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Chromebook Platform Choice Important for Android App Performance

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Since its introduction in 2011, the Chromebook has been a disrupter. It challenged, and continues to do so, the mindset of what a computer is and should do. Often perceived as the low cost competitor to Windows and macOS, Chromebooks provide a computing experience that addresses challenges in cost and accessibility, and the market share for them has continued to grow even as the rest of the PC market struggles to keep its head above water. In 2016, Chromebooks outsold Macs in the US and in 2015 they represented more than 50% of the computer hardware purchased by K-12 scholastic organizations in the US. Business utilization of Chromebooks is growing quickly as well, pointing to more enterprise applications of the platform.

In mid-2016 Google announced its intent to bring the Android Play Store to Chromebooks, essentially merging the two platforms into a single ecosystem for the notebook/tablet products on Chrome OS. Many prominent pundits and analysts immediately saw the implications of such a move, bringing a vast library of applications from the smart phone market to the Chromebook would create a combination of capabilities that would turn the computing spectrum sideways. This move alleviates the sustained notion that Chromebooks are connected-only devices and gives an instant collection of usable offline applications and tools to the market.

Chrome OS Goes Mainstream

Bringing the breadth of content from the Google Play store, which includes applications, games, music, video, and books, instantly makes Chromebooks more relevant to a wider audience of users. The Play Store provides access to apps for social media (Facebook), productivity (Evernote), Communication (Hangouts), education, home automation and much more. As of March 2017, the Play Store has over 2.8 million apps, supplying every user and every segment of users options to expand the usability of Chromebooks.

This integration provides two unique platform combinations: Chromebooks can now act as quality Android tablets with high resolution screens, keyboards and mouse capability previously limited to only a few devices with external accessories. Just as important, any application from the Google Play store now has the ability to be a piece of desktop software, though the viability of each of these solutions will depend on various factors including software integration and performance.

Chromebooks are already considered the best low cost computing solution for consumers and business, but adding the Android app capability, at no cost to the buyer, complements this. A modern Chromebook is now a more flexible solution that can provide users access to all appropriate computing capabilities in a single device. Students can count on the ability to run productive educational software (Body Digital 3D, Google Docs, Solar System Scope) while utilizing the device for double-duty as an entertainment machine, accessing countless number of Android games (Minecraft Story Mode, Candy Crush). With direct access to social media applications that offer better and improved features and

abilities than their web-based alternatives do not, Chromebooks provide a unique combination of options not available on any other platform.

Android Apps are Built for ARM

Bringing Android apps and the Play Store to the Chromebook platform is not a trivial task. Android applications were built and compiled for a specific set of hardware and operating system variants. Chrome OS, despite being designed by the same company, is quite different. It was built initially as an online-only system and has slowly evolved into a hybrid, acknowledging and accepting the need for offline activities. In the Chromebook space today there are two distinct segments of hardware available: one is based on ARM-designed processors and the other uses Intel x86 processors.

Chrome OS was built in tandem with both ARM and Intel platforms and Google understood that both sets of hardware would be running the operating system natively. Because of that, many Chromebook operations run equally well across both ARM and Intel architectures, despite being fundamentally different in terms of instruction sets, memory systems, core design, etc.

Android OS comes from a radically different place. Starting with the very first Android phone on the market, the T-Mobile G1, ARM-based designs were at the heart. The Qualcomm MSM7201A processor in the G1 was based on the ARM11 32-bit design and that architectures dominance has continued through Android's expansion. Though the underlying performance, core design, and feature set has changed, the ARM processor family now powers more than 98% of the current Android hardware market.

With that market dominance as common knowledge, all Android applications are developed targeting ARM hardware, for ARM processors. Compilers and performance profiling software has been built and perfected to improve the experience and efficiency of apps to run on ARMv7 (32-bit) and ARMv8 (64-bit) architectures. This brings to the consumer an improved overall experience, including better application compatibility and better performance.

