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Television device ecologies, prominence and datafication: the neglected importance of the set-top box

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Abstract

A key element of the infrastructure of television now consists of various internet-connected devices, which play an increasingly important role in the distribution, selection and recommendation of content to users. The aim of this article is to locate the emergence of streaming devices within a longer timeframe of television hardware devices and infrastructures, by focusing on the evolution of one crucial category of such devices, television set-top boxes (STBs). STBs are a taken-for- granted part of many people's homes across the world, and their global presence and importance are still growing. However they (and television hardware devices more generally) have been very rarely analysed in television and media studies. To address this lacuna, we trace the development of STBs, delineate changing patterns of ownership and control in STB markets, and outline the diverse forms and functions of STBs. We then show how analysis of STBs enriches understanding of two key recent developments in television: increasing battles over prominence and discoverability in a newly abundant video landscape; and the collection, analysis and exchange of viewer data by businesses. In doing so, the article shows the importance of television hardware in shaping television as a social and cultural institution.

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Introduction: set-top boxes, hardware devices, and the infrastructural turn in television studies

A crucial element of the infrastructure of television in the multi-platform environment consists of the various internet-connected devices – including set-top boxes, gaming consoles, streaming sticks, dongles, and media players – that mediate audience access to the television screen. From pay-TV boxes to "cord-cutting" products like Apple TV, Chromecast, Amazon Fire TV Stick and Roku, these devices and their software play a vital role in the distribution, selection and recommendation of content to the user. Each device reconfigures the television experience in a particular way, while also directing the viewer to a carefully chosen range of apps and content. For example, the Apple TV device and platform are integrated with Apple's content store iTunes, while Android TV devices prioritise content from YouTube and Google's Play Store.[1] These devices also have extensive capabilities for monitoring and tracking viewing behaviour. Yet, despite their widespread use – and their manifest importance for debates about television distribution, policy and regulation – such devices have rarely been the focus of sustained attention in media and television studies.

The aim of this article is to locate the emergence of streaming devices within a longer timeframe of television technologies. At the heart of our analysis is a device rarely considered in media studies, television studies, and science and technology studies, despite its remarkable ubiquity in homes across the world: the set-top box (STB). We argue that the STB, in its many forms, was a vital precursor to today's streaming devices. As we show, the STB anticipated some key research and policy concerns that have been apparent in recent discussions about streaming devices. It played a central role in early debates about the 'prominence' of content in multichannel environments and provoked many of the same policy concerns about consumer privacy, data collection and datafication that are now emerging in relation to smart TVs and streaming devices. STBs continue to play a vital role today.

Our analysis takes the recent proliferation of streaming devices as an opportunity to revisit the crucial role of *hardware* in the history, business and culture of television. In contrast to many prevalent industry and consumer discourses about television in the internet age – which tend to envisage distribution, especially internet distribution, as a dematerialized, virtual process – we foreground the integral role of television's "black boxes" in the distribution of content to the user. Such an approach also helps to correct understandings of digitalisation and of recent changes in television that are excessively internet- and web-centric, and which often accept too readily accounts by Silicon Valley and tech industry cheerleaders, whereby 'television' is portrayed as a dinosaur, or a 'legacy' medium, clumsily failing to adapt to a changing eco-system dominated and driven almost entirely by IT companies. Our position, as will become clear in this article, is that twenty-first century television needs to be understood not as a single industry under threat from Silicon Valley but as a medium that emerges from complex interactions between interlocked industries, technologies and regulations. It includes not only the content production sector that has been the main focus of attention in analysis of the television industry in media industry studies and television studies, but also the consumer electronics and information technology companies that develop, manufacture and market devices, and the telecommunications companies that mainly control the 'pipes' through which TV information and entertainment are delivered (cf. Hesmondhalgh, 2019).

