HACK “START” TO CONTINUE:

A MIXED-METHOD STUDY OF VIDEO GAME HARDWARE MODIFICATIONS

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Kerry Wall

Abstract

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While modifications (“modding” or “mods”) to video-game software are well documented in academic research, mods to game hardware have received significantly less attention. As a range of hardware-focused practices has given rise to related communities and small businesses, an exploration of such practices is necessary. This paper outlines and contextualizes hardware modding through original research illuminating the activities and motivations of hardware modders. A mixed-method approach is employed to gather quantitative data concerning specific acts of modding as well as qualitative information about participants’ reasons for doing so. Results suggest that older, discontinued hardware are overwhelmingly popular objects of modding. Commonalities exist with software modding regarding participants’ enthusiasm for the work of modding, but key differences materialize surrounding classifications of labour and related compensation. Areas for further research include implications for preservation and environmental efforts.

Key words: video games, hardware, consoles, accessories, controllers, modifications, mods

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The line connecting this paper to the hypothetical major research project I described when I applied to this program is not a straight one. There were more than a few leaps, and I wasn't always sure where I'd land. The final product is the result of my having been surrounded by a host of amazing and supportive people. As a non-playable character once famously said, "it's dangerous to go alone".

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Introduction

Video games have long been understood to be a medium for interaction and creativity beyond their intended states of play. Joost Raessens (2005) notes that digital games are "able to form a specific type of participatory media culture" (p. 373) distinct from the cultures of other media because they offer opportunities for user-based reconfiguration and construction in addition to interpretation. One of the most thoroughly explored facets of the culture of fan intervention in this medium is the modification ("modding") of a game's source code. Modifiers ("modders") of game software have edited, added to, and reworked games originally produced by others for as long as digital games have existed; the formative 1962 game *Spacewar!* has been described as "not just the first computer game [but] also the first game to be modded" (Christiansen, 2012, p. 32) due to its distribution through the copying — and editing — of its code. The popularity of game software modding is commonly understood to have surged with the release of official mod kits for the successful first-person shooter *Doom* (Coleman & Dyer-Witheford, 2007), an affordance provided by other game developers in the years since (Waldsdorff, 2022). These practices speak to players' eagerness to interact with game content on deeper levels than those initially intended by the publisher.

A similar willingness to modify game *hardware*, the physical devices through which players see, hear, and interact with a game, can also be traced back several decades to the beginning of the home-console era in the 1970s (Swalwell, 2021). Hardware modding has historical links to software modding; alterations to a *Missile Command* arcade cabinet were a necessary step in the development of the 1981 software mod *Super Missile Strike* (Christiansen, 2012). That hardware modding has continued to take place since the advent of the console era is evident, and curious individuals need only peruse modding-related social media hashtags such as

#consolemods, #controllermods, #retromods, or platform-specific tags for a glimpse of the practice. Copies of Nintendo's original Game Boy handheld, first released in 1989 with a monochromatic dot matrix display (Reynolds, 2016), now boast backlit, full-colour screens. Controllers have been transformed both inside and out via replacement circuit boards and the swapping of buttons, external shells, and cords. Posts and websites advertise completed mods and individual parts for sale, either online or in person at gaming-related conventions. Tutorials chronicling the inner workings of specific hardware are freely available for those interested in altering their own devices; small and freelance businesses offer custom modding services for those who would rather not attempt this work themselves. These examples are easily verified through a few minutes of online searching, yet scarce academic exploration of these practices exists. Scholars have pushed back against the perception that hardware is a tangential or incidental component of the gaming experience: Seth Giddings (2008) writes that video games "are at once computer software with procedural agencies and autonomous operations, computer hardware, and media texts" (p. 147); Mikolaj Dymek (2012) notes that the medium of video games "includes not only the software, but also the hardware needed to enact video gaming" (p. 38); Yinyi Luo and Mark Richard Johnson (2019) argue that, "Just as games cannot be seen as isolated texts without eliding much of their complexity, gaming hardware cannot be seen as isolated artefactual material, a mere simple substrate on which the richness of play takes place" (p. 1,479). Despite hardware's obvious importance to video games, the practice of modding it has received little academic attention. The majority of existing scholarship about video game modding focuses on software, though many of the definitions offered in the course of these studies are equally applicable to the modding of hardware: Andrew Williams (2017) describes mods as "unofficial modifications, created by players, which change the behavior, appearance, or

functionality of games" (p. 183); Walt Scacchi (2010) outlines "a 'Do It Yourself' approach to technology personalization that can establish both socio–technical and distributed cognitions for how to innovate by resting control over technology design from their producers" (para. 9); Tanja Sihvonen (2011) observes games' "inherent potentiality for malleability and alteration" (p. 87). That the work of hardware modders also exemplifies these characteristics speaks to the need to include it in discussions of game-related modding. The purpose of this paper is to shed light on this underexplored area, laying a foundation for future research.

Background

The video game industry operates on a generational model that sees the release of new hardware with greater technological capabilities every several years (Landsman & Stremersch, 2011). A console and its accompanying accessories are produced, sold, and officially supported before the cycle repeats itself; the manufacturer typically announces another product that may leverage more advanced technology alongside a library of games developed in time for launch, either in house or by a developer with a "long-term contractual relationship with the platform" (Haviv et al., 2020). Marketing of the current device is gradually wound down during a "phase-out" (Dymek, 2004, p. 5) period, and production of the outgoing hardware, as well as the software designed for it, ultimately ends. This process, which Christopher Luke Moore (2009) describes as "a rapid production and innovation cycle, one that actively enforces hardware obsolescence" (para. 3), has become a recognized characteristic of the industry. Even the newest game hardware will eventually be superseded as technology advances and a new generation takes hold (Newman, 2012a; Guins, 2014). It is in the industry's own financial interest to actively promote the adoption of the latest hardware and related games in place of continued use of older platforms; console manufacturers often anticipate that newly released hardware will not

itself yield a profit and endeavour to address shortfalls through the sale of software over the console's business life cycle (Williams, 2002; Daim et al., 2014). Researchers have analyzed this cycle's dynamics from historical and economic perspectives, observing that the question of scheduling the launch of a new console is a delicate one: to supersede the current generation of hardware too soon risks alienating a user base that has invested time, energy, and money in existing products, but to wait too long risks allowing competitors to gain a strategic advantage (Schilling, 2003). The length of a life cycle also hinges on the product's sales performance and is "highly variable" (Williams, 2002, p. 47) as a result.

Regardless of announcement or launch timing, players may decide not to embrace the next generation of hardware right away — or at all. The nature of the product life cycle positions consumers on a spectrum that ranges from early to late adoption (Karlsson, 1989); marketing research has suggested that "late adopters are typically risk-averse" (Rietveld & Eggers, 2016, p. 4) and "resistant to change" (Jahanmir & Lages, 2016, p. 1,702), a reasonable view towards an industry that is known to supplant its own products on a routine basis. Cost may also be a factor in the decision to wait to embrace a new hardware generation, as "forward-looking consumers may strategically delay their adoption, and purchase at low prices later" (Nair, 2007, p. 239). Moreover, the choice may simply be related to "satisfaction with past technology" (Atkin, 1993, p. 57). Sustained interest in superseded game hardware is not purely a recent trend: Jaakko Suominen et al. (2015) have taken note of a 1990 magazine column whose author urged readers to revisit the Commodore 64 and the library of games available for it (pp. 83–84) rather than abandon it in favour of the more technologically advanced platforms that were, by that point, already on the market. The writer's point resonates today: hardware platforms are still capable of providing enjoyment once their manufacturers no longer produce or otherwise support them,

even if acknowledgement of their existence fades to "a baseline by which we are invited to judge the additional processing power or graphical resolution of the replacement" (Newman, 2012a, p. 9). The ongoing use of discontinued platforms comprises part of what Raiford Guins (2014) describes as their "afterlife" (p. 6) phase, "a curious state after commodification and consumption, after intended utility and designed functionality, and possibly even after obsolescence; where a standard life span is met with extended or repurposed and recontextualized uses" (p. 7). The afterlife of a game or game device can take many forms, from preservation and display in a museum to resale online, in a specialty shop, at a garage sale, or similar — or, arguably, continued enjoyment and discussion of discontinued games years or decades after "consumers are urged to pack up their outdated hardware so the 'next gen' may assume its rightful place in the current gen" (Altice, 2017, p. 198).

The practice of continuing to use obsolete hardware and the games produced for it, often described as retro or classic gaming, has itself been the focus of considerable study and its appeal has been attributed to several possible factors. Nostalgia is an oft-cited motivator (Wulf et al., 2018; Heineman, 2014), particularly as players who grew up with older generations of hardware mature into a position of greater purchasing power and, in many cases, introduce their children to the games of their own youth (Suominen, 2008; Bowman & Wulf, 2023). Other reasons have also been discussed: Kristian Redhead Ahm (2021) points to a curiosity about gaming *history,* differentiated from nostalgia on the grounds that older games can be (and are) enjoyed in the present day by players who are too young to remember their original release (pp. 662–663). Redhead Ahm also describes collectors who seek out copies of older — perhaps rarer — games as "amateur archaeologists" (p. 667) and compares the act of perusing flea markets and garage sales to "digging through crates" (p. 667). This analogy evokes Guins's (2014) afterlife phase in

its depiction of engagement with obsolete game materials as an almost curatorial interaction with the past.

John Vanderhoef (2017) observes that the industry has worked to monetize this interest, describing the formation of a retro gaming sub-industry that "effectively exploits peoples' intimate memories of older gaming technology, transforming it into a continual stream of revenue derived from nostalgic consumer products" (p. 113). Vanderhoef refers to the re-commodification of retro games — re-releases and remakes of older software for current platforms, and online services that facilitate paid downloads of older game files — without which this "continual stream of revenue" cannot flow. The content of older software is also notably redistributed for *current-generation* devices; the original hardware remains obsolete. Such endeavours are, in part, the industry's attempt to provide a legal, sanctioned alternative to the unauthorized emulation of games (Jordan, 2007), a process in which specialized computer software "tries to mimic another system in order to run applications the way they were run on their original system" (Dor, 2016, p. 25) and thus enables game files to be accessed and distributed without original consoles, cartridges or discs. Re-releases of this nature are also a response to the unprofitable nature of the afterlife state. To continue to make money from discontinued products, their manufacturer must repurpose and reintroduce them into the primary market; players occasionally have strong opinions about changes or adjustments made to such games in the process (Heineman, 2014; Newman, 2012c).

Despite being caught up in a constant cycle of release, support, and obsolescence, hardware has a substantial role to play in providing ongoing access to its accompanying game software in its original form — without curated involvement from the industry. Discontinuation impacts the availability of original devices, and subsequent generations of hardware do not

always offer backwards compatibility with previous generations' games (Monnens, 2009). Preservationists have discussed emulation as a potential method of maintaining and protecting older games (Guttenbrunner et al., 2010; Guay-Bélanger, 2021), although in addition to presenting legal concerns (Newman, 2012b), the practice does little to ensure the continued survival of the hardware itself. Original hardware is not merely a means through which software can be accessed but a part of video game history in its own right (Sotamaa, 2016), one that is susceptible to material damage and decay (Glas et al., 2017). Its continued use by players, even as the industry makes some attempts to reintroduce older games for newer systems, may stem from a preference for the original gaming experience — a matter of importance to preservationists (Guttenbrunner et al., 2010) — and a desire to "protect its authenticity" (Downing, 2011, p. 756). Steve Cuff and Christopher Terry (2017) attribute this sentiment to hardware's "existence as physical, real-world objects that are also period appropriate" (p. 25), citing examples of older games being removed from online shops "without warning or explanation" (p. 28). Entire virtual services (such as Nintendo's Virtual Consoles and eShops) have also been shut down, significantly affecting the availability of thousands of titles (Faulkner, 2023). In this way, physical hardware offers a layer of protection from the ephemeral nature of cloud-based availability and storage. While the associated risk of material deterioration is a concern, the collection, repair, and modification of such hardware are examples of ways in which players — in Guins's words — extend, repurpose, and recontextualize (2014, p. 7) devices, and consequently stretch the boundaries of their utility by prolonging their functional lives and by bringing them more in line with present-day expectations. Such user-driven initiatives form an important part of the public or social history of games: they serve as a reminder that game

hardware and software persist beyond the industry's cycle of release and discontinuation, with assistance from the collector, modder, and player.

Current Study

This paper functions both as a summary of hardware modding activities and as a contextualization thereof alongside published work about software modding and other game-related topics. Its primary focus is modding that is intended to alter the function or appearance of game hardware, either individually or in combination; modding for the purpose of infringing copyright protections is not within the scope of this research. A wide-ranging review of existing literature helps to situate this topic within the broader field of video game studies. Despite a scarcity of research devoted *exclusively* to hardware modding, the practice has been described in broader analyses of specific platforms and gaming communities, and scholarship about associated subjects — such as sales life cycles, planned obsolescence, and differing perspectives on game history — outlines the environments in which hardware modding takes place. Original research about modding activities, business practices, and motivation was gathered using a mixed-method approach: more than 100 modders contributed to this study through an anonymous online survey, while three professional modders participated in interviews. Quantitative data about specific activities provides important context about which products are modded and what modifications are made, as well as how modders acquire parts, whether or not they sell their work (and for how much), and how long they have engaged in the practice. Qualitative methods were employed to ascertain information about what motivates participants to mod game hardware. Trends within the data have been observed, and results have been contrasted with existing studies in order to enhance the academic view of game-related modding as a whole.

The results of this research depict a range of modding activities that are analogous to software modding in some respects and markedly dissimilar in others. Both types of modders cite an enthusiasm for the process of creating and a passion for the objects they mod, be they physical devices or individual games, but differences emerge in how their labour is classified. Much has been written about how the frequently unpaid labour of software modding yields financial benefits for the professional video game industry (Kücklich, 2005; Postigo, 2008; Schleiner, 2017), but this dynamic is not apparent in hardware modding. Nearly half of this study's participants sell or have sold modded products, yet profit is not always an impetus for doing so. These sales also offer no financial advantage to the original manufacturer, which may conversely benefit from software mods. Results also indicate that participants gravitate heavily towards devices that are officially considered obsolete, and while successful, high-selling hardware is well represented in the results, respondents also described modding products that failed commercially or did not receive a wide international release. Several written responses directly referred to modding's ability to "breathe new life" into older devices that might otherwise sit unused or forgotten. Some scholars have already begun to reference user-produced mods in studies and analyses of specific hardware, speaking to modding's role in the broader platform history of these devices and reinforcing the fact that these histories are still unfolding. Game hardware has much to offer even after its official life cycle ends, and the act of modding is one way in which users continue to confer relevance on it. As such, a deeper exploration of this practice is necessary.

Literature Review

The state of academic research into video game modifications can be described as lopsided. Most of the existing scholarship focuses primarily on player-initiated edits or additions to *software*, while hardware mods have received less attention. Software mods have been explored as a method of expanding a game through the introduction of new levels or other content (Postigo, 2007); of correcting issues of underrepresentation (Condis, 2018; Welch, 2018); of providing aspiring programmers with practical experience (Kücklich, 2005); of generating new challenges via the randomization of items and locations (Johnson et al., 2021); and of dismantling language barriers through amateur translation (O'Hagan, 2009 & 2017), among other purposes. Scholarship concerning *hardware* mods has largely addressed questions of legality (Harris, 2007; Leppink & Schutte, 2010; O'Donnell, 2013), specifically relating to the use of mod chips "to either rewrite or bypass the hardware code on video game systems allowing the owner to run programs not provided by the manufacturer" (Harris, 2007, p. 116). These programs may comprise "illegally copied software" (Leppink and Schutte, 2010, p. 836) or "homebrew" (O'Donnell, 2013, p. 738) content created by amateur users. Devices have also been modified to run new operating systems that may drastically change their capabilities (Ruffino, 2018).