When applications need to run on a hardware platform that they were not designed or compiled to run on, they need to go through a step of emulation or dynamic binary translation. The process of translating a pre-compiled application from compatibility in one instruction set to another is technically impressive but problematic. It adds performance overhead and increases the potential for compatibility issues.

Intel has been using this tactic for its entry into Android smart phones and tablets for several years, in order to offer support for the application ecosystem. But with Intel leaving the smartphone business last year and the number of Intel-based Android tablets remaining fairly static, there are questions about the long term viability of this binary translation method for the long haul. Even modern Android app developers have very little reason to spend time tweaking and perfecting code to run on Intel processors with such a small market share.

What does this mean for Android applications on Chromebooks? The same rules apply for Mobile Strike on your Chromebook as they do your Android phone – if the application *was not* compiled with Intel architecture hardware as a target then it will require binary translation to run on any Intel-based Chromebook. A machine using an ARM-based processor will not require that extra step and as a result, should run faster and more reliably.

Performance Testing Android Applications on Chromebooks

Comparing the user experience of running various Android applications on modern Chromebooks is an interesting process. There are no benchmarks, no preset apps to run to tell you how they will behave, and instead we go into a real-world scenario: running the application, measuring load times, behaviors and working conditions to judge the overall impact of architecture on our experiences.

We will evaluate performance in a subjective manner, the “feel” of the applications. We will also be looking for visual anomalies that might appear on one platform but not the other, including animation stuttering, lag between rendered frames or frame drops. Finally, we will be looking at the wall time for certain processes to complete including application loading and the opening of standard data sets in software like Google Sheets or start a match in a game like Mortal Kombat X.

Our testing revolves around two Chromebooks from Acer, the R13 and the R11. The R13 is powered by a big.LITTLE MediaTek M8173C SoC with dual Cortex-A72 cores and dual Cortex-A53 cores. The R11 runs the dual-core Intel Celeron N3060.

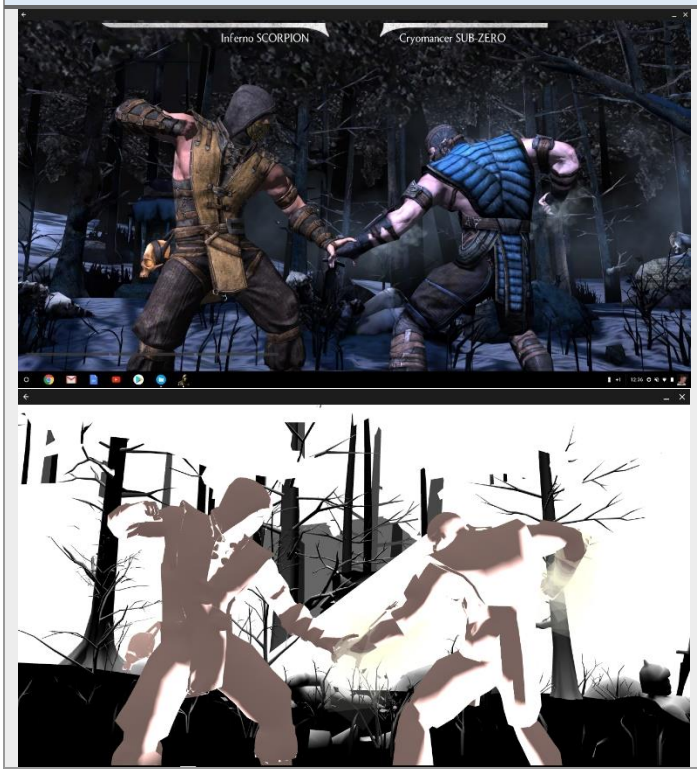
	Acer Chromebook R13	*Acer Chromebook R11*
Processor	MediaTek MT8173C 2x Cortex-A72 @ 2.1 GHz 2x Cortex-A53 @ 1.7 GHz 1.5MB cache	Intel Celeron N3060 Dual-core x86 @ 1.6 GHz 2MB cache
Memory	4GB	4GB
Flash Storage	32GB	16GB
Display Size	13.3”	11.6”
Display Resolution	1920x1080	1366x768

Both systems include 4GB of system memory and eMMC storage typical of today’s Chromebooks. The Acer R13 has a 13.3-in 1080p display and the Acer R11 has an 11.6-in 1366x768 resolution screen. While I don’t expect the results to be affected much in either direction because of it, in theory, the lower resolution screen should provide less rendering work for the Intel-based platform.

