limitation of the App Factory approach may be the limited success (based on volume of downloads) of some apps. While the volume of downloads for some apps is small, our premise from the onset has been to support development of apps for disabled users. The app may be targeted to either a large or small potential user population, as long as the app addresses an important user need. The aim is to support solutions not likely to be produced by mainstream developers due to lack of awareness or relative lack of profitability. In any case, the App Factory approach provides an efficient development process regardless of the commercial success of the app. And ultimately, success will be determined in the existing mobile apps marketplace.

There were also notable differences in the success (as evidenced by publication on a marketplace and volume of downloads) of apps developed by commercial developers versus those working in an academic environment. Of the 16 funded app proposals, nine were from commercial developers and seven were from developers in university settings. Funding was about equally split between commercial ($112,046 for nine apps) and academic developers ($102,842 for seven apps). However, eight of nine apps by commercial developers (89%) were published, while only three of seven apps by academic developers (43%) reached the apps marketplace. Consequently, downloads of commercially developed apps (578,580) were significantly higher than downloads for apps from academic developers (21,580). We identified two factors that may account for these differences. First, commercial developers have experience bringing their apps to the marketplace whereas academic developers typically do not. As a result the commercialization pathway for commercial developers is already established. This was not the case in academic settings and, in at least one case, the university posed a barrier to publication of the app because of the lack of a policy concerning university branding of apps. Second, as noted previously, we found it more difficult to base payment on performance in contracting with universities for app development. We had to rely on the university's administration to deliver payments contingent upon meeting milestones and in, virtually every case, the university had no mechanism for managing payments using this methodology. Instead, funds were allocated to individual departments for dispersal and payment was provided based on expenses rather than deliverables.

In general, mobile apps have been criticized for having a relatively short shelf life; with just over half of apps in the marketplace reaching their "half-life" of downloads within 3 months of commercial release (Gordon, 2015). Those that maintain a robust number of downloads after 3 months tend to decay at a much slower rate. Our initial experience with accessibility apps suggests a different outcome, largely determined by the lack of a large initial bump of downloads immediately after launch. As may be expected because there is no advertising budget for the apps developed through the App Factory, none of the apps has had a large peak of downloads immediately after launch. Instead, most of the successful apps (those with at least 1,000 downloads) experienced slow, steady growth in users, suggesting that word of mouth among users may account more for growth. The notable exception to this trend was seen with the most successful app—the IDEAL Group Accessible App Installer. This app was made available (free) to users by Sprint and was publicized on the Sprint accessibility website. As a result there was a very high volume of downloads (more than 15,000 per month) for 17 months after launch of the app. At that point, Sprint was no longer publicizing the app's availability and the number of downloads has subsequently dropped to approximately 5,000 per month.

Downloads (or installs) are only one measure of an app's success. Uninstalls and usage rates (e.g., average daily or monthly users), which are provided by the major app marketplaces and by third-party tracking services like Flurry, provide more detail on an app's impact. Because the App Factory is not the publisher of the apps (the individual developers are the publishers), it does not have direct access to these data. It must instead rely on the developers to supply these data, which is a highly inefficient process. The use of a third-party tracking service like Flurry or App Annie has been considered. However, concerns about user privacy have not been adequately addressed to date. Additional data on impact could include user reviews on the app marketplaces, or even follow-up structured interviews with a sample of users. The value of more detailed impact evidence became clearer as the App Factory project team gained more experience. As a consequence, we now require that developers commit to provide more detailed impact metrics as a condition for approval of funding.

The App Factory model appears to be successful in achieving the goal of promoting development and commercialization of accessibility apps for people with disabilities. The approach may also have broader implications as a funding strategy for grant-funded rehabilitation research and development efforts. Central to this paradigm is the secondary dispersal of grant funds to address emerging accessibility concerns or to take advantage of new technologies that may not have existed when a multi-year award was initially made. The approach provides flexibility to both the sponsor and grantee to guide and adapt projects across the life of a grant. And with a rigorous process is in place for prioritizing, selecting, and managing the development process, as provided by the App Factory, the approach can optimize the return on investment of limited grant funds.

The approach of secondary dispersal of grant funds could also be scaled up to a model similar to the Canadian Network of Centres of Excellence (NCE) program for research and development. Established in 1989 as a joint initiative of the Natural Sciences and Engineering Research Council, the Social Sciences and Humanities Research Council, and the Canadian Institutes of Health Research, the NCE program supports consortia of investigators and organizations who apply for funding in an area of research or technology development. The proposal identifies broad aims and topic areas for research or development and proposes a process by which discrete projects will be solicited, approved, funded, and managed within the consortia. Most recently, the AGE-WELL NCE was funded to create technologies and services that benefit older adults (http://www.agewell-nce.ca/). It is conceivable that a similar funding scheme could be applied to the RERC program, encouraging collaboration among broad networks of investigators, with a clear mission and mandate, but also with tremendous flexibility to respond to changing needs and exploit emerging technologies that might be used to advance their mission.

Conclusion

The power and flexibility of today's consumer electronics present an opportunity to provide people with disabilities powerful tools for independent living and community participation. At the same time, the rapid transformation of technology challenges rehabilitation engineers to develop and transfer new technology products on relatively short cycles. The Wireless RERC's App Factory project takes advantage of these opportunities and meets these challenges by leveraging established technology platforms and distribution channels offered by mobile devices and their application marketplaces.

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