Such activities, Paolo Ruffino observes, "show that video games, in both hardware and software, are malleable entities" (2018, p. 86). Malleability has long been a feature of hardware, though scholarship has primarily discussed hardware modding in broader contexts. In an exploration of homebrew software development, Melanie Swalwell notes that "home hobbyists had begun to build and mod electronic game consoles in the 1970s, prior to the popular takeoff of microcomputers" (2021, p. 133). Hector Postigo similarly connects users' interest in

modifying game hardware to the longstanding practice of altering personal computers; he also connects game-related hardware modification directly to software modification, arguing that "what began as software and design modification has spread to hardware as well" (2016, p. 330). This association is apparent within certain individual cases: the software mod *Super Missile Attack,* a modded expansion of Atari's *Missile Command* arcade game, was achieved not only through code changes but also through the addition of a custom circuit board to the original's cabinet — a supplementary piece of hardware its creators reproduced and sold to interested gamers until Atari sued for copyright infringement (Christiansen, 2012). It is clear from both existing literature and the results of the current study, however, that hardware mods have uses that extend well beyond the facilitation of software mods. In a brief exploration of hardware mods, which consists of a short section within a larger study of software mods, Postigo describes the implementation of accessibility measures into controllers and other devices — as well as automated input adjustments intended to give players an unfair advantage over their opponents (2016, p. 330). While these examples illustrate that hardware modding serves a range of purposes, they are also only part of a larger practice.

Other forms of hardware modding, such as aesthetic personalization and functional changes, have received reflection in broader studies of specific game platforms (Custodio, 2020) and communities (Rappaport, 2020) but have less frequently been the subject of focused research. In an exploration of the practice of PC case modding, a practice specific to gaming computers, Bart Simon observes that "there has been very little research on case modding and cultures of hardware modification in general" (2007, p. 197). Swalwell has similarly noted a lack of attention to user-driven hardware alteration, particularly from a historical perspective: "With only a few exceptions, mentions of early users' electronics nous and hardware hacking in

computer history have also been scarce, perhaps because users and consumption have not been considered priorities of the discipline up until now" (2021, p. 142). Possible reasons for this gap in scholarship include academic fields that "are not well equipped to notice or theorize users with deeply technical engagements who make cultural artifacts" (Swalwell, 2021, p. 144) and the industry-driven "lack of corporate legitimacy" (Custodio, 2020, p. 176) afforded to amateur projects including hardware mods. While the relationship between the video game industry and *software* modders has sometimes been combative to the point of legal action (Postigo, 2008), research in this area also reveals examples of both tacit and explicit endorsement and even collaboration: software communities have been "used as a recruiting pool for the games industry" (Kücklich, 2005, para. 19), and some developers and intellectual property holders have actively encouraged software modders through the release of official mod kits (Postigo, 2010). The choice to acknowledge certain amateur mods but not others may relate to the fact that producers "benefit greatly from the work of these dedicated teams of gamers" (Newman, 2008, p. 152) via extensions of the "shelf-life" (Kücklich, 2005, para. 5) of the source material, or the generation of new content valued at tens of millions of dollars at no cost to the company (Postigo, 2007). Alex Custodio notes that other elements of mod culture, in contrast, defy "the regime of planned obsolescence and gives agency to consumers in an increasingly platformized commodity culture" (2020, p. 176); the industry may only be interested in the mods that yield tangible benefits for it.

Lives and Afterlives

From a corporate perspective, the life cycle of a game or game device is concretely defined as the period during which it is actively manufactured and sold by its developer (Clements & Ohashi, 2005; Liu, 2010; Newman, 2012a). The duration of the average life cycle

has evolved over time — Nathan Altice (2017) observes that while generations were originally defined by their processing power, these classifications were eventually abandoned:

> in favor of less quantitative distinctions, whether they were about media formats (e.g., DVD vs. CD), industrial design (e.g., "slim" models), add-on services (e.g., embedded apps), or merely a nod to established tradition (e.g., the "five-year cycle"). (p. 197)

The cycle's transient nature is well established: Hongju Liu states that "a product life cycle of approximately five years is expected in this market" (2010, p. 436), while Matthew T. Clements and Hiroshi Ohashi deliberately measure these cycles using monthly data "because of the short life cycle of hardware, and the even shorter life cycle of software titles" (2005, p. 527). The definition of *obsolescence* is more nebulous; James Newman's assessment that "platforms are superseded and eventually rendered obsolete as games are no longer available for them" (2012a, p. 9) is consistent with John Davis's description of "a formal status of technical incompatibility with popular and widely used digital media" (2007, p. 223). Davis, however, further argues that the technical definition of obsolescence exists alongside a symbolic definition: "whether a medium is obsolete depends largely on its status as shaped by structural forces both formal and informal" (2007, p. 224). These observations appear in Davis's study of the motivations of collectors of vinyl records, but parallels to certain gaming communities — modders, collectors, and retro enthusiasts, among others — are clear. His description of the "subculture of vinyl aficionados… who refused to abandon the format" (2007, p. 223) is echoed in Custodio's reference to game enthusiasts who "refuse the regime of planned obsolescence" (2020, p. 176). Such refusals reinforce the imprecise nature of a game's life *status* beyond the largely agreed-upon business definition of its life *cycle*. Official obsolescence or discontinuation do not necessarily impact how long a device or game functions, the availability of leftover stock, ongoing accessibility on the used market, or whether or how often players continue to use it. As

previously mentioned, Raiford Guins offers the term “afterlife history” (2014, p. 6) to describe these and similar activities, defining it as “a curious state after commodification and consumption, after intended utility and designed functionality, and possibly even after obsolescence; where a standard life span is met with extended or repurposed and recontextualized uses” (2014, p. 7). This is reminiscent of Ron Eglash’s description of “technological appropriation” as “a second phase in which this techno-science is reinterpreted, adapted, or reinvented” (2004, p. ix). Custodio cites Guins’s definition of afterlife history in choosing to categorize hardware mods as one facet of the Game Boy Advance’s post-commercial afterlife (2020, p. 6) orchestrated by individuals and groups not involved in its initial production. These definitions insinuate that the original manufacturer has little or no jurisdiction over the afterlife or appropriation of a game or device. Given Newman’s suggestion that “technological obsolescence is produced, often in the service of commercial interest” (2012, p. 8), and the established cyclical nature of video game hardware production (Landsman & Stremersch, 2011), research implies that the industry may not perceive any benefits — and may even perceive threats — to itself in the afterlife period.

Guins observes that strategic use of obsolescence leads to “shorter and shorter ‘life spans’ of our computing technologies” (2014, p. 4) and that “the game industry’s planned obsolescence rushes to discontinue the last ‘next gen’ before the ‘next, next gen’ debuts” (2014, p. 5). Newman is similarly direct, asserting that “much of the work of the games industry, in its broadest sense, is diametrically opposed to the project of game history, heritage and preservation” (2012a, p. 9). The nature of the conflict that exists between the industry-driven obsolescence described by Guins and Newman and the resistance thereto discussed by Davis and Custodio is explained in work by David S. Heineman that outlines “the tensions between official and vernacular versions

of gaming history" (2014, para. 1). Official histories are maintained by established institutions such as the game development industry, while vernacular histories evolve through the actions of "small collectives and individuals" (Heineman, 2014, para. 9). These parallel histories often represent different motivations and interests; if one purpose of official versions of history is, as Heineman notes, to "benefit social institutions" (2014, para. 9) that create them, it follows that these versions will be curated to maximize the potential for benefit. Conversely, Marçal Mora-Cantallops and Ignacio Bergillos observe that fan preservation efforts occasionally centre around "failed games and systems, as those objects that are often considered 'bad', unreleased or 'flopped' (those that failed commercially), often forgotten and buried by the official channels" (2018, p. 214); the forgetting and burying of such works — or, at least, not drawing attention to them — is in the interest of the manufacturer. James K. Harris further illustrates this friction between official history and vernacular history through a case study of Nintendo's NES and SNES Classic Editions, officially sanctioned "emulators inside small plastic casings perfectly designed to resemble a 1:6 scale replica of the original console" (2021, p. 1,418). The decision to populate these emulators with a predetermined library of games for each console, Harris notes, constitutes "a heavily curated version of video game history" (2021, p. 1,428); player dissatisfaction with the Classic Editions' official game options, which comprised roughly four and three percent of the NES and SNES game libraries, respectively, led to an influx of online tutorials explaining how to add other files to the systems. This, Harris continues, suggests that a subset of gamers is "unwilling to accept the corporate-approved rewriting of gaming history laying down" (2021, p. 1,432) — a statement evocative of conclusions drawn by Heineman, Newman, Guins, and Custodio, and even reminiscent of Davis's description of vinyl enthusiasts. Though written about homebrew software developers, Swalwell's observation that "users are

demonstrating not only that the 8-bit era is not obsolete but, by making something new with something old, they are exhibiting the dynamic relation between past and present" (2021, p. 148) is also applicable to user-driven modifications to hardware whose official lifespan has ended. That consumers are less willing to set aside both hardware and software the industry has deemed obsolete is clear from existing literature; it is also important to consider potential reasons why.

The Tactile and Embodied Experience

Published studies suggest that answers may lie in the significance of the physical relationship between players and their hardware. Custodio's book *Who Are You? Nintendo's Game Boy Advance Platform* opens not with a retrospective or summary of the device's official life or sales metrics but with a thorough description of the physical sensations evoked by a custom-modded console:

> I'm holding a Game Boy Advance (GBA). Or, at least, I'm holding an object that looks and feels uncannily like Nintendo's 2001 handheld videogame platform. Pressing any of the buttons is instinctive, each touch delivering a jolt of remembrance of patterns buried deep in muscle memory. The ergonomic curves of the chassis are a homecoming for fingers that spent many childhood years clutching the console in the back seat of my parents' Corolla. (2020, p. 1)

This leads into a list of ways in which the device differs from the original; the modded version features "a bespoke audio amplifier and speaker upgrade" (2020, p. 1) and "a rechargeable lithium ion battery" (2020, p. 1), while new backlighting has rendered the display "crisp and dazzlingly bright—a balm for eyes that are no longer the indefatigable ones of a ten-year-old" (2020, p. 1). The order in which Custodio makes these observations is significant; she has chosen to open her account not with the quality-of-life upgrades present in the modded device but instead with the ways in which it "feels uncannily like" (2020, p. 1) the specific Game Boy Advance she remembers from childhood. An emphasis on the tactile connection between player

and device is a recurring theme in hardware scholarship: Timothy Crick's statement that "the control device acts as an extension of the player's body" (2011, p. 266) and Graeme Kirkpatrick's evaluation that "controllers represent the bodies of players" (2011, p. 112) evoke Marshall McLuhan's assessment that "any invention or technology is an extension or self-amputation of our physical bodies" (1964, p. 54). Similarly, Brendan Keogh states that "without the player's playing body coupled to the videogame through an input device, there is no video-game experience to consider otherwise" (2018, p. 87) and that games "demand particular integrations of flesh, sensorial perception, hardware, and audiovisual signs" (2018, p. 171). Input devices have been analyzed from semiotic (Blomberg, 2018), ergonomic (Ting & Hedge, 2001), and accessibility (Anderson & Schrier, 2021) perspectives, among others; the experience of playing a game is as connected to the sense of touch as it is to the senses of sight or sound — or, as Daniel Reynolds argues, "the experience of gameplay does not occur *in* the mind or *on* the screen, but *across* the dynamic between body, hardware, and game" (2016, para. 7). The reliance of certain games' intended playing experience on specific hardware has also been observed (Carta, 2017).

Attempts to retain or enhance the physical connection between player and game therefore have relevance in preservation efforts; in their assessment of methods for preserving console games, Mark Guttenbrunner et al. note that "the presentation of the original look and feel was considered to be of the highest priority" (2010, p. 81). A.J. Rappaport also addresses the importance of a "subjective perception of a controller's *feel*" (2020, p. 50) to the ways in which competitive *Super Smash Bros. Melee* players may modify GameCube controllers to act as more effective extensions of their physical selves. A player's way of holding or gripping the controller may vary according to ergonomic or accessibility needs, or even on the in-game mechanics of

their preferred character (Rappaport, 2020, p. 45); divergence between the way in which a player wants a controller to react and the way it reacts in reality may lead to a desire for functional changes to the device (Rappaport, 2020, p. 51). The physical connection between the player and their device is deeply personal, one that may motivate either the preservation or customization of original hardware through modification. This personal connection to the device also runs through the practice of aesthetic modifications. Language used by Crick and Kirkpatrick about extensions and representations of the player's body has implications beyond the mechanical process of interacting with the game; Rappaport likens the act of playing with an aesthetically modified controller to "trying on a new outfit to boost one's confidence" (2020, p. 55).

Tools for Self-Expression

The potential for self-expression afforded by hardware mods is a theme in scholarship about PC case mods and custom builds, practices in which users adjust parts of a computer's machinery or build a new device in order to attain a desired level of machine performance (Simon, 2007). Bart Simon notes that case modders who make performance-motivated hardware adjustments often also modify the device aesthetically to draw attention to their functional changes. This is contrary to industry design trends intended to "hide the hardware or disguise it" (2007, p. 180) — a philosophy he also associates with game consoles, observing that "the goal of console and console game design is to minimize the hardware and maximize the spectacle of the gaming experience" (2007, p. 181). A computer modder, Simon notes, benefits from the "increasingly modular system of upgradability" (2007, p. 181) in which original manufacturers actively sell replacement and upgrade components, whereas console manufacturing has historically been a closed process. Despite these differences, Simon's description of case modding as "a means of self-expression and, importantly, a means of demonstrating machine

knowledge and skill" (2007, p. 187) is echoed closely in Custodio's summary of users' modding of the Game Boy Advance console "as a way of demonstrating their technical mastery and aesthetic preferences" (2020, p. 23). Similarly, Rappaport's statement that accessory mods "often signify the player's alignment in a given community or fandom or reveals parts of their identities to which they wish to draw attention" (2020, p. 52) is reminiscent of Walt Scacchi's acknowledgement of "a game player's interest or technological projection of self–identity onto their game play platform" (2010, para. 20) as a key motivation for creating and using case mods. Custodio also draws a line between the practice of fan-driven modifications for the purposes of self-expression and Nintendo's "Who Are You?" campaign, which advertised the officially sanctioned customization options present in the "SP" Game Boy Advance model (2020, p. 23). The SP, a redesigned version of the Game Boy Advance, was sold in a range of shell colours "to suit all personalities" (Custodio, 2020, p. 22); the advertising campaign assigned personality traits to the colours themselves through the depiction of the console as an anthropomorphized object, an act of transforming the device "into something relatable, something that can be absorbed into the player's sense of self and subsequently used to broadcast their identity to others" (Custodio, 2020, p. 23). The Game Boy Advance SP and its advertising were neither the first nor the last official incorporation of opportunity for players' personal expression into corporate design: consoles and accessories have long been released or re-released in an array of colour options or in game-related limited editions, a trend Guins attributes to "a collector's culture" (2016, p. 70). First produced in 1995, Nintendo's "Play It Loud" Game Boy series recast the device, functionally unchanged from its original 1989 release, in a new range of shell colours (Reynolds, 2016; Valdovinos, 2018). More recently, Microsoft has afforded players the option to design and purchase custom controllers, with colours selectable on a component-by-component

basis, through its Xbox Design Lab (Eisenbardt, 2021). These customization options, however, are limited to what a manufacturer provides; a player who wants greater creative control over the final product, or a wider range of options than what is being officially offered, may take matters into their own hands.

A Layering of Technologies

Published research also suggests that modding allows users to leverage current technologies to extend a device's lifespan or to bring its performance more in line with present-day expectations while maintaining a sense of historical authenticity. Simon observes that the practice of PC case modding "ostensibly began with users' desire to increase the performance of their computer systems" (2007, p. 184) by adding components that were not part of the original build. Mentions of adding or changing functionality also appear in existing literature about modding game consoles and related devices. The account of the custom-modded Game Boy Advance that opens Custodio's book singles out the addition of a newly backlit screen, upgraded speaker, and rechargeable battery; she later notes that changes of this nature reflect "the expectations we have of our electronics in the present moment… Context always mediates our approach to a platform" (2020, p. 205). A player may, in other words, wish to preserve the *feel* of a device while incorporating technologies and quality-of-life features that were not present during its official life cycle. Custodio further posits that these technological upgrades may create a device that "paradoxically feels truer to what we might consider the 'original' object" (2020, p. 2) despite the use of "knowledge protocols and material objects of nearly two decades of technological development" (2020, p. 2). This is evocative of what Guins describes as "extended or repurposed and recontextualized uses" (2014, p. 7) in his definition of a device's afterlife history, of the act of being "reinterpreted, adapted, or reinvented" summarized by Eglash (2004,

p. ix), and of the imposition of public or vernacular memory on a history outlined by Heineman and illustrated by Harris. The extension of an older device's life through new technology also suggests a stand against planned obsolescence as described by Davis, Newman, and Custodio; rather than abandon such devices in favour of newly released models, modders may adapt them to better suit the present day.