Games Testing

Candy Crush Saga	
	*Launches 73% faster on ARM with less stutter and freezing*

Candy Crush Saga opened on both the Intel-powered R11 and the ARM-powered R13 Chromebooks, launching us into the game and on our way. Start time did vary noticeably between the two configurations however, taking nearly 26s on the R11 and 15s on the R13, a difference of 73%. And while the game was playable on both machines, there were significantly more stutters and screen freezes on the Intel hardware, making game time less enjoyable.

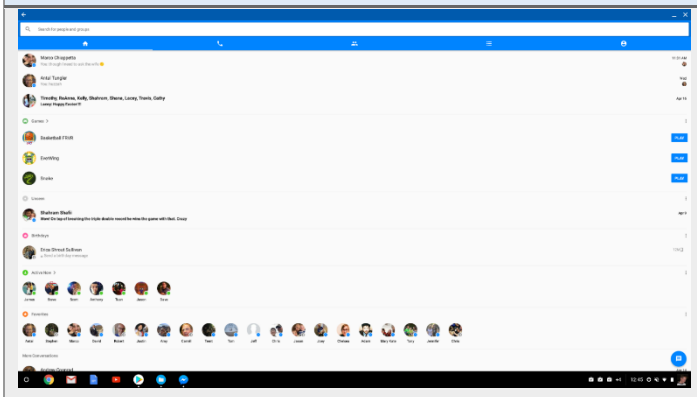
Mortal Kombat X	
	*Loads 75% faster on ARM and shows image corruption on Intel*

Mortal Kombat X is a game that loads across both platforms but shows some horrible data corruption on the translated application. The screenshot on the top shows how the game looks on the Acer R13 powered by the MediaTek processor. The one on the bottom is from the R11 powered by the Intel Celeron processor and exhibits significant texture corruption that makes the application unusable. Adding to the advantage the R13 holds, load times for this sub-par version running on the R11 come in at an average of 72s compared to just 41s on the R13, a difference of 75%.

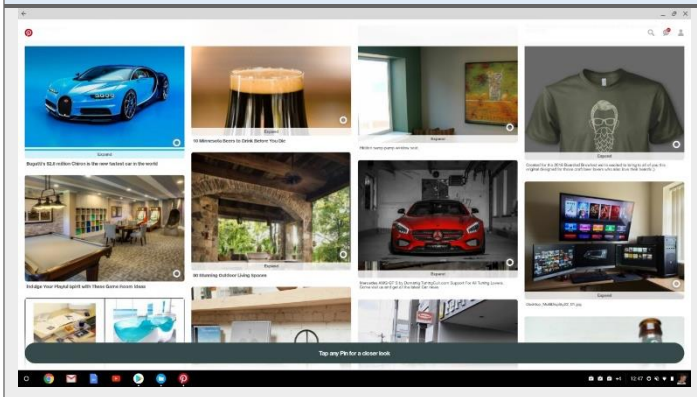
Minecraft Story Mode	
	*Runs great on ARM but crashes to desktop and refuses to load on Intel*

Minecraft Story Mode is the narrative driven variant of the world's second most popular video game (behind only Tetris). Running this native Android game on the Acer R13 with the ARM-powered processor resulted in a good experience with an agreeable frame rate and minimal frame drops or stutter. On the Intel-powered system the application refused to go past the opening splash screen, remaining there until it eventually crashed back to the desktop of the Chromebook. Obviously this is one of the extreme cases where the Intel system just cannot run the game in question.