Where hardware devices have been analysed within media and television studies, they tend to be treated separately from questions of industry and audience, mainly as topics in the study of media technology (e.g., Winston, 1998). There has been little influential research specifically on television hardware and software, and the industry and regulation behind them, in spite of their key role in in the development of television as a social institution. Major studies of the television industry, such as economist Richard Caves' *Switching Channels* (2005), for example, barely mention consumer electronics and television devices. While a tradition of historical and political-economic research on the VCR exists (Wasko, 1995; Wasser, 2001), much of the more recent body of admirable research on television as digital media (e.g., Bennett and Strange, 2012) does not address devices such as STBs or even television sets – although Catherine Johnson's *Online Television* (2019) is a recent and welcome exception, with its attention to what Johnson calls 'add-on devices'. [2]

The 'infrastructural turn' in media studies, often inspired by interventions in science and technology studies and actor-network theory, has helped to challenge the neglect of TV hardware devices by drawing attention to how our interactions with media are often underpinned by banal and often mainly invisible systems (Parks and Starosielski, 2015; Sterne, 2012). Inspired by such approaches, some important contributions have analysed the different actors and practices at work in, for example, the development of television-related hardware and software (Braun, 2013) or in the imbrication of popular entertainment and public service media with military technologies (Parks, 2005). The notion of the 'black box', which was picked up from engineering by science and technology studies writers, particularly the social construction of technology (SCoT) and actor network theory (ANT) approaches (Bijker et al., 1987), and was used to refer to the way that habitual use of certain technologies leads to their workings being taken for granted, is particularly apt here, given that STBs, digital video recorders, and other key television devices are often quite literally black metal boxes, the everyday, habitual and unquestioned use of which seems to render their development and operation difficult to scrutinise.

This strand of research has begun to examine the kinds of devices that sustain contemporary television viewing, including Microsoft's Xbox (Baumann, forthcoming) and digital video recorders (Meese et al., 2015). Such research joins a small group of studies from other perspectives (e.g., Parthasarathi et al., 2016; Zhao, 2017; Evens and Berte, 2014). One of the main exceptions to the neglect of television devices has been the study of digital video recorders, especially the firm TiVo and its hardware and software, studied by critical media analysts (Carlson, 2006) and business studies (Ansari et al., 2016), as well as those drawn to ANT (Meese et al., 2015). Television devices are also discussed in some historical and historiographical studies of television and video (Dawson, 2014; Newman, 2014; Parsons, 2008). But these scattered studies have rarely discussed the forces shaping television hardware and software, and with reference to effects of consumer electronics devices on television as a social and cultural institution, which are our main concerns here.

One of the most significant exceptions to the general neglect of the forces shaping how television hardware and software have developed was Hernan Galperin's important (2004) political-economic study of the transition to digital television in the UK and USA. Galperin showed how the emergence of television took very different forms in those two countries, owing to their very different regulatory traditions, but he also showed that digital television in general was the result of concerted efforts on the part of governments to boost the consumer electronics and information technology industries in the face of declining growth and international competition, and to increase spectrum frequency as potential uses of it multiplied (see also Collins and Murroni, 1996; Starks, 2007). Like Galperin's approach to digital television, we see TV hardware devices as shaped by the sometimes conflicting strategies of key industrial players, policy-makers and regulators, responding to various economic, political and cultural imperatives, as exemplified in the STB.

A brief history of the set top box (STB)

Television sets, the most important and iconic items of television hardware, have always been supplemented by other devices. In the 1960s and 1970s, the most notable of these were receiver 'aerials' (whether rooftop or set-top), remote controls, and the converter boxes that were the predecessors of STBs.[3] Such boxes would for example convert UHF signals to VHF signals, or convert additional cable signals to television signals before television sets evolved in such a way to receive large numbers of channels. Two developments in the 1980s and 1990s made it increasingly common for television sets to be supplemented by other devices. The first was the increasing adoption of cable and satellite modes of delivery (pushed hard by governments), which required various forms of access control (encryption, scrambling) so that only paying users could access content. The initial function of the STB was to decode this scrambled content. The second development was the rise of video cassette recorders (VCRs). The centrality of STBs to contemporary television is based on a hybridisation of developments that emerged from these two sets of devices. A new generation of more powerful STBs developed to support multi-channel television, and then was combined with the new capabilities provided by the digital video recorders (DVRs) that replaced VCRs.