Looking Ahead

It is apparent that player-driven hardware modifications, while by no means a new or recent practice, are an increasingly important aspect of video game culture. A survey of existing scholarship reveals significant research by Custodio and Rappaport that specifically addresses the topic of altering and modifying specific discontinued hardware within the context of the history and ongoing life of a specific platform and of communities devoted to particular games. These studies touch on the creation of small and freelance modding businesses and the importance of modding to competitive gaming communities, although opportunities for further studies of these areas also exist. Simon's study of PC case modding and Swalwell's research concerning the history of both software and hardware aspects of homebrew gaming provide historical context to the functionality- and aesthetic-driven modifications to physical devices; this scholarship also provides a basis for a broader exploration of the reasons modders have for working on hardware. Adjacent literature about obsolescence, life cycles, afterlife history, preservation, and competing versions of memory also suggest possible research avenues concerning the causes and impacts of these practices. The motivations of *software* modders have also been thoroughly documented. Work by Hector Postigo (2007) suggesting three themes in the motivations of "fan-programmers" (p. 300) — that they are drawn to software modding "as an artistic endeavor" (p. 309), because it "increased their enjoyment of game play" (p. 309), and in

order to “use their experience creating add-ons to acquire a job” (p. 310) — has provided a basis for further study of this topic (Sotamaa, 2010; Poor, 2013; Curtis et al. 2021). Such research provides a foundation for *comparison* with the activities and motivations of hardware modders; however, in order to assemble an understanding of the range of hardware modding activities, to determine the motivations of those who engage in them, and to assess the extent to which they correspond with those of their software-focused counterparts, it is necessary to hear from the modders themselves.

Methodology

This study aims to record details about video game hardware modifications that have not yet been the focus of published scholarship. As these details include quantitative data about specific activities as well as qualitative information about what motivates participation therein, a mixed-method approach was required. Two means of data collection — an anonymous online survey combining quantitative and qualitative questions, and a series of private interviews focusing primarily on qualitative topics — were employed. Existing research into the activities and motivations of video game software modders served as a model in preparing these methods. Responses relating to motivation collected in this study were also compared to previously published results in order to situate the motivations of hardware modders alongside those of their software-modding counterparts and to broaden existing understanding of what may drive all forms of video game-related modding.

Existing Studies

Published research by Hector Postigo (2007) and Olli Sotamaa (2010) concerning the motivations of video game software modders formed a basis for the current study's design. Primarily an investigation of the hypothetical monetary value of modding work performed by fans of the computer game *Battlefield 1942*, Postigo's study also investigated what motivates individuals to engage in such modding activities. Results pointed to three recurring themes: modding as artistic endeavour, as a means of contributing to a community, and as a way of acquiring experience that could lead to work in the game development industry (2007, pp. 309-310). Sotamaa built upon Postigo's research in his own exploration of the motivations of software modders, expanding the three categories that emerged in the existing study to five more specific topics: playing, hacking, researching, artistic expression, and cooperation (2010, p. 246).

Postigo and Sotamaa each employed open-ended questions about motivation in their research; this study takes a similarly fluid approach to this question in order to avoid influencing participants' responses and in order to obtain as much information as possible in modders' own words. Nathaniel Poor (2013)'s investigation into the motivations of software modders also employed a mixed-method approach; Poor's survey used quantitative measurements to assess participants' sense of community, attitudes towards play, learning methods, and reasons for modding (pp. 1,253–1,257), while subsequent online discussions about the survey served as "an informal qualitative interview" (p. 1,261). Although the specific research design of Poor's study did not serve as a direct model for this paper, it is an important example of a mixed-method examination of video game modding and the motivations that drive it.

Survey

In their study of pseudonym usage in online video game communities, Anne Clara Tally et al. (2021) observe that "players seek to both protect themselves as individuals, and to be welcomed as members of a specific gaming community, as they manage both personally identifying and personally meaningful information" (p. 2), further arguing that screen names "can be used to both protect and project identity, drawing important boundaries according to the user's wishes" (p. 6). This is consistent with initial observations of online hardware modding communities; many modders similarly opt to discuss and promote their activities while keeping their true identities confidential. Consequently, an anonymous survey provided the greatest potential for encouraging wide participation in the study while respecting modders' desire for confidentiality. As tangible incentives for participation were not offered, the likelihood of deliberately false or repetitive submissions is believed to be low or non-existent. No demographic or other identifying information was requested as part of the survey, which was

designed to be completed within 15 minutes. Responses were accepted between May 25, 2023, and June 15, 2023. One hundred participants were initially sought; this total was reached on June 2, 2023, and a revised maximum of 250 participants was submitted to the Research Ethics Board. The survey received 107 responses in total.

Structure

The survey was built using Google Forms in accordance with the recommendations of Toronto Metropolitan University's Research Ethics Board (REB) as well as its Computing and Communications Services (CCS). Google Forms provides some opportunity for conditional branching, which allowed respondents to be directed to a specific section based on their answers to previous questions. As a result, not all of the questions were intended for all of the participants. Google Forms's conditional options have some limitations, however: only multiple choice and dropdown question formats provide the ability to direct a respondent to a specific section based on their answer. The nature of some of the questions necessitated a checkbox format so that participants could select all relevant options; it was not possible to direct participants to specific sections based on their responses to such questions.

Introduction

The survey's opening page outlined key information about the study: the topic of and reasons for this research; the identity of the primary investigator and supervisor; the tasks being asked of prospective participants; potential benefits and risks to participants; the anonymous nature of the survey; plans for protection, storage, and eventual destruction of data; means of accessing results; participant rights; how to contact the primary investigator or supervisor with questions; the study's review and approval by the Toronto Metropolitan University Research Ethics Board. Participants were advised to print a copy of this page for their reference. Google

Forms automatically confirmed whether the participant was logged into a Google account as well as the fact that this survey would not collect this information if so.

Section 1: Eligibility

The sole criterion for participation in the survey portion of this study was self-identification as a modder of video game hardware. The first question asked respondents "Do you mod video game hardware?" This was the survey's only required question; all others could be bypassed without selecting any answer. Participants who selected "Yes" were directed to Section 2. Those who selected either "No" or "Prefer not to answer" were directed to a section explaining that the survey was specific to modders of hardware and that its contents would not be relevant to individuals who do not engage in this practice. This section included the option to end the survey by submitting the form.

Section 2: Types of Hardware Mods

Participants who were directed to Section 2 were asked "Do you mod/have you modded game consoles (including handheld and TV consoles), accessories (including controllers or cords) or both?" and provided with a list of responses that included the option "Prefer not to answer" (which was provided wherever possible throughout the survey). Conditional branching was used to determine which section the respondent saw next based on their selection or lack thereof; selecting "Consoles", "Accessories", or "Both" sent participants to Sections 2A, 2B, or 2C, respectively, while those who selected "Prefer not to answer" or skipped the question without selecting a response were directed to Section 3.

"Consoles" → Section 2A: Types of Hardware Mods: Consoles

Participants who selected "Consoles" were directed to a section consisting of three questions specific to console modding. The first of these was a multiple-choice question asking

whether the participant modifies handheld consoles, TV-based consoles, or both. A checkbox-based question asked which companies' hardware the respondent modifies; Nintendo, Sony, Sega, and Microsoft were provided as options, as was an "Other" field participants could use to manually enter companies that had not been listed. The second checkbox-based question asked about means by which respondents create or customize modding parts; 3D printing, casting, painting, and dyeing were provided as options alongside an "Other" field that allowed manual content entry.

"Accessories" → Section 2B: Types of Hardware Mods: Accessories

Participants who selected "Accessories" in Section 2 were directed to a separate section consisting of three questions. The first of these was a multiple-choice question asking whether the respondent mods officially released accessories, aftermarket or third-party accessories, or both. The checkbox-based questions asking which companies' hardware the participant mods and means by which they create or customize modding parts, outlined in section 2A, were also asked of these participants. The question about manufacturers included a note advising respondents who mod third-party or aftermarket hardware to select the manufacturers whose products the third-party or aftermarket devices were intended to be used alongside. For example, an independent manufacturer may unofficially produce controllers intended to be compatible with the PlayStation 5 console. A participant who mods such controllers should select "Sony" from the provided list of companies despite the fact that Sony did not produce the device. This reflects the fact that the "target" hardware was of greater importance to this study than specific third-party manufacturers. Aftermarket manufacturers may also produce devices or accessories intended to be used with the hardware of multiple competing official manufacturers. Participants

were asked to specify the compatible official manufacturer instead of the third-party manufacturer in order to preserve the clarity of responses.

"Both" → Section 2C: Types of Hardware Mods: Consoles & Accessories

Participants who answered "Both" in Section 2 were directed to a section in which they were asked a total of four questions: the question about handheld and TV consoles outlined in Section 2A, the question about official releases and third-party or aftermarket accessories outlined in Section 2B, and the two checkbox-based questions about manufacturers and the creation of custom modding parts outlined in Sections 2A and 2B.

Section 3: Products

As the question about manufacturers that appeared in all sub-sections of Section 2 used the checkbox-selection format to allow multiple responses, conditional branching based on responses to this question was not possible. In order to collect more detailed information about the hardware they mod, all participants who completed Section 2 were shown lists of specific products manufactured by Nintendo, Sony, Sega, and Microsoft, and asked to select all applicable options. As the total number of hardware options exceeded 50, it was not desirable to present them in a single question. A note was included in the question text advising participants to skip the question by clicking the "Next" button if a company was not relevant to them. An effort was made to provide a comprehensive list of major hardware releases by each company; the list pertaining to each company also featured an "Other" option that allowed respondents to manually input any products that had not been listed. Following questions about the four listed companies' products, participants were also asked about any other products they had modded and provided with an open text field for their responses.

Section 4: Modding History

Participants were asked, via a multiple-choice question, how long they had been modding video game hardware. The options were “Less than a year”, “1-2 years”, “2-4 years”, and “4+ years”. Respondents also had the option to indicate that they preferred not to answer this question or to skip the question without selecting any of the options.

Section 5: Purpose of Modding

The next section asked respondents “Do you mod game hardware for functional purposes, aesthetic purposes, or both?” The options were provided as multiple-choice answers in addition to an option indicating that they preferred not to answer this question. Definitions of “functional” and “aesthetic” were provided: the former was defined as any mod that impacts gameplay or device life, such as changes to the display or power source; the latter was defined as any mod that changes the look of the device without impacting gameplay, such as button or shell swaps, or the addition of lighting or other parts that do not affect gameplay, such as the use of decorative LEDs. For the purpose of clarity, this lighting is distinct from screen backlighting. The provided answer determined which sub-section the participant saw next; those who skipped the question or selected “Prefer not to answer” were directed to Section 6.

“Functional” → Section 5A: Functional Modding

Respondents who selected “Functional” in Section 5 were asked “What type of functional mods do you perform?” Four answers were supplied — “Screen/display upgrades (including backlighting)”, “Battery pack installation”, “Durability-focused part replacements (including replacing plastic parts with metal equivalents)”, and “Audio amplification or enhancement” — and participants were asked to check all relevant items. An option to manually enter “Other”

answers was also provided, as was an option indicating that the respondent preferred not to answer this question.

"Aesthetic" → Section 5B: Aesthetic Modding

Respondents who selected "Aesthetic" in Section 5 were asked "What type of aesthetic mods do you perform?" and invited to check all applicable answers: "Shell swap/replacements", "Button swap/replacements", "Painting or dyeing of existing shells/buttons", "Cord swap/replacements", and "Addition of lighting/LEDs for aesthetic purposes". An option to manually enter "Other" answers was also provided, as was an option indicating that the respondent preferred not to answer this question.

"Both" → Section 5C: Functional & Aesthetic Modding

Selecting "Both" in Section 5 led respondents to a section that asked all of the questions outlined in Sections 5B and 5C.

Section 6: Business & Hobby Activities

In this section, participants were asked "Do you sell or have you sold modded hardware to others in exchange for financial compensation?" Selecting "Yes" led to Section 6A, which asked questions relating to business activities; selecting "No" led to Section 6B, which focused on hobby activities. As the question was centred around whether or not a participant sells or has sold modded hardware, a "Both" option was not provided; it was assumed that respondents who sell modded products may also engage in modding as a hobby. Selecting "Prefer not to answer" or skipping the question without providing an answer led directly to Section 7.

"Yes" → Section 6A: Business Activities

This section contained nine questions, beginning with "Do you sell completed mods (including full console or controller builds), parts (including shells, buttons, or other

components), or both?" Participants were asked to select all applicable answers from a list consisting of "Completed console mods", "Completed controller mods", "Console mod parts", and "Controller mod parts". An option indicating a preference to not answer was also provided. Participants were next asked two multiple-choice questions about how much they charge per completed console mod and completed controller mod. Given the prominence of U.S. currency in the online hardware modding market, respondents were asked to treat all of the provided figures as USD. Each list of answers consisted of seven price points increasing in $50 increments and spanning from $1 to $301 and up. An option to indicate a preference not to answer was provided for both questions. As Section 6A's first question about the types of products sold enabled the selection of multiple responses, it was not possible to use conditional branching to determine whether respondents saw one, both, or neither of the follow-up questions about pricing. As such, "I don't sell console mods" and "I don't sell controller mods" options were included as options for each of these questions.

The Business Activities section continued with a question about whether participants take commissions (whether those commissions are currently open or closed), sell pre-built mods, or both. This multiple-choice question also included an option indicating a preference to not answer. Participants were then asked how many products they sold in the calendar year 2022; a series of multiple-choice options spanning from 1 to 21 or higher was provided, as was an option to indicate a preference to not answer. Three questions permitting multiple answer selections followed, asking "How do you advertise your mods and/or parts?", "What platforms/methods do you use to sell your mods and/or parts?", and "How do you obtain parts for modding hardware?" A range of options was included in each question's list of potential answers, including social media platforms, word of mouth, and well-known e-commerce services including Shopify and

Etsy. As with the survey's other checkbox-based questions, an option to manually enter a response under "Other" was included.

This section ended with an open-ended question asking "What motivates you to modify game hardware and accessories and sell the results?" Answers to this question were collected via open text field; answers using the participant's own words were desired, and this method avoided influencing responses through the use of suggestions or prompts. This mirrors the qualitative approach taken by Postigo (2007) and Sotamaa (2010) in their earlier research about the motivations of software modders. As Google Forms's "short answer" question format provides a single text field, participants were advised via the question text that they may opt not to answer this question by clicking the "Next" button without inputting a response.

"No" → Section 6B: Hobby Activities

Participants who indicated that they do not sell mods were asked "Have you modded your own devices or purchased devices with the intent to mod them?" and provided with the multiple-choice answers "Yes", "No", "Both", and "Prefer not to answer". They were then asked an open-ended question similar to the question put to respondents who were directed to Section 6A that asked "Why do you modify game hardware as a hobby?" As with the related question in Section 6A, participants were advised that they may skip this question by clicking the "Next" button without inputting a response.

Section 7: Modding Communities

The survey's final question asked participants "Do you participate in any communities relating to game hardware modding?" and provided a checklist of potential answers: "I follow and interact with other modders on social media", "I belong to online modding groups such as Discords or message boards", "I attend in-person events where modding is a focus", and "I do

not participate in game hardware modding communities". The ability to select "Other" and specify was also provided, as was the option to indicate that the respondent preferred not to answer the question.