Social Media Testing

Facebook Messenger	
	*Exhibits crashing and stability issues on Intel platform*

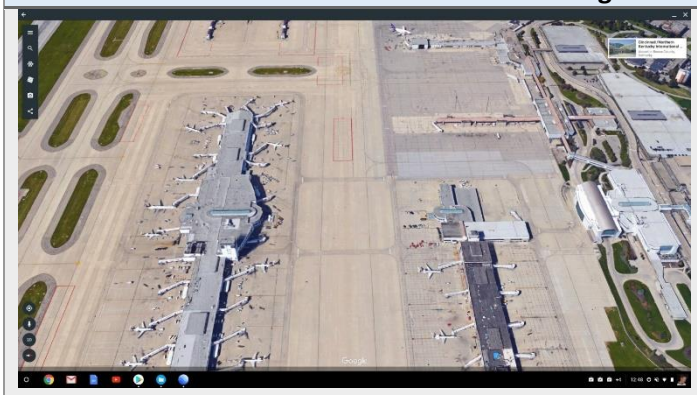
Facebook Messenger is an example of an application that provides a better and unique experience when compared to the web-based equivalent. Though the application loads up in 1-2s for both systems, the experience between the two varied in interesting ways. Through nearly an hour of conversations, but in text and video form, the R11 powered by the Intel Celeron processor exhibited some odd behavior including random orientation changes and crashing back to the desktop. In just under an hour of use we observed three instances of Messenger crashing. When running Messenger on the R13 system for the same amount of time and with the same division of work (text versus video), I saw no performance or behavioral oddities. The Facebook Messenger Android app on the ARM-based platform provided a better user experience.

Pinterest	
	*Image loads and scrolling are much smoother on ARM platform*

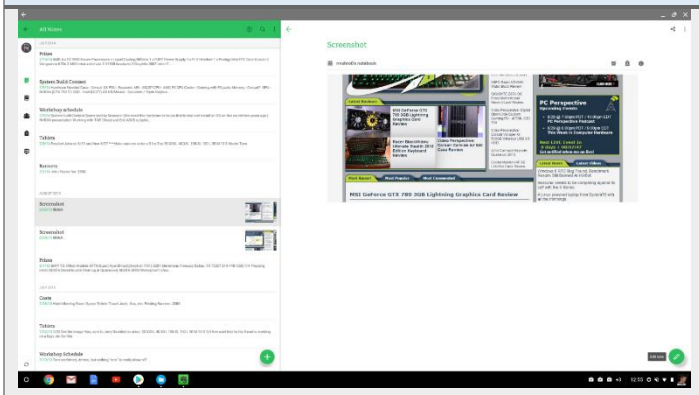
The Pinterest Android application running on the R13 Chromebook powered by the MediaTek processor showed a much smoother and more consistent experience when utilizing it to browse for new content.

Images loaded faster and the scrolling movement was more consistent on the ARM system. By comparison, the Intel-powered Chromebook had significant freezing and stutter when moving through content even at a slowed scrolling rate. Though the initial load time between both systems were within 1-2s of each other, the ARM-powered system proved to be the better solution.

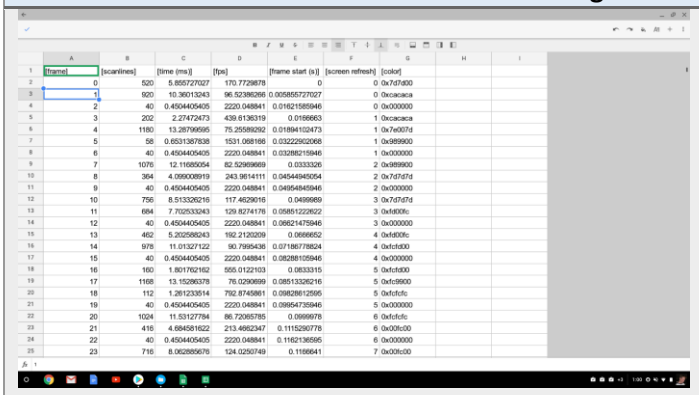
General Application Testing

Google Earth	
	*Streaming imagery and visuals show dropped frames and stutter on Intel platform*

Google Earth is a popular entertainment and educational application that runs natively through the Android platform and the Play store. On the Intel-powered R11 Chromebook the load time before input was accepted was 7s while on the ARM-powered R13 machine it was just under 4s on average. Both systems exhibited a reasonable experience with the heavy compute-focus and data-heavy application workload but the Intel processor seemed unable to handle the streaming media content that occurs when quickly relocating the focus area on the globe. More frame drops and stutter were apparent on the Intel system than the ARM Chromebook, with the R13 showing a better overall experience.