Section 8: Submission

Participants were thanked for filling out the survey and reminded that submitting the form constituted full consent to participate in the study. The fact that submitted data could not be deleted upon request was reiterated. A final mention was made of the study's review and approval by the Toronto Metropolitan University Research Ethics Board.

Distribution

The primary investigator and supervisor shared the survey link on the social media networks Twitter and Mastodon; the primary investigator also distributed the survey link on approximately 30 video game-related Discord servers after obtaining the permission of the server administrators or moderators. Several of these servers focused specifically on game hardware modding; others were devoted to modding in general (including software) or to discussion of specific game consoles or manufacturers. Some servers were identified through web searches and open directories of public servers whose focus was relevant to this study. The primary researcher also received private suggestions about other modding- or hardware-focused servers whose membership may be interested in the study from several individuals who had seen the survey advertised; the initial tweet was also retweeted by several individual modders and accounts associated with retro gaming communities.

Interviews

Observation of hardware modding communities indicated that some modders maintain significant online presences devoted to this practice. These presences include running websites and online storefronts, running and maintaining wikis and other informational or "how-to" sites, and moderating online forums and servers. This willingness to be openly seen as hardware modders and to engage in discussion about modding strongly implied that at least some of these publicly active community members would be open to participating in interviews for this research. A precedent for such willingness is reflected in existing studies: Yong Ming Kow and Bonnie Nardi (2010) interviewed 15 *World of Warcraft* modders, "including leaders of the WoW modding community" (para. 12), in their research about the ownership of software mods; Leônidas Soares Pereira and Maurício Moreira E Silva Bernardes (2021) conducted nine interviews with software modders as part of their study of what led mod software modding to expand beyond amateur practice (p. 154); Daniel Nielsen and Alessandro Nanì (2021) also interviewed nine software modders in their exploration of the "moral economy" (p. 285) created by modders' free labour as it relates to the professional video-game industry.

Recruitment

Eight individuals who actively publicize their involvement in hardware modding were privately approached about participating in the study via interviews. As a demonstrated willingness to be contacted about modding was a prerequisite for consideration, requests were sent to email addresses that had been voluntarily published on personal modding-focused websites or on social media profiles, or through website contact forms. The request outlined the parameters of the study and explained that participants were sought for individual interviews of no more than one hour taking place over Zoom. Specific requirements for participation,

including the necessity of recording audio, were also disclosed. Recipients were told about the option to complete the anonymous survey should they wish to be involved in the study but not to be interviewed. Contact information was provided for both the primary researcher and supervisor in the event that prospective interviewees had questions or otherwise wished to discuss the interview process before making a decision.

Structure

While there was some overlap with the quantitative portions of the survey, such as questions about how long the interviewee had been involved in hardware modding and the types of hardware modding they engage in, interviews were largely qualitative in nature. The prepared interview guide covered topics such as what motivates the interviewee to mod game hardware and how they would explain hardware modding to someone who was unfamiliar with the practice, though the semi-structured nature of the interview permitted open discussion and allowed the primary investigator to follow up on participant statements. The identities of the interview participants were known to the primary researcher and supervisor but treated confidentially in the completed study; interviewees were assigned an anonymized identifier that was used for attribution in the final report.

Consent

In accordance with ethics requirements, the interviewee's ongoing consent to participate was an important part of this process. Interviewees were asked to fill out a consent form confirming their intention to participate and their permission to aurally record the interview. Participants were free to withdraw their consent to participate at any point, including after the completion of their interview, up until 11:59pm ET on July 15, 2023; information gathered in any interviews with participants who withdrew their consent was not used in the study. The form

provided the option to consent to the use of direct quotations from interviews; this was not a requirement of participation but did clarify which interviewees were willing to have their statements quoted directly (attributed to the anonymized identifier). Participants were informed that consenting to participation in the study but not to the use of direct quotations would result in their information being paraphrased in the final paper.

Data Storage

Recordings of the interviews were stored locally on the primary researcher's computer until the completion of a transcript, at which point the recordings were deleted. The contents of the interview were transcribed manually; this eliminated the need to assess the storage and privacy practices of online transcription services. PDF versions of each transcript were uploaded to a Google Drive to which the primary researcher and supervisor had access. Each participant was offered the opportunity to access to their individual transcript file in order to review it for accuracy. Interviewees were asked to submit any concerns about accuracy to the primary researcher via email by July 1, 2023. The Toronto Metropolitan University Research Ethics Board approved the primary investigator's plan to retain the survey data and interview transcripts for six months following final submission of the major research paper, with deletion to follow.

Results

This research was designed as a mixed-method investigation of the actions and motivations of video game hardware modders; the survey was intended as a means of gathering primarily quantitative data alongside a limited number of qualitative open-ended questions, while interviews were expected to be predominantly qualitative in nature. Responses to the survey subverted these expectations somewhat. Several multiple-choice questions included an "Other" option that provided participants with the ability to submit written responses; respondents occasionally used this feature to contextualize their other selections or to write longer responses that touched on related topics in addition to or instead of the original question. These submissions nonetheless provide valuable information about the activities and motivations of hardware modders. As a result of these qualitative details, the results of this study are best presented thematically; this allows survey respondents' interjections to be noted in the appropriate place regardless of which question prompted it. It also facilitates the inclusion of relevant references from the interviews and provides a foundation for the next section's analysis and contextualization of this study alongside existing research.

Survey Participation

Three of the survey's 107 responses did not contain associated data because the participants selected "No" or "Prefer not to answer" in response to the eligibility-screening question asking whether they consider themselves modders of video game hardware. A respondent who said they had selected "Prefer not to answer" later reached out to the primary researcher to inquire about the length of the survey; their selection had caused them to bypass all questions and be directed to the submission page. It transpired that they had chosen "Prefer not to answer" as a result of not being certain whether the activities they engage in constituted

hardware modding as per the parameters of the study. After determining that these activities were within the scope of the research, the individual expressed an interest in resubmitting the survey. Given that they later informed the primary researcher that they had completed the full survey, it is believed that they are also captured in the 104 responses containing usable data. As no data were captured from participants who selected “No” or “Prefer not to answer”, this resubmission does not skew the results of the study. For the purpose of discussing results, the 104 individuals who submitted “Yes” responses are considered to be survey respondents; the three submissions that did not contain usable data will not be discussed further.

Interview Participation

Two of the eight individuals who had been contacted with requests for interviews responded and expressed willingness to participate; one of these individuals, who runs a console modding and repair business in addition to having an unrelated full-time job (Interviewee 3), filled out the consent form and agreed to a time and date to speak to the primary researcher over Zoom. The primary researcher also received an email from an employee of an online retailer of hardware modding and repair parts who had seen the survey advertised on social media. This individual (Interviewee 1) agreed to be interviewed alongside a coworker (Interviewee 2); these participants filled out separate interview consent forms and were interviewed simultaneously. Interviews took place over Zoom on June 5 and June 6, 2023. It is not believed that any of the interviewees also completed the survey.

Synopsis of Results

The survey and interviews present a wide-ranging view of video game hardware modding as both a business practice and a hobby. A review of the survey data provides context as to the types of modding activities being performed and reveals patterns concerning the popularity of

certain hardware and manufacturers and the factors that motivate modders. The current section of this major research paper contains a high-level overview of the information gathered via surveys and interviews; the following section will discuss key results in connection with published research about software modding as well as other existing scholarship about game hardware. The results of quantitative survey questions are presented in tables throughout this section. As conditional branching enabled survey participants to be directed to different subsections based on their answers to certain questions, results of follow-up questions may be discussed both using the resulting segmentation and in aggregate.

Types of Hardware Modding

Quantitative Breakdown of Consoles and Accessories

Responses to the survey's opening question concerning the types of hardware participants mod indicate that more than three-quarters (78.85%) of respondents mod both consoles and accessories (Table 1); an exclusive focus on modding consoles was more common than an exclusive focus on modding accessories. Participants who mod both consoles and accessories were also more likely to indicate that they mod both handheld and television-based consoles (Table 2) and both original and third-party, or aftermarket, accessories (Table 3) than those who exclusively mod consoles (Table 4) or those who exclusively mod accessories (Table 5). Among those who indicated that they focus on a specific type of console, results were evenly or nearly evenly divided between handheld and TV consoles.

Table 1
Types of Hardware Mods Performed

Type of Hardware Mod	Responses (% of 104 Respondents)
Consoles	16 (15.38%)
Accessories	6 (5.77%)
Both	82 (78.85%)

Table 2
Types of Console Mods by Participants who Mod Consoles and Accessories

Type of Console Mod	Responses (% of 82 Participants)
Handheld consoles	8 (9.76%)
TV consoles	8 (9.76%)
Both	66 (80.49%)

Table 3
Types of Accessories Modded by Participants who Mod Consoles and Accessories

Type of Accessory Modded	Responses (% of 82 Participants)
Official/original	26 (31.71%)
Aftermarket/third-party	3 (3.67%)
Both	53 (64.63%)

Table 4
Types of Console Mods Performed by Participants who Exclusively Mod Consoles

Type of Console Mod	Responses (% of 16 Respondents)
Handheld consoles	6 (37.5%)
TV consoles	5 (31.25%)
Both	5 (31.25%)

Table 5
Types of Accessories Modded by Participants who Exclusively Mod Accessories

Type of Accessory Modded	Responses (% of 6 Participants)
Official/original	3 (50%)
Aftermarket/third-party	0 (0%)
Both	3 (50%)

Manufacturers and Products

Information about the specific products that participants mod, as well as the manufacturers that produce them, was gathered over the course of multiple survey questions. Responses indicate that that the supplied responses of Nintendo, Sony, Microsoft, and Sega were, in descending order of frequency, the most commonly selected manufacturers (Table 6), a ranking that is reinforced by the total number of responses received for the product-specific questions about each company. The question about manufacturers included an "Other" option; Atari was the company most frequently selected through this method. Participants also indicated that they mod products manufactured by (in descending order of frequency) NEC, Coleco, Apple, Bandai, Konami, Mattel, Motorola, Samsung, SNK, and Commodore.

Table 6
Responses about Manufacturers (Aggregate)

Company	Responses (% of 104 Respondents)
Nintendo	93 (89.42%)
Sony	65 (62.5%)
Microsoft	53 (50.96%)
Sega	41 (39.42%)
Atari	6 (5.77%)
NEC	4 (3.85%)

Company	Responses (% of 104 Respondents)
Coleco	2 (1.92%)
Apple	2 (1.92%)
Bandai	2 (1.92%)
Konami	1 (0.96%)
Mattel	1 (0.96%)
Motorola	1 (0.96%)
Samsung	1 (0.96%)
SNK	1 (0.96%)
Commodore	1 (0.96%)

All participants were shown lists of major hardware releases by Nintendo, Sony, Microsoft, and Sega, and asked to select the products that they mod or have modded (Tables 7–10). Several patterns emerged across results relating to these products (Table 11): television consoles generally outnumber their respective controllers across all four of the major manufacturers; this trend appears to be reversed, however, when examining recent- and current-generation consoles. The Nintendo Switch joycons are the most frequently modded controllers by participants in this study, outnumbering selections of the Switch console itself. As many respondents indicated that they mod PlayStation 4 controllers as PlayStation 4 consoles, and selections of the PlayStation 5 console were outnumbered by that device's controllers. Similarly, more respondents indicated that they mod Xbox One and Xbox X/S series controllers than their respective consoles.

Comments by Interviewee 3 may provide an explanation for this trend: in response to a question about whether he specializes in modding and repairing particular hardware, he stated that he works on consoles exclusively and declines requests to work on controllers because

"controllers are a consumable part of the system" and that manufacturers sell replacements "because the assumption is you're going to break the controller… The consoles, on the other hand, are the expensive part of the system". The cost of acquiring or replacing recent- and current-generation consoles may make them less appealing subjects for modders; this study did not collect sufficient data to draw conclusions on this topic, but the question may provide an interesting foundation for further research.

Table 7
Responses about Specific Nintendo Products

Nintendo Product	**Responses (% of 98 Respondents)**
Game Boy Advance (including SP model)	62 (63.27%)
Game Boy Color	57 (58.16%)
GameCube console	52 (53.06%)
Game Boy (DMG)	50 (51.02%)
Wii console	48 (48.98%)
Nintendo DS (including DS Lite model)	42 (42.86%)
Nintendo Switch joycons	41 (41.84%)
Nintendo 64 console	40 (40.82%)
Game Boy Pocket	39 (39.8%)
Nintendo 3DS (or 2DS)	37 (37.75%)
GameCube controllers	37 (37.75%)
NES console	35 (35.71%)
Nintendo Switch console	35 (35.71%)
SNES console	33 (33.67%)
Nintendo 64 controllers	29 (29.59%)
SNES controllers	22 (22.45%)
NES controllers	19 (19.39%)
Wii controllers (Wiimote, "Classic" controllers)	19 (19.39%)

Nintendo Product	Responses (% of 98 Respondents)
Wii U console	11 (11.22%)
Wii U GamePad/Pro Controller	5 (5.1%)
Prefer not to answer	1 (1.02%)
Other: Switch Pro controller	1 (1.02%)
Other: Game Boy Micro	1 (1.02%)
Other: SNES cartridges	1 (1.02%)
Other: Game & Watch Mario 35th Anniversary	1 (1.02%)
Other: Virtual Boy	1 (1.02%)
Other: Virtual Boy Stand and projection LED strips	1 (1.02%)
Other: Game Boy Advance cartridges	1 (1.02%)
Other: Game Boy Color cartridges	1 (1.02%)
Other: Nintendo 64 cartridges	1 (1.02%)
Other: Famiclones (aftermarket clone console compatible with Famicom games)	1 (1.02%)
Other: Aftermarket GameCube RGB SCART cable for SNES compatibility	1 (1.02%)

Table 8
Responses about Specific Sony Products

Sony Product	Responses (% of 73 Respondents)
PlayStation console (original or slimline)	47 (64.38%)
PlayStation 2 console (original or slimline)	45 (61.64%)
PlayStation Portable (PSP)	39 (53.42%)
PlayStation 3 console (original or slimline)	33 (45.2%)
PlayStation Vita	26 (35.62%)
PlayStation controllers	23 (35.51%)
PlayStation 2 controllers	20 (27.4%)
PlayStation 3 controllers	15 (20.55%)
PlayStation 4 console	10 (13.7%)
PlayStation 4 controllers	10 (13.7%)
PlayStation 5 controllers	7 (9.59%)
PlayStation 5 console	2 (2.74%)
Other: PlayStation 3D TV shutter glasses	1 (1.37%)
Other: PlayStation 2 multitap peripheral	1 (1.37%)
Other: PlayStation 3 memory card adapter	1 (1.37%)
Other: Third-party memory cards for PlayStation consoles	1 (1.37%)
Other: Action Replay (Game Shark) devices	1 (1.37%)

Table 9
Responses about Specific Sega Products

Sega Product	Responses (% of 46 Respondents)
Dreamcast console	29 (63.04%)
Genesis console	27 (58.7%)
GameGear	16 (34.78%)
Saturn console	15 (32.61%)
Genesis controllers	12 (26.09%)
Dreamcast controllers	11 (23.91%)
Master System console	9 (19.57%)
Saturn controllers	8 (17.39%)
Master System controllers	6 (13.04%)
32X console	4 (8.7%)
Other: Nomad	3 (6.52%)
32X controllers	2 (4.35%)
Prefer not to answer	2 (4.35%)
Other: SG-1000	1 (2.17%)
Other: Sega CD	1 (2.17%)
Other: JVC X'eye	1 (2.17%)
Other: Dreamcast Virtual Memory Unit	1 (2.17%)

Table 10
Responses about Specific Microsoft Products

Microsoft Product	Responses (% of 62 Respondents)
Xbox console	43 (69.35%)
Xbox 360 console (all versions)	37 (59.68%)
Xbox 360 controllers	33 (53.23%)
Xbox controllers	22 (35.48%)
Xbox One controllers	16 (25.81%)
Xbox One console (all versions)	11 (17.74%)
Xbox Series X/S controllers	6 (9.68%)
Xbox Series X/S console	3 (4.84%)
Prefer not to answer	1 (1.61%)
Other: Microsoft Surface Pro tablet	1 (1.61%)

Table 11
Aggregated Responses about Specific Manufacturers' Products

Product	Responses (% of 104 Survey Respondents)
Game Boy Advance (including SP model)	62 (59.61%)
Game Boy Color	57 (54.81%)
GameCube console	52 (50%)
Game Boy (DMG)	50 (48.08%)
Wii console	48 (46.15%)
PlayStation console (original or slimline)	47 (45.19%)
PlayStation 2 console (original or slimline)	45 (43.27%)
Xbox console	43 (41.35%)
Nintendo DS (including DS Lite model)	42 (40.38%)
Nintendo Switch joycons	41 (39.42%)
Nintendo 64 console	40 (38.46%)
Game Boy Pocket	39 (37.5%)
PlayStation Portable (PSP)	39 (37.5%)

Product	Responses (% of 104 Survey Respondents)
Nintendo 3DS (or 2DS)	37 (35.58%)
GameCube controllers	37 (35.58%)
Xbox 360 console (all versions)	37 (35.58%)
NES console	35 (33.65%)
Nintendo Switch console	35 (33.65%)
SNES console	33 (31.73%)
PlayStation 3 console (original or slimline)	33 (31.73%)
Xbox 360 controllers	33 (31.73%)
Nintendo 64 controllers	29 (27.88%)
Dreamcast console	29 (27.88%)
Genesis console	27 (25.96%)
PlayStation Vita	26 (25%)
PlayStation controllers	23 (25.12%)
SNES controllers	22 (21.15%)
Xbox controllers	22 (21.15%)
PlayStation 2 controllers	20 (19.23%)
NES controllers	19 (18.27%)
Wii controllers (Wiimote, “Classic” controllers)	19 (18.27%)
GameGear	16 (15.38%)
Xbox One controllers	16 (15.38%)
PlayStation 3 controllers	15 (14.42%)
Saturn console	15 (14.42%)
Genesis controllers	12 (11.54%)
Wii U console	11 (10.58%)
Dreamcast controllers	11 (10.58%)
Xbox One console (all versions)	11 (10.58%)
PlayStation 4 console	10 (9.61%)
PlayStation 4 controllers	10 (9.61%)

Product	Responses (% of 104 Survey Respondents)
Master System console	9 (8.65%)
Saturn controllers	8 (7.69%)
PlayStation 5 controllers	7 (6.73%)
Master System controllers	6 (5.77%)
Xbox Series X/S controllers	6 (5.77%)
Wii U GamePad/Pro Controller	5 (4.81%)
32X console	4 (3.85%)
Other: Sega Nomad	3 (2.88%)
Xbox Series X/S console	3 (2.88%)
PlayStation 5 console	2 (1.92%)
32X controllers	2 (1.92%)
Other: Switch Pro controller	1 (0.96%)
Other: Game Boy Micro	1 (0.96%)
Other: SNES cartridges	1 (0.96%)
Other: Game & Watch Mario 35th Anniversary	1 (0.96%)
Other: Virtual Boy	1 (0.96%)
Other: Virtual Boy Stand and projection LED strips	1 (0.96%)
Other: Game Boy Advance cartridges	1 (0.96%)
Other: Game Boy Color cartridges	1 (0.96%)
Other: Nintendo 64 cartridges	1 (0.96%)
Other: Famiclones (aftermarket clone console compatible with Famicom games)	1 (0.96%)
Other: Aftermarket GameCube RGB SCART cable for SNES compatibility	1 (0.96%)
Other: PlayStation 3D TV shutter glasses	1 (0.96%)
Other: PlayStation 2 multitap peripheral	1 (0.96%)
Other: PlayStation 3 memory card adapter	1 (0.96%)

Product	Responses (% of 104 Survey Respondents)
Other: Third-party memory cards for PlayStation consoles	1 (0.96%)
Other: Action Replay (Game Shark) devices	1 (0.96%)
Other: SG-1000	1 (0.96%)
Other: Sega CD	1 (0.96%)
Other: JVC X'eye	1 (0.96%)
Other: Dreamcast Virtual Memory Unit	1 (0.96%)
Other: Microsoft Surface Pro tablet	1 (0.96%)

The question specific to Nintendo products received 98 responses, the largest number of submissions; 73 participants submitted responses to the question about Sony products; 62 responded to the question about Microsoft products; 46 answered the question about Sega products. The popularity of Nintendo products among respondents was also echoed in comments by Interviewee 3; in response to a question about whether his modding and repair business focuses on the products of specific manufacturers, he said "there are some consoles that are more popular than others — anything starting with the word 'Nintendo' is super popular". The five most-selected Nintendo products were also the most-selected products overall, and a total of seven Nintendo products appear in the 10 most-selected products across all manufacturers alongside the PlayStation, PlayStation 2, and Xbox consoles. Of these seven, four (the Game Boy Advance, Game Boy Color, original or DMG Game Boy, and Nintendo DS) were handheld consoles. The survey's most frequently selected handheld produced by a manufacturer other than Nintendo was the PlayStation Portable — a product that was "able to significantly dilute Nintendo's monopoly" (Burak, 2021, p. 104) in the handheld market— which was selected by

more than half (53.42%) of the 73 participants who submitted a response to the question about Sony products.

The breakdown of product-related results by manufacturer-specific question suggests that distribution of participants' interest across a company's products varies by company. The results concerning Nintendo products, for example, suggest a broad allocation of respondents' modding history across the 20 listed devices. Fourteen of these products were selected by more than one-third of the respondents to the question. Conversely, only three of the 11 listed Sega products were selected by more than one-third of the respondents to that question. The Genesis (58.7%) and Dreamcast (63.04%) consoles were the most popular hardware produced by this manufacturer among modders who completed this survey; the GameGear (34.78%) and Saturn (32.61%) consoles were the next-most frequently selected pieces of Sega hardware. The popularity of the Genesis and Dreamcast among survey participants who mod Sega products is this study's clearest instance of two devices dominating a manufacturer's results.

The written submissions to these questions, as well as to the open-ended question inviting responses about products by other manufacturers (Table 12), also provide interesting insight into the range of hardware being modded. Respondents referred to multiple products released by Atari, Konami, NEC, Neo Geo, and Bandai, among others; responses ranged from early consoles such as the Atari 2600, to arcade cabinets, to contemporary game hardware such as the Steam Deck. The most frequently submitted written response concerning the four listed manufacturers was the Sega Nomad handheld console, which was mentioned by three participants. The open question about other manufacturers' products also received numerous responses that are not listed in Table 12. Some participants indicated that they mod game-related computers and computer parts, such as gaming mice and keyboards, without specifying individual

manufacturers. Computers were also referenced outside of the gaming context; one respondent mentioned having modded the Macintosh 512k and Macintosh SE; others discussed laptops, PCs, and implementing custom BIOS. Cell phones were also represented in these results, with some respondents specifying models (the Samsung Galaxy S20 and Motorola G Play both received mentions) and others referencing phones in general. A widespread affinity for making physical modifications to electronics is apparent both in the range of devices present in the results as well as the fact that the comments “pretty much any electronic device I get my hands on”, “anything I can get my hands on”, and “anything really” were each submitted as responses to this question.

Table 12
Video Game-Related Responses to Open-Text Question about Other Products

Other Product	**Responses (% of 46 Written Responses)**
Atari 2600	4 (8.7%)
NEC TurboGrafx-16/PC Engine	4 (8.7%)
Neo Geo Pocket Color	4 (8.7%)
Bandai Wonderswan Color	3 (6.52%)
Atari Lynx	2 (4.35%)
Commodore 64	2 (4.35%)
Bandai Wonderswan	2 (4.35%)
Atari 5200	1 (2.17%)
Atari 7800	1 (2.17%)
ColecoVision	1 (2.17%)
Mattel Intellivision	1 (2.17%)
Atari arcade cabinets	1 (2.17%)
Konami arcade cabinets	1 (2.17%)
3DO Interactive Multiplayer	1 (2.17%)
Neo Geo MVS/AES	1 (2.17%)
Valve Steam Deck	1 (2.17%)

Other Product	Responses (% of 46 Written Responses)
NEC Super CD-ROM²	1 (2.17%)
NEC Interface Unit	1 (2.17%)
Neo Geo	1 (2.17%)
Neo Geo Pocket	1 (2.17%)
NEC TurboExpress	1 (2.17%)
MiSTer FPGA Hardware	1 (2.17%)
Evercade	1 (2.17%)
Leapfrog consoles	1 (2.17%)
Atari 2600 clones	1 (2.17%)

Modding Practices

The survey asked participants to indicate whether they mod game hardware for functional purposes (defined as any adjustment that impacts device life or gameplay), aesthetic purposes (defined as any mod that changes the look of the device without impacting gameplay), or both (Table 13). Three-quarters of respondents indicate that they perform both functional and aesthetic mods; the remaining 25% focus on functional mods.

Table 13
Responses about Functional and Aesthetic Modding

Purpose of Modding	Responses (% of 104 Respondents)
Functional	26 (25%)
Aesthetic	0 (0%)
Both	78 (75%)

Functional Mods

While the follow-up question about specific functional mods (Table 14) was intended as a quantitative assessment of the types of adjustments respondents perform, 30 of the 104 participants who answered this question used the "Other" option to provide written responses containing varying levels of detail. Table 14 contains results relating to the four *supplied* responses, which indicate that durability-focused part replacement and screen upgrades and replacements are the most popular acts of functional modding among survey participants. The popularity of screen and display upgrades and battery pack replacements in the quantitative survey results were echoed in comments by Interviewee 2, who summarized his employer's sales trends by noting that "after displays, the next-most popular thing is a battery pack". In his view, the installation of power sources that can be recharged using a USB cable provide a quality-of-life upgrade because "it's not only longer battery life, it's having the battery with you, faster charging, continuous play". Interviewee 1 added that another appeal of rechargeable battery packs is their comparatively quick installation process, "unlike with a screen, where you have to remove everything". Modding older consoles — particularly those intended to be used with cathode-ray tube (CRT) displays — in order to improve the quality of their video output on modern flat-screen displays was a recurring theme in the written responses of both segments. Seven of the 30 written responses referred to this practice in varying levels of detail; one participant described this type of mod as "visual enhancement" and specifically mentioned "adding RGB/Component output to Composite consoles". Three other participants referenced the addition of HDMI output to consoles that predate the use of that interface; another described implementing an "AV mod on Atari". Two others described the practice of upgrading the visual output without specifying a method or device type. This variety of modding was a significant

topic of conversation with Interviewee 3, who described the ability to connect retro consoles to modern displays as “the most common enhancement that I get asked for today”. Interviewee 3 further noted that connecting unmodified retro consoles to modern displays can introduce lag between player input and events being reflected on screen, providing additional context as to the functional reasons why modders may be interested in this area:

> In a lot of those games, the appeal was you memorizing the pattern of jumping or pressing the button at just the right time. Now, when you're doing it on a system that introduces lag, you have no hope of actually finishing the game because the timing is all off. So it looks bad, it feels bad.

Interviewee 3 also spoke at length about the hardware options that enable the upscaling or improvement of video output, observing that continued innovation is required in order to provide the means to modify console video output as display technology evolves further. This particular form of modding is so significant to his small business that, when asked how he would explain hardware modding to someone unfamiliar with the practice, he said “the high-level elevator pitch is: ‘how do I take a console designed to interact with display technology that doesn't exist today and work with modern display devices with no compromise?’”

Another theme of the written responses to this question concerns ergonomics, particularly among respondents who indicated that they exclusively mod GameCube controllers. Ergonomics and “ease-of-use mods” were cited by one such participant, while another referred to “better-feeling triggers”. A third participant who mods GameCube controllers in addition to Xbox One controllers and several parts relating to gaming computers described performing mods related to “ergonomic buttons, reducing spring tension on triggers, gate notching”, and “moving buttons to ergonomic positions”. The reference to gate notching was one of several descriptions of electronic- and circuit-related modding present in the written submissions: the installation of custom motherboards and printed circuit boards (PCB), was mentioned in three other responses,

with another participant referencing circuit trace repair. Other respondents referenced modding devices to facilitate arbitrary code execution (ACE) or tool-assisted speedrunning (TAS), technical processes used to optimize speedruns. Several written responses described methods for preventing or offsetting physical deterioration of hardware; one such answer, relating to the installation of "Hall Effect" joysticks, was submitted in combination with a selection of the supplied "Durability-focused part replacements", while the other, which referred to "replacing broken controller sticks", was not.

Aesthetic Mods

As no participants indicated that they exclusively focus on aesthetic mods, only those who indicated that they perform both functional and aesthetic mods were asked the follow-up question about specific types of aesthetic mods (Table 15). Swaps and replacements of shells and buttons were the most commonly selected aesthetic mods among respondents; these options not only received an equal number of submissions but were selected by more than 90% of respondents to this question. Only one written submission, which referenced the use of stickers and decals, was recorded concerning aesthetic mods. Results indicate that participants who perform shell swaps and replacements likely also perform button swaps and replacements; of the 72 participants who selected the former, only four did not also select the latter. There were also only four instances of button swaps and replacements not being selected alongside shell swaps and replacements. All answers to this question included the selection of at least one of the options; none of the provided mods were selected in isolation.

Table 14
Aggregated Responses to Supplied Answers about Functional Modding

Type of Functional Modding	Responses (% of 104 Respondents)
Screen/display upgrades (including backlighting)	76 (73.07%)
Battery pack replacement	63 (60.58%)
Durability-focused part replacements (including replacing plastic parts with metal equivalents)	75 (72.11%)
Audio amplification or enhancement	46 (44.23%)

Table 15
Responses about Aesthetic Mods

Type of Aesthetic Modding	Responses (% of 78 Respondents)
Shell swap/replacements	72 (92.31%)
Button swap/replacements	72 (92.31%)
Cord swap/replacements	46 (58.97%)
Addition of lighting/LEDs for aesthetic purposes	42 (53.85%)
Painting or dyeing of existing shells/buttons	32 (41.02%)
Other: Stickers/decals	1 (1.28%)

Part Creation and Customization

All participants were asked whether they create or customize their own parts using 3D printing, casting, painting, dyeing, or other means (Table 16). The question was intended to assess the ways in which modders create or customize parts in addition to or in place of purchasing; 18 respondents submitted written answers using the "Other" option. Two of these simply informed the researcher that they do not create parts; two others mentioned that they acquire their parts online. Other responses about purchasing included more detail: one participant

submitted a written response in addition to selecting 3D printing from the supplied options and noted that they acquire parts via “ordering online whenever available, 3D printing is a last resort”. Another respondent shared that they “cannot afford a 3D printer but if I had one available to me, I would use it regularly”. Participants also submitted methods of creation and customization that were not included in the supplied responses, including drilling, filing, sanding, cutting, and the use of computer numerical control (CNC) machines. Other respondents shared that they use fabric and acrylic in their modding work.

The methods used to create modding parts was a central part of the conversation with Interviewees 1 & 2, whose company produces some parts in house through the use of fused deposition modeling (FDM) 3D printing, resin 3D printing, laser cutting, vinyl printing and cutting, UV printing, and PCB production. The company also outsources the production of certain parts to a factory in China whose production methods include injection molding, 3D scanning, CNC machining, and selective laser sintering (SLS) 3D printing. Interviewee 2 described the lengthy iteration process by which the company and factory work together to produce parts that are later sold to modders:

> They don't go through their whole process with us, but I've done research on how it's usually done. They scan it, then they have an engineer who spends a lot of time sitting there and modeling every angle and stuff. And to be honest, that's not always 100%. I'd say that, depending on which product we've done, it could be 70 to 90% of the way there. Then that last 10 or 20% is me going through, reviewing the 3D model, looking at every angle, taking calipers, taking microscopes. It's a lot of going back and forth, writing out very detailed explanations about exactly what we want moved, exactly how we want it. We do that a handful of times back and forth.

Interviewee 2 estimated that the process of finalizing a prototype of a handheld console’s outer shell has never taken the company less than one year and has sometimes taken up to two years.