Evernote	
	*Populated notebooks load 2x as quickly on the ARM platform*

With empty notebooks, both Intel and ARM based Chromebooks operate smoothly and provide quick input and interaction with the consumer. The story changes when we load down several notebooks with content, uploading images, saving webpages, clipping text and recording audio. With that Evernote environment, we found that the Intel-powered R11 took significantly longer opening those notes and displaying the content thumbnails required to click and expand the content itself. The ARM-powered R13 brought them up in about half the time, lowering the wait from application load to viewing and acting on the content.

Google Sheets	
	*Intel platform loads large spreadsheets as much as 5x slower*

Similar to our experience with Evernote above, both the Intel and ARM systems opened Google Sheets quickly to an empty spreadsheet, within 3s. When opening a spreadsheet populated with 30,000 rows of data, typical for our survey and data gathering input, the Intel system would take as much as 5x longer to render the sheet and allow us to navigate or interact. A sheet that would open fully on the R13 in 7-8s

would take more than 30s on the Intel Celeron based R11 Chrombeook. This delay seems to scale with the content scope as well, meaning any larger or data-heavy spreadsheets would see a wider variance between the ARM and Intel processors.

Summary of Performance

The data and descriptions above highlight some of the areas where the performance delta between Intel and ARM-powered Chromebooks stood out to us. In our internal testing, we also evaluated numerous other applications and scenarios, the results of which we have summarized below.

Performance ratings in the table below are based on an experience-based index, with results categorized into one of four different ratings. A “very good” experience with the Android app means we detected no visual anomalies or issues when running the software. A “good” rating means the experience overall was solid, with only minor issues detected and often only when under a heavy load. When we rate an experience as “poor” it means we see stutters and input latency while attempting to interact with the software, but it is usable for a patient consumer. Finally, a “very bad” experience rating is given when the app either will not open correctly, has extreme visual corruption or has so much animation stutter and freezing that it is completely unusable. Launch time is generally not included in the rating designation for our testing purposes but instead is discussed separately.

Rating	
Very Good	No issues detected
Good	Minor issues under load
Poor	Stutter, input latency
Very Bad	Crashes, corruption, unusable

Application	Acer R13 (ARM) Performance	Acer R11 (Intel) Performance	Comments
Gaming Tests			
Candy Crush Saga	Good	Poor	Intel showed significant stutter
Mortal Kombat X	Good	Very Bad	Intel showed mass image corruption
Minecraft Story Mode	Very Good	Very Bad	Intel wouldn't load game completely
Game of War	Good	Good	
Mobile Strike	Very Good	Very Good	
Angry Birds 2	Very Good	Good	
Social Media Tests			
Facebook Messenger	Good	Poor	Intel crashed, orientation bug
Pinterest	Very Good	Poor	Intel showed stutter and slow scrolling
Snapchat	Good	Very Good	
Twitter	Very Good	Very Good	
Instagram	Very Good	Very Good	
Productivity Tests			
Google Maps	Good	Very Good	ARM showed slower loading of stream data
Google Earth	Very Good	Good	Intel stuttered during location swaps
Evernote	Very Good	Good	Intel took noticeably longer to load
Google Sheets	Very Good	Good	Intel load times on filled sheets 5x longer
Dropbox	Very Good	Very Good	
Entertainment Tests			
Netflix	Very Good	Very Good	
DirecTV Now	Good	Good	
Skype	Very Good	Very Good	

Through 19 tested Android apps we found that the ARM-powered R13 Chromebook performed better than the Intel-powered R11 Chromebook in 9 of them. In 8 of the apps tested, both platforms performed equally well. In 2 of the test applications, the Intel-powered system performed better (Snapchat and Google Maps).