Table 16
Aggregated Responses to Supplied Answers about Creating and Customizing Parts

Means of Creation or Customization	Responses (% of 75 Respondents)
3D printing	51 (68%)
Painting	26 (34.67%)
Dyeing	8 (10.67%)
Casting	6 (8%)
Prefer not to answer	5 (6.67%)

Business and Hobby Activities

Survey participants were asked whether they sell or have sold modded game hardware for financial compensation (Table 17) and directed to follow-up questions based on their response. More than 40% of respondents indicated that they have sold modded or modding-related work. Results of the question about the types of modded product sold (Table 18) indicate that the sales of completed mods are more common than sales of modded components. A question about the pricing of completed console mods was answered by 30 of the 45 survey participants who had indicated that they sell mods (Table 19), while a similar question about the pricing of completed controller mods was answered by 24 of the 45 participants who sell modded products (Table 20). Results indicate that, among survey participants who sell modded products, the most expensive console mods are sold for more than $300 USD and the most expensive controller mods are sold for between $251 and $300 USD. More than half of the segment of participants who sell mods indicated that they take commissions in addition to selling pre-built products (Table 21); this group was also asked how many products they sold in the calendar year 2022 (Table 22). Nearly half of respondents to the latter question indicated that they sold between one and five products, while 20% sold 21 products or more.

Table 17
Answers about Selling Mods

"Do you sell/have you sold modded hardware to others in exchange for financial compensation?"	**Responses (% of 104 Respondents)**
Yes	45 (43.27%)
No	57 (54.81%)
Prefer not to answer	2 (1.92%)

Table 18
Answers about Product Categorization

Type of Modding Product Sold	**Responses (% of 40 Respondents)**
Completed console mods	29 (72.5%)
Completed controller mods	23 (57.5%)
Console mod parts	15 (37.5%)
Controller mod parts	10 (25%)
Prefer not to answer	1 (2.5%)

Table 19
Responses about Pricing of Completed Console Mods

Price Range (USD)	**Responses (% of 32 Respondents)**
$1–$50	2 (6.25%)
$51–$100	8 (25%)
$101–$150	7 (21.88%)
$151–$200	2 (6.25%)
$201–$250	2 (6.25%)
$251–$300	3 (9.38%)
$300+	6 (18.75%)
Prefer not to answer	2 (6.25%)

Table 20
Responses about Pricing of Completed Controller Mods

Price Range (USD)	Responses (% of 26 Respondents)
$1–$50	7 (26.92%)
$51–$100	11 (42.31%)
$101–$150	1 (3.85%)
$151–$200	2 (7.69%)
$201–$250	1 (3.85%)
$251–$300	2 (7.69%)
$300+	0 (0%)
Prefer not to answer	2 (7.69%)

Table 21
Responses about Commissions and Pre-built Mods

Type of Sales	Responses (% of 44 Respondents)
Both	23 (52.27%)
Commissions	11 (25%)
Pre-built mods	7 (15.91%)
Prefer not to answer	3 (6.82%)

Table 22
Responses about Quantity of Products Sold in 2022

Number of Products Sold	Responses (% of 45 Respondents)
1–5	20 (44.44%)
6–10	4 (8.89%)
11–15	8 (17.78%)
16–20	2 (4.44%)
21+	9 (20%)
Prefer not to answer	2 (4.44%)

Participants indicated that they advertise the products they sell through a range of means (Table 23); written submissions to this question include YouTube, eBay, Reddit, Twitch, and two distinct arrangements with the owners of local retro game stores. The most commonly selected method of advertising was word of mouth, which appeared in the responses of more than 80% of the 45 participants who answered this question. While most of those who use word of mouth to promote sales selected it in combination with other forms of advertising, eight respondents listed it as their only means of promotion. One participant submitted this information as a written response, adding “if I advertised I would be too busy”. eBay appeared in responses to the questions about the sales platforms modders use (Table 24) and the ways in which they acquire parts for modding (Table 25); there was, however, no overlap between the participants who use eBay as a means of selling their product and the participant who uses it as a means of acquiring parts. The respondents who sell modded products indicated that they predominantly acquire parts from modding retailers (77.78%) and independent sellers (71.11%); more than half (55.55%) signified that they make their own parts.

While not asked about this topic directly, the rising cost of acquiring old consoles was mentioned by all three interview participants; Interviewee 1 observed that the company that employs himself and Interviewee 2 has shifted away from providing custom modding services in part because “the price of the donor consoles is rising all the time” and “the whole margin was going down”. Interviewee 2 added that, “especially over COVID, people really got into this stuff and the prices of old consoles really shot up”. Interviewee 3 also referenced this trend while discussing his initial foray into collecting retro hardware in the late 1990s: “even the retro consoles themselves were much cheaper then”.

Table 23
Responses about Means of Advertising Mods

Method of Advertising	**Responses (% of 45 Respondents)**
Word of mouth	37 (82.22%)
Discord	26 (57.78%)
Twitter	14 (31.11%)
In person at events	14 (31.11%)
Instagram	10 (22.22%)
Prefer not to answer	2 (4.44%)
Email lists	1 (2.22%)
Other: SEO	1 (2.22%)
Other: YouTube	1 (2.22%)
Other: eBay	1 (2.22%)
Other: Reddit	1 (2.22%)
Other: Twitch	1 (2.22%)
Other: Sell on consignment at local retro game store	1 (2.22%)
Other: Contacted by local retro game store with business	1 (2.22%)

Table 24
Responses about Sales Platforms

Sales Platform	Responses (% of 45 Respondents)
Social media (no separate online storefront)	18 (40%)
In person at events	12 (26.67%)
Etsy	7 (15.55%)
Other: eBay	6 (13.33%)
Shopify	5 (11.11%)
Ko-Fi	5 (11.11%)
Prefer not to answer	4 (8.89%)
Other: Reddit	1 (2.22%)
Other: Tindie	1 (2.22%)
Other: Mercarie	1 (2.22%)
Other: Venmo	1 (2.22%)
Other: Wallapop	1 (2.22%)
Other: Square	1 (2.22%)

Table 25
Responses to Supplied Answers about Part Acquisition

Means of Acquiring Parts	Responses (% of 45 Respondents)
Modding retailers	35 (77.78%)
Independent sellers	32 (71.11%)
Self-made (including 3D printing)	25 (55.55%)
Prefer not to answer	1 (2.22%)

Community

Given that recruitment for this study took place entirely online, it is not surprising that social media (75%) and online collectives such as Discord servers and message boards (92.31%) were the types of group most frequently selected via the survey question about community participation (Table 26). In addition to the supplied option of attending in-person events with a modding focus, which 7.69% of participants selected, responses about meeting up with other modders and hosting modding-focused events at a makerspace were also submitted. Hardware modding as a basis for both in-person interaction and online community building may form an interesting foundation for further study.

Table 26
Responses to Supplied Answers about Participation in Modding Communities

Community Participation	Responses (% of 104 Respondents)
I belong to online modding groups such as Discords and message boards	96 (92.31%)
I follow and interact with other modders on social media	78 (75%)
I attend in-person events where modding is a focus	8 (7.69%)
I do not participate in hardware modding communities	5 (4.81%)

Motivation

Survey participants were also asked what motivates them to mod game hardware. A total of 82 of the 104 survey respondents submitted answers to an instance of this question. As noted previously, these questions were deliberately open-ended in order to avoid biasing responses. While crossover between themes is present, trends relating to personal enjoyment, a desire to improve the player experience through the fusion of old and current technology, and the importance of preservation are apparent in the results.

Financial Motivations

While members of the Business segment were directly asked what motivates them to mod game hardware and accessories and sell the results, only eight of the 34 responses made any reference to sales or money. Four of these responses mentioned that selling mods is a form of cost recovery that enables the participant to continue modding: “really it’s for hobby, and it pays enough that I can break even on the hobby”; “To share my creations, fund future creations”; “Modding consoles is a very expensive hobby. Selling modded systems and modding consoles for other people allows me to try mods I might not do for myself, and recoup some of the money I dump into this hobby”. The fourth respondent who mentioned cost recovery answered similarly but provided more context as to when they decide to sell their work:

> I typically only sell modded consoles/accessories if I buy a large lot of broken units, and end up repairing more than one successfully. I'll then mod any leftovers to sell, mostly so I can pay for the original lot I purchased and get a ‘free’ console/accessory out of it.

Another participant likewise mentioned using sales as a way to clear their own inventory: “I don’t mod to sell or as income. I mainly mod as a hobby to test my skill and sell when I have too many units laying around”. Two other respondents who addressed this topic indicated that generating revenue is a motivating factor, in both cases alongside other reasons: “Wanting to

make cool unique consoles, and make some money doing it"; "It's fun, I can sometimes make money off it and hell I just like making things that look nice and unique". Another cited the fact that "the demand outweighed the supply, so it was a good market to break into" alongside "a [*Super Smash Bros.*] *Melee* obsession, an enjoyment of fiddling with things, a desire to be able to upkeep my own controllers and a tactile fetish". Interviewee 2 touched on the topic of demand in relation to what may motivate people to consider purchasing hardware modded by others: "there's a big subset, I think, of people who don't trust their skills or just have enough free money that they don't really mind purchasing one if they see the design they like".

The "Joy of Inventing"

The "enjoyment of fiddling with things" cited by an aforementioned participant was also referenced in multiple other responses; one mentioned "the opportunity to develop new technologies that people consider cool or interesting", which they summarized as "so-called 'joy of inventing'". Other participants responded similarly: "it's a fun hobby, and I like tinkering with things"; "it makes me happy to do the work as well as to improve players' experience"; "I enjoy adding function and customization to my consoles and accessories to make them more 'mine' as well as just enjoying the process of working on electronics and building my skills"; "It's fun and can teach you about how things work"; "I enjoy the enhancement of capabilities and it's a combination of all my technical interests (electronics, fabrication etc)"; "It is fun and made me more practiced in electronics repair in general"; "I like tinkering with hardware too, and modding consoles is very fun and rewarding". Several other respondents indicated that they find the process of physically modding hardware to be gratifying without specifically mentioning the enjoyment derived from "tinkering" or "fiddling": "It's fun and makes them unique or better"; "Personal enjoyment"; "Because it's fun!"

Functional Improvement

Other responses further indicate that some of this enjoyment is derived from the process of building upon the hardware's original potential. One participant said they are motivated by the prospect of "Improving functionality. Controllers that work better and consoles that output cleaner video"; another similarly mentioned "Ensuring old hardware is compatible with modern display technology". A respondent suggested that modding hardware enables them "To get more use out of it (clearer visuals, homebrew)", a theme echoed by a participant who wrote "I really enjoy improving old systems to work and look better than they originally did. Sometimes I enjoy the modding process more than playing the games". Other respondents cited similar motivations: "I like pushing the boundary of what the original hardware can do"; "To enhance the game console's functionality or add special features"; "Creating a no-compromise device with many quality of life features that improves retro gaming experience".

Preservation

A desire to preserve game hardware was also evident in several other responses. One respondent wrote "What motivates me is the preservation of older technology for later generations to enjoy, either selling repaired consoles which are still original parts, or modified ones for people who want an improved experience with their game console". Preservation as an act of nostalgia was also a factor for the participant who said "I like preserving the hardware for people to remember and play their childhood favorites and/or share them with their kids"; another stated "I enjoy electronics and have enjoyed gaming on these consoles since I was a kid, modding them enables me to keep them updated and playable for me and my kids, doing a small part in protecting video game history". One participant implied that this protection falls to modders because "Manufacturers are unwilling to provide long term support to keep their

systems functional". Another respondent referenced the fleeting official life cycle of game hardware:

> Primarily for continuing to use my consoles well past their time in the retail marketplace, which includes being able to return to games decades after they've come out and are not available for sale on newer platforms or PC as well as the convenience of being able to use them with newer display technologies.

While not addressing preservation for historical reasons directly, one participant also mentioned "knowing that one less console is going in the bin because of my work is fulfilling. Reducing e-waste is important, and I'm quite happy to be part of the effort to reduce it". This theme was also reflected in the response that stated, "I find it satisfying to fix electronics that would otherwise be thrown out, I like to customize my devices, and I find all of the development and history of console modding very interesting". Preservation is also a significant basis of the work of Interviewee 3, who described his current focus as "preservation and enhancement of hardware". He spoke at length about the ways in which optical-disc hardware can fail over time, and the implications of that failure for game preservation:

> The laser itself is a diode and a diode is no different than your LED lights, and everybody knows that those LED lights eventually burn out. So those lasers burn out as well... What ends up happening is you have a console, and you have the media, but there's no way for the console to read the media.

Interviewee 3 further explained that one solution to this problem is the use of optical drive emulators:

> Where you replace the CD-ROM drive with a circuit board that has the exact same connectors as the original CD-ROM drive. So as far as the system is concerned, it's just a CD-ROM drive, but then it has an SD slot or a USB port, or an SSD port in some cases.

He also indicated that, although such solutions have been applied to certain consoles, “there’s five times as many more consoles that do not have a solution today, and it’s where people are working on it. And the big ones too, like PlayStation 2, PlayStation 3, Xbox 360.” The survey received one written response pertaining to the installation of optical drive emulators from a participant who indicated that they mod the original PlayStation console exclusively.

Summary

Through their participation in this research, more than 100 individuals provided information about the hardware they mod as well as how and why they mod it. Results suggest an interest in a range of hardware: early consoles and devices that did not receive international or widespread release, or failed commercially, are represented alongside those that achieved significant sales success and became cultural touchstones. Participants also provided information about the variety of ways they work to preserve, enhance, or otherwise modify the look, feel, and performance of these devices, as well as a range of reasons as to why, and details about their methods. Responses also provide a sense of the role commerce activity has within hardware modding. This section has aimed to serve as an overview of the data gathered through this study; contextualization of the results alongside existing scholarship is also necessary. The next section of this paper will position this study’s results in the broader context of existing research and consider the place of hardware modding within game-related scholarship.

Analysis

Hardware modding and software modding share a definition, in the broadest sense, as user-driven interventions in existing video game-related products. The differing nature of those products creates obvious divergence in the way these interventions play out. Hardware mods are, by necessity, acts of physical alteration performed on a device-by-device basis that may only be kept by (or sold to) one owner at a time; in contrast, Hector Postigo (2008) notes that the code that comprises an individual software mod "may be downloaded by thousands who will then play the new code, layered onto the old" (pp. 60–61). Viewed in combination with existing research about software modding, the results of the current study provide a more comprehensive view of game-related modding in general: common threads in what motivates these activities emerge despite the aforementioned practical differences between hardware and software. Differences are similarly instructive and also contribute to a broader understanding of hardware modding. Discussion of the current study's results alongside conclusions reached in other published scholarship also serves to further contextualize the practice of hardware modding and to position it within the larger field of video game studies.

Motivation

As previously mentioned in this paper, numerous examinations of the motivations of software modders exist. Recurring themes include modding's appeal as a creative outlet (Postigo 2007; Sotamaa, 2010) and as a source of personal enjoyment (Sotamaa, 2010; Poor, 2013). Olli Sotamaa identifies five themes among the responses to his study's questions about software modding, illustrating each with a quotation from a participant that exemplifies it. The topics of "artistic expression" and "hacking" (2010, p. 246) are of particular relevance to the current study: Sotamaa described the former through the quotation "The best thing in modding is the

experience of creation, it's like painting a picture" (2010, p. 246) and the latter with the answer "I've always been interested in studying how different things work" (2010, p. 246). These themes are evident throughout responses to the current study's survey questions about the motivation to mod hardware, sometimes in combination:

> I love to tinker with electronics and learn new skills. Modding consoles was a great and somewhat cheap entry to understanding electronics. From simple designs like Game Boys and up to even more advanced home consoles. It feels great to build and fix something!
>
> Even buying broken consoles and getting them to turn on is amazing!
>
> I really enjoy improving old systems to work and look better than they originally did. Sometimes I enjoy the modding process more than playing the games. Soldering is fun, and seems like it'd be a good skill.
>
> When it comes to development of my own mods (including designing GBA flashcart from scratch), for the creative and technical challenge and to learn and understand the system better up to very technical detail.

These explanations are replete with what Melanie Swalwell (2021) describes as "the will to mod" (p. 133), "an ethic of playfulness and enthusiastic curiosity" (p. 133) that facilitates the enjoyment of tinkering with electronics. Several other respondents attributed their interest in hardware modding to a sense of enjoyment and fun without specifically mentioning the modding process itself. Recurring references to fun as a motivating factor for engaging in hardware modding are also consistent with a broader study of the motivations of do-it-yourself (DIY) communities by Stacey Kuznetsov & Eric Paulos (2010), which observed that "a large portion of free responses emphasizes fun as a motivation" (p. 5). For at least some modders of game-related products, be they hardware or software, satisfaction is found in the labour. Where more significant differences between the two forms of modding occur is in how this labour is classified.

Labour and Compensation

Software mods are generally distributed for free (Kücklich, 2005; Postigo, 2007), regardless of whether their creation is endorsed or permitted by the original game's publisher. In the case of developer-approved software modding, for-profit distribution is often expressly prohibited by the terms of service (Kücklich, 2005; Schleiner, 2017); where conflict has arisen over permission to mod, software modders have pointed to the absence of financial compensation as a defence (Postigo, 2008). Romhacking, a form of software modding specific to console games, requires access to an extracted copy of a game's read-only memory file — a process rife with "complex and hotly contested legal issues" (Jordan, 2007) that discourage "modders from commercializing their labor, such as by charging for downloads or commissioned work (and even, in some cases, accepting donations)" (Fuller, 2019, para. 24). Certain attempts to monetize software mods have caused controversy; a 2015 experiment by publishers Valve and Bethesda that allowed modders to sell their work in the Steam Workshop (with 75% of the revenue being split between the two publishing companies) "caused great backlash among both modders and players, and resulted in an influx of complaints, petitions and protest" (Waldsdorff, 2022, p. 174). Julian Kücklich (2005) was describing the practice of creating, disseminating, and — importantly — not charging for software mods when he wrote:

> Modding and other, similar forms of "free labour" do not fit the categories of wage labour, freelance or voluntary work, and neither do they fit the categories of leisure, play or art. While free labour, or "playbour", shares traits with all of these occupational types, it can only be understood on its own terms. (para. 29)

Hardware modding is not easily positioned on this spectrum. More than 40% of the current study's survey participants indicated that they have sold modded hardware in exchange for financial compensation. The existence of businesses that sell mods or modding-related materials,

such as the company that employs Interviewee 1 and Interviewee 2, indicates that the broader realm of hardware modding includes wage labour. Nearly one-third (32.69%) of *all* survey participants accept paid modding commissions, a practice that arguably constitutes freelance work (Kitching & Smallbone, 2012). A survey respondent who sells their work described hardware modding as "a good market to break into" due to their view that demand for modded products outweighs supply.

However, several other participants indicated that their motivation for selling products is not profit but cost recovery or inventory clearance; the expense of acquiring components such as consoles was specifically noted as a factor in the decision to sell modded hardware. The current study's results suggest that even participants who earn money through hardware modding continue to view themselves as hobbyists. A survey respondent who sells mods explained their decision to do so through the observation that "modding is an expensive hobby". Interviewee 2 described "dabbling with more hobby modding" prior to working for his current modding-focused employer. Interviewee 3 noted that, despite running a modding-related side business in addition to his unrelated full-time job, "everything I do is a hobby. It's something that I do only in the evenings after work, on the weekends, because I just like tinkering with electronics." The connection between hobbies and entrepreneurship has been analyzed by Matilde Milanesi (2018), who observes that "the steps toward starting a company are taken by the hobby-related entrepreneur without a formal acknowledgment or evaluation of a commercial opportunity" (p. 429). That several survey respondents indicated that they did not initially set out to sell mods reinforces this, as does the prominence of word-of-mouth advertising and social media as a sales platform. These methods provide modders with opportunities to promote their work at little or no cost at a moment's notice; a modding hobbyist can enter the realm of modding sales on a whim

and depart just as easily. If the concept of "playbour" is relevant in relation to hardware modding, it may be most apparent in unpaid community activities such as those referenced in this study's results. More than 90% of the current study's survey respondents indicated that they belong to virtual groups, such as message boards or Discord servers, that have a hardware-modding focus. Benjamin Woo (2012) observes that, among non-profit organizations and clubs focusing on "nerd culture" (p. 660) — defined as consisting of "gamers, comic book collectors, media fans, re-creationists and so on" (p. 660) — "organizers' voluntary labour is a direct expression of fan activity and has no significant economic incentives" (p. 667). It is the moderators of such communities who are performing some form of free labour related to hardware modding for others.

Kücklich's definition of "playbour" is itself based on Tiziana Terranova's (2000) description of free online labour as being "voluntarily given and unwaged, enjoyed and exploited" (p. 33). Paid hardware modding may not necessarily be *waged* but nonetheless involves some amount of compensation. Where such modding is performed for free, its results are often intended to be kept by the modders themselves — voluntarily done but not necessarily given, enjoyed but not exploited. Anne Marie Schleiner (2017) describes software modding practices as "exterior voluntary labor that ultimately serves in the company's interests" (p. 55). By Postigo's (2007) calculations, fan-produced mods for the PC game *Battlefield 1942* would have cost "between $10.1 million to $30.4 million in salaries" (p. 303) had they instead been produced by the original publisher (estimates have not been adjusted for inflation). These corporate benefits are not easily transferable to hardware because the manufacturer receives no quantifiable benefit from them. Information gathered through the current study indicates that hardware modders gravitate towards devices officially considered obsolete; of the 73 products

selected in survey responses, including those provided via written submission, only seven have not been formally discontinued internationally. Obsolete devices can be acquired, if not already owned, through a number of methods such as second-hand sales; survey responses point to eBay and other online resources as means through which modders obtain hardware. These transactions do not generate additional revenue for the manufacturer, nor do they affect official sales figures. The benefit to the original producer, if any, is drawn from continued positive association with the modded object. Postigo's (2007) wider-ranging definition of a game's life, which has provided an important basis for this study, has greater significance to hardware modding than definitions relating to sales:

> not only to how long a game stays on the best-seller lists or is able to maintain its release price but also to the time a game remains a subject of active involvement with the consumer base as when, for example, fans talk about their favorite games on gaming Web sites and magazines, host servers for team play, distribute gaming information, and discuss the latest add-on. (p. 302)

These actions are evident in the types of communities approached during the current study's recruitment phase. Discord servers and other groups coalesce around long-discontinued platforms and activities, including modding, related to them. The extent to which survey participants submitted written responses about hardware that was not provided in the survey speaks to this; fans add to the life of a device or accessory not only by modding it but by wanting to talk about it.

Reconsidering Commercially Unsuccessful Hardware

Viewed in combination with Raiford Guins's (2014) discussion of games' afterlife history, as well as research by Marçal Mora-Cantallops and Ignacio Bergillos (2018) concerning fan efforts to maintain and preserve commercially unsuccessful hardware, Postigo's assessment of the life of a game also provides context to the current study's data about individual platforms.

Nintendo's Virtual Boy headset — commercially "an undeniable failure" (Boyer, 2009, p. 23) — was not listed among the products from which survey participants were asked to select; two respondents nonetheless felt strongly enough about their modding work on this device, or peripherals thereof, to manually submit it as a response. The Sega Dreamcast has been observed as having had a "short commercial life" (Montfort & Consalvo, 2012, p. 82) and as being "commonly understood as a quirky industrial failure lamented by fans for being far ahead of its time" (Deeming & Murphy, 2017, p. 76); it is also the most-modded Sega product by participants in this study, receiving more selections than Genesis console, which "had been a successful challenger to Nintendo's dominance of the game console industry" (Montfort & Consalvo, 2012, p. 86). Three participants indicated via written submission that they have modded the Sega Nomad, a handheld device that sold fewer than one million units; David Wesley and Gloria Barczak (2010) describe Sega's decision to retire the Game Gear in order to focus on the Nomad as "one of the biggest mistakes in video game history" (p. 85). The fact that modders have found a use for the console does nothing to bolster its lacklustre official sales figures, nor does it improve Sega's financial standing. It does, however, sustain the existence and functionality of a device that is not in wide circulation, helping prevent working editions from becoming lost. Interviewee 3 alluded to possible reasons why modders may be drawn to platforms officially viewed as commercially unviable, observing that such hardware "has their unique contribution, something that they invented that was not repeated because it was kind of silly, or set a new standard". (This conversation, incidentally, took place a day after Apple unveiled its own virtual-reality headset, prompting Interviewee 3 to quip "who knows, maybe it's [the Virtual Boy] coming back".) A survey respondent who indicated that they mod the Dreamcast described "being able to return to games decades after they've come out and are not available for sale on

newer platforms or PC", a clear incentive to maintain or upgrade commercially unsuccessful hardware whose software may not have been re-released later. "The notion of modding as a means of extending game hardware's life, in either the physical or metaphorical sense, is not purely an extrapolated conclusion: several participants addressed this topic directly.

Modding as Preservation

Preservation was also a theme in multiple survey responses as well as a significant topic of conversation with Interviewee 3. Alex Custodio (2020) discusses the relationship between hardware modding and preservation in her exploration of the Game Boy Advance console; she describes the distinctions as "compelling — albeit hazy" (p. 202), noting that "hardcore preservationists might see modding as transgressive, as stripping the aura from the object" (p. 202), particularly when the mod in question makes a significant functional change, such as an upgrade to a handheld console's display. Despite these potential concerns, survey responses reveal that some modders actively see themselves as performing this work. One participant wrote that "Manufacturers are unwilling to provide long-term support to keep their systems functional", suggesting that in the absence of officially mandated or organized preservation, modders feel compelled to (literally) take such efforts into their own hands. Another response referred to "doing a small part in protecting video game history", echoing Custodio's observation that the ongoing survival of consoles long considered officially obsolete "is a kind of preservation in itself" (2020, p. 202). A preservationist mentality can also be detected in other responses about motivation; as previously mentioned in this paper, care was taken to avoid the use of survey language that might influence participants' answers, particularly in the phrasing of open-ended questions. While the topic of a game or device's "life" was not actively presented to

survey or interview participants, modding as an act of bestowing "new life" upon a device nonetheless appeared in four responses to survey questions about motivation:

> the excited look on people's faces when they see new life breathed into a beaten-up console never gets old.
>
> It's fun and for older systems breathes new life into systems I grew up with.
>
> I love breathing new life into old hardware, especially resurrecting broken machines.
>
> I love to give old consoles new life, and help others relive their childhood.

(In addition to these, another respondent similarly wrote "I love reviving old consoles to use them in the future or currently".) These responses evoke Guins's (2014) description of "extended or repurposed and recontextualized uses" (p. 7) for platforms that have entered obsolescence. While their work forms part of a broader effort to keep such consoles "alive", these survey respondents also describe the infusion of new life at the device level. A piece of hardware can also be said to be "alive" not only when it works but when it, as Postigo (2007) notes of software, is the subject of continued and active use and a topic of ongoing interest and discussion.

User-Driven Enhancements

The evolution of gaming technology has led to changes in consumer expectations, including those applied to older or "retro" hardware. That modders engage in the practice in order to impose quality-of-life improvements that reflect their own needs and wants on hardware is reinforced by the results of this study. Custodio discusses such improvements at length in her analysis of the Game Boy Advance, noting that the advancements in display technology achieved since that console's original release means that "we can no longer imagine playing videogames on dim screens" (2020, p. 205). The nearly three-quarters (73.07%) of study participants who said they have upgraded a device's screen appear to agree; Interviewee 2 also estimated that

components used in screen upgrades are his company's most-sold products. While Custodio observes that acquiring a used Game Boy Advance SP (Nintendo's backlit, redesigned model) or Nintendo DS (which offered backwards compatibility for Game Boy Advance games) is the "easiest and most affordable way" (2020, p. 204) to enjoy Game Boy Advance games on a backlit screen, modders nonetheless go to the trouble of disassembling the original device and soldering in a replacement display. The tactile feel of specific hardware appears to play a role in motivating these activities, potentially making the addition of quality-of-life features to original hardware more desirable than the acquisition of other, newer consoles or accessories. Interviewee 2 observed that people interested in modded retro hardware:

> want to have that exact texture of the plastic, the button-press feeling. All that stuff is encoded somewhere in your brain. As soon as you get a console with a stuck button or a different texture, you realize something's off there, and I think that's a big part of it.

A.J. Rappaport's (2020) study of the competitive scene surrounding *Super Smash Bros. Melee* describes the lengths players go to in order to optimize their GameCube controllers' reliability and input response; certain performance-enhancing mods, such as "soldering Arduino microprocessors onto the electronics of their controllers to achieve frame-perfect inputs" are "illegal according to the rules of most tournaments" (p. 45). Rappaport also described ways in which players "adjust their bodies in line with the tools in use" (2020, p. 45) — including experimenting with different ways to grip the controller, playing with their feet instead of their hands, or playing lying down — as a way of creating a physical state of playing that works best for them. Several survey responses referenced modding hardware for reasons of ergonomics and comfort; players not only adjust their bodies to fit the tools, as Rappaport observes, but also adjust the tools to fit their bodies. This practice has parallels in software modding: modders have endeavoured to better address players' physical needs through the addition of closed captioning

(Bierre et al., 2005) and descriptive audio (Mangiron, 2018), or the removal of potentially triggering effects such as visual flashing — a concern noted by neurologists (Bureau et al., 2004). In this way, hardware and software modding similarly weave contemporary expectations throughout older products, acting as a link between gaming's past and present.

Making Hardware One's Own

Game manufacturers and developers have offered players opportunities for self-expression through hardware sold in an array of colours or game-themed special editions (Guins, 2016) and the ability to customize in-game elements such as character designs (Teng, 2010). As acts of user-driven interventions in completed projects, both hardware and software mods extend beyond choices such as these. The way in which some manufacturers have promoted these editions may prove to have had an influence on modding. Custodio ties the Game Boy Advance's continuing popularity among modders to a Nintendo advertising campaign that anthropomorphized and assigned personality traits to instances of the console's SP model and posed the question "Who are you?" Modding the console, she writes, is a way of "continuing to answer that question" (2020, p. 24). Nintendo had already asked similar questions in its marketing for the Game Boy's colourful "Play It Loud" line, a functionally unchanged reissue of the original model that was released in 1995. One print advertisement displayed the new array of six shell colour options atop the heads of models with matching hair colours (the transparent case was positioned by a woman with a shaved head) and the tagline "What color is yours?"; another likened the new colour options to condiments — the red casing compared to ketchup, yellow to mustard, and so on — with the adjusted tagline "What flavor is yours?" Nearly half of survey respondents indicated that they have modded the original "DMG" Game Boy model (a designation that includes the "Play It Loud" line). As in Custodio's example, these modders also

continue to answer Nintendo's questions about the colours and metaphorical flavours of their devices. More contemporary examples of this trend are also evident in survey results. Microsoft's Xbox Design Lab has enabled players to purchase built-to-order controllers for the Xbox One and Xbox X/S Series consoles since 2016, at one point advertising "more than one billion possible color combinations" (Eisenbardt, 2021 p. 1,840). In both cases, more survey participants indicated that they mod these controllers than their related consoles, the only two instances of this trend among Microsoft products. The Nintendo Switch's "joycon" controllers, which can be purchased in a range of colours separately from the console, were also selected more frequently than the Switch itself. The extent to which modders may be inspired or influenced by manufacturer-endorsed personalization options, particularly those that are actively advertised as means of self-expression, is another topic deserving of more focused study.