Impact of Platform on Battery Life

As important as the performance and experience of using a Chromebook is to the student or enterprise customer, battery life may be a more important factor in the buying decision. After we had determined that the Google Play Store and Android application performance benefited from running on the Acer R13 with the ARM-based MediaTek processor, we wanted to see if battery life and power consumption would tell an interesting story too.

We used a simulated education usage model scenario to test this with real world applications. Composed of three unique 45 minute segments, one focused on writing, one on science and one on history, they all use applications that the middle school classes are known to utilize with Chromebooks.

- Story Scenario
  - Open Edmodo
  - Create an account
  - Using Google Docs we input text manually (15 mins)
  - We share the document with another Edmodo account via Google Drive
  - We download another document through Google Drive and read (15 mins)
  - Reopen Google Docs to modify our story and add images, uploading afterward (15 mins)
  - Total time utilized: 45 minutes
- Science Scenario
  - Open Solar Explorer HD and browse content for (15 mins)
  - Watch NASA TV video and browse images (15 mins)
  - Open Google Docs and summarize video with screenshots from the NASA TV app (15 mins)
  - Total time utilized: 45 minutes
- History Scenario
  - Watch three videos from BBC Bitesize website (15 mins)
  - Use Flashcards Maker app to create flashcards on facts from the videos (15 mins)
  - Open Google Docs and make a quiz based on flashcards information (15 mins)
  - Total time utilized: 45 minutes

Our school day simulation consists of running each of the above scenarios one time, with a 5 minute pause between them, and measuring total device-level power consumed in that 150 minute experience. The process was repeated three times for each system and the average results are presented in our data below.

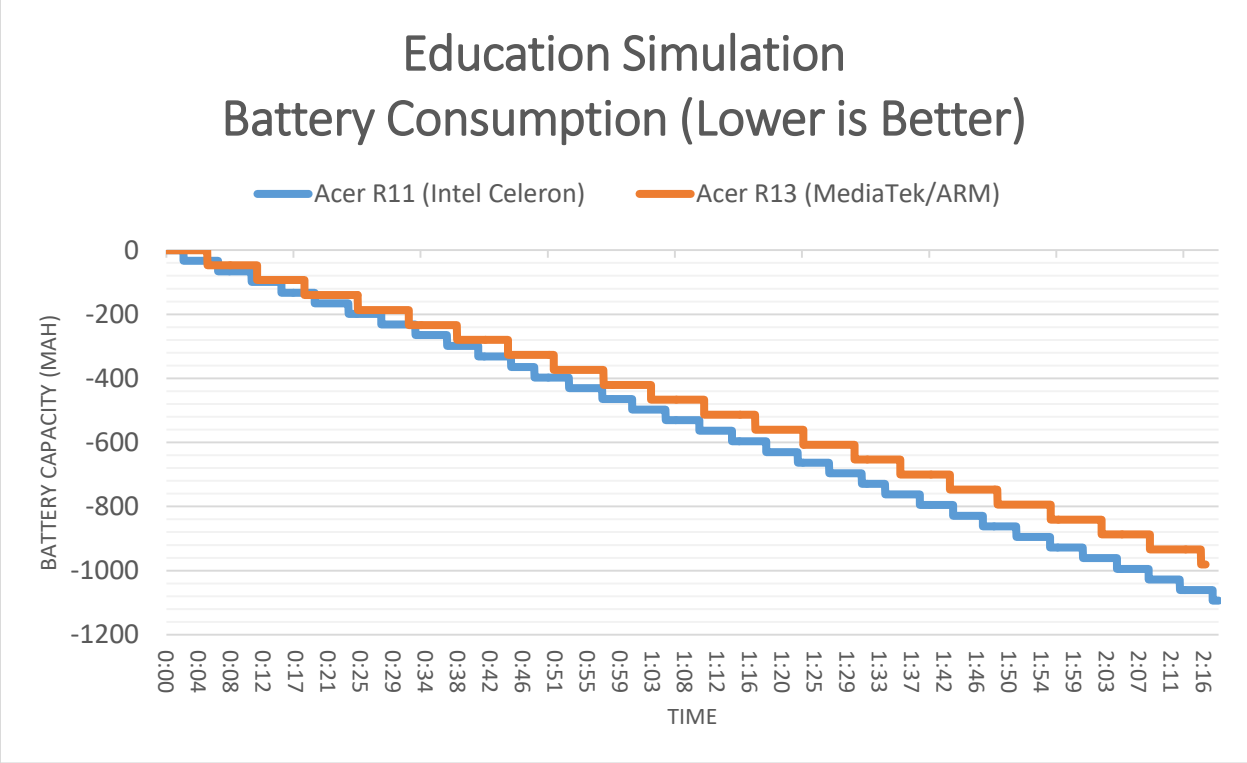
A couple of points to consider:

1. Both system displays were set to a brightness of 180 lux.

2. We are measuring power consumption of the entire system, not the processor specifically. As such, there are other components that could affect results including the display, storage, and memory. In general, a lower resolution screen will require less power to operate and less GPU horsepower to be rendered to. In theory, that would give the advantage to the Acer R11 using the Intel Celeron processor with the lower resolution screen.

3. We are showing power used for the combined scenario, not estimated battery life of a particular system. Because of the different battery sizes in our testing hardware, and the various battery sizes in the market, knowing power consumption independent of battery size is a more useful metric.

4. Power consumption data was measured by monitoring the Chrome OS sysfs file system and what it reports for battery states.



Power Consumed (Lower is better)	*Acer R13 (ARM)*	*Acer R11 (Intel)*
Pass 1	980 mAh	1093 mAh
Pass 2	980 mAh	1060 mAh
Pass 3	934 mAh	1093 mAh
Average	**964.6 mAh**	**1082.1 mAh**

Our testing indicates the Acer R13, using the ARM-powered processor, uses 11.5% less power on average in our 150 minutes of use through our education simulation. This is a significant margin and would indicate that with two systems equally configured, one with the MediaTek ARM processor and another with the Intel Celeron processor, the ARM-powered platform would get 11.5% additional usage time before requiring a charge. Based on typical Chromebook battery life (11 hours), the ARM system would see an additional 75 minutes of usability.

Android Apps on Chrome OS: Advantage ARM

The importance and impact of bringing the Google Play Store and the entirety of the Android app ecosystem to Chromebooks should not be overlooked by system vendors, consumers, or educators. The ability to instantly turn a low cost and user friendly Chromebook into a dual-use device that can run any number of Android applications previously limited to phones and tablets gives the platform more viability for a wider audience without raising costs. This disruptive move by Google will create waves through the market, including other low cost hardware segments, as the players involved figure out the lasting importance of Android on Chrome OS.

Based on our experience based testing shown here today, the platform that powers a Chromebook is a significant factor in determining how well Android apps will run on Chrome OS. Of the two competing processor architectures for Chromebooks, the ARM-based processor tested in the Acer R13 exhibited significant and user-impacting benefits that include not only smoother animations and faster loading times, but fundamental compatibility advantages. The Intel-based platform showed reduced user experience, lengthened load times or the inability to start some applications in nearly half of our tested software.

The scenario-based power consumption testing also revealed battery life advantages to the ARM-based MediaTek SoC compared to the Intel Celeron. By using 11.5% less power to complete the same tasks over the same amount of time, a student or other consumer would see an estimated 75 minutes of additional use. That could mean the difference between completing a project on time or not when away from your charger.

For organizations and consumers looking to buy Chromebooks today, these two results should help direct your hardware selection. With advantages in both Android app performance and compatibility, as well as battery life, ARM and its partners have made a firm statement on their commitment to the Chromebook market.

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Please direct questions about this paper to ryan@shroutresearch.com.

Disclosure: This paper was commissioned by ARM Holdings. All testing, evaluation and analysis was performed in-house by Shrout Research and its contractors. Shrout Research provides consulting and research services for many companies in the technology field, other of which are mentioned in this work.