Summary

This research illuminates hardware modding's position within several areas of video game studies. Its relationship to software modding consists primarily of their common status as user-initiated appropriations of or insertions into existing game-related products, as well as their shared classification as craft; participants of both types of modding have cited a desire to integrate their own interests on the product and a fondness for the modding process itself as motivating factors. Hardware modding, however, has formed a basis for companies and freelance businesses while software modders are prohibited from seeking financial compensation for their work. This necessitates explorations of the labour involved in hardware modding that are specific to this practice, as existing analysis of the labour of software modding does not universally apply. The topic also deserves a place in broader studies of game hardware; it is a reflection of the close personal connection players form with physical gaming devices, both in the sense of the

embodied quality of the hardware (Keogh, 2018) and emotional attachment to it. It often takes place within what Guins (2014) describes as a game's afterlife state, but not always; the presence of current-generation devices among the products survey participants mod indicates that the practice is not exclusively limited to hardware considered obsolete. It is a form of craft that uses an unexpected medium; a means of physical preservation; a stand against obsolescence; a way of adapting a device to better suit the player's needs and wants. It is a way in which some video game enthusiasts use video game hardware to enjoy themselves, one unintended by its original manufacturers. For all of these reasons, and perhaps others that have yet to be uncovered, it has a place in this field.

Conclusion

Video game hardware lives a transient life, at least officially. The accepted cycle is one in which such hardware is temporarily enjoyed before being surpassed and superseded (Newman, 2012a; Schilling, 2003), and until consumers are prodded "to replace 'old' technological items with 'new' ones through the promises of better quality" (Luo & Johnson, 2019, p. 1,466). Some features — processing power, storage capability, memory, and the like — are quantitatively measurable, and subsequent generations can certainly be viewed as having technical advancements in these areas. The broader question of *better*, however, is a subjective one that may not be based on quantitative figures and is best left to the individual player; Dominic Arsenault (2017) openly questions "these processes of crunching down the aesthetic pleasures that games and consoles provide into hard data points that contribute to a standardized 'quality' metric" (p. 51). Enjoyment of such games and consoles does not automatically end with official discontinuation, though they may become harder to access as attention turns to the latest developments and as pressure to adopt the newest generation builds. James Newman and Iain Simons (2009) note that "We, whether as players, as academics, or as members of the global industry, simply do not — simply *are* not — encouraged to place value on old games. The best game is always the next game" (p. 2). Despite this aggressive forward thinking, many players "actively work to forestall the obsolescence of their games" (Moore, 2009, para. 5) through engagement in retro gaming and participatory practices such as modding. Such acts highlight the fact that discontinued games and obsolete hardware have life in them yet. This research reveals hardware modding's relevance to several related fields and reveals opportunities for further scholarship.

As the results of this study establish that some hardware modders view their work as acts of preservation, professional game preservationists may benefit from closer attention to the practice. Niklas Nylund et al. (2020) have argued in favour of a more "grassroots" (p. 268) approach to preservation that better represents the "participatory media culture" (Raessens, 2005, p. 373) evident in the realm of digital games, citing player creations such as software mods and written guides as examples of tangential works deserving of safeguarding. Whether the infusion of contemporary technology into older devices aids or hinders the cause of preservation is up for debate (Custodio, 2020), and the field must determine its own relationship to hardware modding. It is clear, however, that the practice is an underexplored aspect of video game fan culture that has the potential to add to a platform's social history. Even if such alterations run contrary to the values of preservation, modded objects are evidence of hardware as participatory culture and, by the logic presented by Nylund et al., artifacts worthy of preservation in their own right. This is particularly relevant for hardware that was not considered commercially successful during its official lifespan, or that did not receive a wide international release. Such devices are also part of video game history, whether their manufacturers choose to embrace their legacy or attempt to bury it. Modding's role in this area is potentially of interest to game historians. David S. Heineman (2014) has chronicled the tension that exists between official and public versions of memory within retro gaming; modding, particularly of retro hardware, can be viewed as an assertion of public memory on a device originally intended to be static and unchanging. As Melanie Swalwell (2021) has described the hacking of early microcomputers and consoles, and Alex Custodio (2020) has made modding a centrepiece of her survey of the Game Boy Advance platform, future platform- or era-specific studies may benefit from explorations of modifications to relevant hardware. Such acts, as well as the communities that have formed around them, align

with Hector Postigo's (2007) suggested definition of "the life of a game" (p. 302), which considers engagement beyond sales and production. As such, these activities should have a place in scholarship about vernacular and community histories within the broader field of video game research.

The recurring description of modding as "breathing new life" into hardware by participants in the current study also has relevance in this area. Analogies such as this position modders as having the ability to confer life on hardware that may otherwise be viewed as being past its prime. This is a means by which players claim control over material gaming objects and assert their own place in the broader history of their preferred platforms. In this way, it resembles another user-driven endeavour: homebrew development. Swalwell (2021) defines this practice as the independent (as opposed to institutional) production of original game software by largely self-taught programmers who often work alone, limit distribution of their work, and harbour a spirit of experimentation (pp. 2–3). Given that it often involves programming new content for discontinued systems, John Vanderhoef (2017) observes that homebrew "indirectly challenges the larger cultural myth of the technological sublime and opposes the consumer electronics industry practice of manufactured obsolescence" (p. 112). This analysis could just as easily be applied to the act of modding obsolete hardware. One of the objectives of this study was to provide a more interconnected understanding of game-related modifications as a whole through contrast with existing studies about software modding. This evaluation has yielded interesting similarities, such as a common affinity for the modding process, as well as key differences relating to how labour is classified and what, if anything, the industry gains from it. A similar focus on parallels to homebrew development may be a useful starting point for further research. Both activities largely centre on extended uses for platforms deemed obsolete by their

manufacturers, defying industry pleas to leave the past behind and move on to the latest (and more profitable) generation of hardware.

That interest in both practices is often attributed to a sense of nostalgia is clear from existing studies about homebrew development and from the results of this study, which include an obvious affection for game software and hardware of the past. Nostalgia is not always viewed as having positive connotations. Jaakko Suominen (2008) speculates that some may view the inverse of "technological renewal and revolution" as "technical retrogression" (para. 44). The industry certainly promotes this view through its use of the generational hardware cycle and an inconsistent application of backwards-compatibility technology (Newman & Simons, 2009). Homebrew development and hardware modding are means through which players derive sustained enjoyment from older systems after the industry has officially left them behind, not just by continuing to use them as intended but by treating them as springboards for creativity. Older platforms and their capabilities, no matter how technologically limited they may seem by current standards, continue to hold importance for players. The satisfaction of working through these limitations is another common attraction of homebrew development and hardware modding. Swalwell (2021) observes that "the challenging constraints of early microcomputers" (p. 152) is a recurring motivation among those who continue to produce code for long-obsolete systems; several participants in the current study similarly mentioned an enjoyment of "the challenge" as part of their reasons for engaging in hardware modding. Such activities, Swalwell argues, are not about becoming hung up in the past but "bringing the past into a dynamic relation with the present" (2021, p. 153). Moreover, as Vanderhoef (2017) observes about homebrew, the extended use of discontinued game platforms "insists on the continued value of aging technology in the

face of rapid innovation" (p. 112). This hints at potential causes of what Custodio describes as the "lack of corporate legitimacy" (2020, p. 176) afforded to hardware modders.

The established video game industry has a complicated relationship with users' interventions in their devices. Legislation and other mandates granting users the right to repair their own electronics is the subject of considerable legal debate (Grinvald & Tur-Sinai, 2019) and a direct target of opposition from major game manufacturers. The industry argues that "a 'right to repair' mandate could have a rapid and severely detrimental impact on the video game industry and consumers alike" (Entertainment Software Association, 2021, p. 1). Opposition to such legislation arises from the possibility that engaging with the inner workings of hardware may grant users proprietary knowledge of how it works, which may in turn fuel acts of copyright infringement. This debate centres around the question of exactly who owns game hardware, a question that also emerges in conversations about the right to resell products, to purchase games from second-hand retailers (Kim et al., 2021; Newman & Simons, 2009) — or to install chips or other mechanisms intended to impact a device's functionality (Ruffino, 2018; O'Donnell, 2014). Such alterations are not always intended to evade intellectual property law, and mods that extend the functional lives of older hardware arguably provide expanded means of enjoying the related software without the use of emulation, another practice the industry staunchly opposes. Legal scholar Philip A. Harris, Jr. (2007) posits that "It is wrong to pirate video games, but it is not wrong to improve your own video game system through creativity and innovation" (pp. 136–137). In other words, there is an argument to be made that a game system should be usable as a medium for experimentation and self-expression within the boundaries of the law. Nonetheless, perceived overlap between unauthorized repair and the circumvention of copyright appears to

prevent the industry from officially acknowledging or condoning even the least infringing of mods.

Harris's statement also has parallels to the permissive view at least some of the industry has adopted towards software modding — one that occasionally allows, enables, and encourages software modding through the use of officially released software development kits (SDKs) (Nieborg & van der Graaf, 2008), provided that the mods produced are distributed for free (Kücklich, 2005). Leo Poretski and Ofer Arazy (2017) note that "the games which are modded most are those that explicitly invite modding" (p. 488) and highlight the extent to which publishers such as Bethesda support modders of their games, including hosting discussion boards and tutorials. It is difficult to imagine a comparable understanding between manufacturers and hardware modders, even (or perhaps especially) in circumstances where the hardware in question has been officially discontinued. As previously noted in this paper, software modding has been analyzed as a means through which the industry may benefit from the largely unpaid work of modders. While the results of the current study demonstrate that hardware modding can be transactional, the manufacturer is absent from this process, just as it is absent from the second-hand or aftermarket sale of game hardware and software (Kim et al., 2021). Julian Kücklich (2005) describes software modding's ability to extend the "shelf life" (para. 5) of a game title through the creation of additional content, and the financial benefits the publisher can reap as a result. Hardware modding offers the industry no such advantage. Continued positive associations with discontinued legacy products may benefit a brand in the long term (Srivastava & Thomas, 2010), and the metaphorical second acts afforded to platforms that were commercially unsuccessful during their sales life cycle may help to soften their portrayal in historical accounts, but these are qualitative gains. They do nothing to extend the "shelf life" of hardware in the

commercial sense because, in most cases (as per the results of this study), that life came to an end when the manufacturer discontinued it. Official attempts to leverage the physicality of discontinued commercially successful hardware, such as the "Classic" and "Mini" console editions released by Nintendo, Sony, and Sega (Harris, 2021), are not *re-releases* of the originals but something else entirely.

Given their common ability to extend the functional life of a device, the distinction between modding and repair is nebulous. Not all hardware mods are repairs; a modder may make functional or aesthetic changes to a device that is otherwise in good working order for no other reason than because they want to. Similarly, not all repairs are mods. A broken device can be fixed in a manner that preserves its original appearance and functionality. Sociologist Laureen Snider (2010) was not writing exclusively about games when she argued that "a viable updating and repair industry would reduce the volume of E-waste and change the built-in obsolescence policies that govern electronics (and most other) industries today" (p. 570), but her point has obvious relevance to this field. The ecological impacts of the cycle of release and obsolescence that is specific to the professional video game industry has not escaped notice (Cruea, 2017). Olli Sotamaa (2016) has urged his fellow game scholars to pay more attention to this issue, noting that "academic study of video games has done very little to connect the constantly increasing consumption of natural resources and energy and the toxic substances leaking back into nature, to the entertaining and moving experiences provided by video games" (p. 8). For its own part, the industry has argued that advocates of right-to-repair mandates "exaggerate the environmental impact" (Entertainment Software Association, 2021, p. 2) of such legislation, pointing to the continued availability of older devices in online marketplaces as proof of their "long life-cycle" (Entertainment Software Association, 2021, p. 2). Newman and Simons (2009) had previously

observed an unwillingness among manufacturers to embrace or even accept "the pre-owned, secondhand and rental markets" (p. 3), though the availability of obsolete games and hardware on such markets now seem to serve as an argument against allowing players to repair their own devices. Moreover, the results of this study highlight the fact that not all of the older devices sold online are in working order. Several participants said they turn to online services such as eBay to acquire "junk", then use the components in their mods. To sell broken hardware is more environmentally friendly than to improperly dispose of it, though the success of these sales hinges on the recipient's ability to leverage the components through repairs or mods. Other trends evident in this study's results also point to improved sustainability; the installation of rechargeable battery packs in handheld consoles originally designed to use disposable batteries, a popular practice among participants, is in line with the recommendations of environmental scientists (Kuchhal & Sharma, 2019). One survey respondent addressed the environmental topic directly in their response to the open-ended questions about motivation, observing that "reducing e-waste is important" and "knowing that one less console is going in the bin because of my work is fulfilling". By repurposing a device that might otherwise be thrown away, a modder may engage in a combined act of historical and environmental preservation.

The results of this study also indicate that modding serves other purposes that the video game industry, as well as others, would do well to heed. It is a given that companies cannot accommodate every possible user preference when designing hardware, but the lengths to which modders go to impose their own needs and personalities on their devices indicates a market demand for a wider range of options — at minimum, for a greater incorporation of ergonomic and accessibility measures into controller design. The popularity of aesthetic modding, as well as the success of Microsoft's popular Xbox Design Lab, suggests wider opportunities for other

manufacturers to offer (and profit from) custom design options for gaming accessories. This is in no way to suggest that an increase in officially sanctioned opportunities for self-expression through game hardware can or should replace the practice of hardware modding; this paper merely indicates that many players desire greater control over their devices than manufacturers currently provide. Several participants also cited hardware modding as their entry point into hobbyist electronics in general, and while the question of how to encourage greater amateur participation in electronics has been raised (Mellis et al., 2016; Anderson et al., 2017), interventions in game hardware have not yet been offered as a suggestion. The results of this survey suggest that it may be an effective gateway to this hobby. This is another area in which a parallel with software modding exists: such mods have been identified not only as a means through which modders work to gain game development experience (Kücklich, 2005; Postigo, 2007) but as a potential tool in information technology and coding education (Yucel et al., 2006; Gee & Tran, 2015). While there are some financial barriers to hardware modding, as noted by some participants, the prospect of customizing game devices may appeal to individuals who might not otherwise show interest in tinkering with hardware or exploring electronics. Conversely, individuals with existing electronics experience may be drawn to modding as a new way of putting their skills to work either for themselves or as a paid hobby. One participant in the current study indicated that they chose to sell modded products because “the demand far outweighed the supply, so it was a good market to break into”. Others may see similar opportunities in this area. Hardware modding may also provide a basis for additional studies of businesses developed out of hobbies and crafts. In this case, existing mass-produced objects are altered and reworked by individuals using either original or newly created material; this process arguably gives modded hardware a layer of “unalienated personal labour, in contrast to

impersonal industrial mass production" (Krugh, 2014, p. 293), though the original hardware began its life as the latter. In an exploration of domestic craft, Fiona Hackney (2013) describes "practices of connecting, dialog, new economies of making, swapping, gift giving, and micro-business" (p. 187). All of these characteristics are apparent in the results of this study; discussions about the commodification of craft may be augmented by explorations of hardware modding within this context. The practice has given at least some hobbyists a creative outlet and a use for (often) older technologies, and a market for the finished product — as well as for components used in the process — clearly exists. The practice may serve as a useful case study for further research into the ways in which craft communities form, as well as how business demand materializes around such undertakings and how bygone, obsolete products can be not only infused with new life but freshly re-commodified.

There is much to learn from the practice of modding video game hardware, and this paper constitutes an early offering in this area. The results of this study provide a view of hardware-related endeavours, but additional activities, methods, and reasons for participating in hardware modding surely exist. The broader field of video game research can only benefit from continued exploration of this topic, and the possibilities for future scholarship are many. The implications for important, timely issues such as preservation and environmental efforts are too important to ignore, and modding's relationship thereto signifies the existence of a community of hobbyists willing to assist with such efforts. Modding changes and strengthens the player's relationship with physical game materials. It adds new strata to the history of such objects, which is all too often viewed through a corporate perspective that ends with discontinuation, laments commercial failure, and moves on to the next generation as soon as is viable. As a key component of the embodied experience of gaming (Keogh, 2018), it is no wonder that hardware — even that which

failed to meet sales targets or was quickly superseded by more advanced technology — continues to have significance for players. Hardware is more than a means of accessing content, and modding grants players the opportunity to impose more of themselves on it, to adjust it so it better meets their individual needs, and to layer new technology on top of old. It adds to our understanding of what video game hardware is and what it can be and reminds us that the lives and qualities of games and game devices are not solely defined by their creators.

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