One of the primary functions of the STB, as it evolved throughout the 1980s and 1990s, was to offer an interface that could make sense of the increasing numbers of channels being made available via cable and satellite, in the form of electronic programme guides (EPGs), as well as new features such as parental locks and sleep timers. Just as importantly, STBs also offered a way for cable and satellite operators to work with channel and content providers to introduce increasingly convenient forms of pay television (including video on demand, or VOD) whether in the form of premium channels or one-off purchases of sporting events or films, all integrated into customer billing. STBs were typically developed and manufactured by consumer electronics firms such as General Instrument and Scientific-Atlanta, but the business model was based on selling the STBs to cable and satellite operators, on terms shaped by the latter companies in a business-to-business market.

When integrated with the new capabilities enabled by DVRs from 1999-2000 onwards, STBs began to assume their tremendous presence across the television landscape in the global north. While the introduction of VCRs involved fierce battles between the consumer electronics industry and the audiovisual industries – exemplified by debates about video piracy and the 1984 'Betamax' case in the US (Wasser, 2002) – DVRs were also lastingly disruptive or transformative of television, by enabling much more convenient recording and time-shifting than VCRs. They allowed the rewinding and fast forwarding of recordings and even of 'live' television, by storing content on a hard disk embedded in the box. The most famous brand associated with this shift was TiVo, which gained huge media coverage because of the television networks' fears that its introduction would allow viewers to skip (or rather fast-forward) adverts and thus undermine the basis of their business in selling television audiences to advertisers. In fact, as is so often the case, there were many other similar technologies, and many other companies developing them. TiVo's greater prominence can probably be explained by the fact that it was more effectively marketed and publicised than other similar technologies in the US epicentre of global television (Ansari et al, 2016).

The take-up of TiVo was highly uneven across the world (see Meese et al., 2015). Many cable and satellite operators in fact were able to commission or in some cases develop in-house their own version of DVR technologies. Nevertheless, the important fact is that DVR systems were incorporated into many of the STBs provided by cable and satellite operators to their subscribers globally.

The TiVo case is an important reminder of the diversity that characterises STB markets, broadly defined, and television hardware more generally. The category of STB actually covers a wide variety of distinct products – including terrestrial STBs designed to convert digital signal to analog for use in older TV sets (still used in those nations where switchover from analog to digital is underway); cable and satellite STBs designed to access and decode pay-TV feeds; IPTV (internet protocol television) STBs for use over managed networks; and 'cord-cutter' products designed for streaming video 'over the top' (OTT) via apps (see Table 1). Every country has a different mix of STBs in circulation, shaped by divergent histories of infrastructure investment, standards, and digital television policy. For example, cable STBs have long been the norm in the US, while IPTV boxes are widely used in East Asia, especially in Korea and mainland China.[4] India's famous network of 'cablewallahs' (informal cable operators involved in 'last mile' provision) has driven national demand for cable STBs, which redistribute feeds from satellite TV connections (Parthasarathi et al., 2016). The geographic variability of STB markets and adoption frustrates any attempt to write a unitary global history of this technology; hence it is important to consider the geographical, technical and policy differences that shape the use of STBs around the world.

Table 1: Set-top box sub-types

Device type (with US and UK examples)	Leading manufacturers	Market arrangement
Set-top boxes		
Terrestrial (DTT) STBs *(e.g., Freeview boxes)*	ADB, Arris, Echostar (satellite), Huawei, Humax, Kaonmedia, Samsung, Technicolor, Sagemcom	Sold direct to consumer (sometimes with government subsidy)
Cable STBs *(e.g., Virgin TV box, Xfinity X1)*		Provided by pay-TV operators, telcos
Satellite STBs *(e.g., Sky Q, DirecTV Genie boxes)*		Provided by pay-TV operators, telcos
IPTV STBs *(e.g., BT TV's YouView, Google Fiber TV Box)*		Provided by pay-TV operators, telcos, ISPs
Pay-TV OTT STBs *(e.g., Now TV, Slingbox)*	Roku, Kaonmedia	Provided by pay-TV operators or sold direct to consumer

Related products		
Streaming media players *(e.g., Apple TV, Roku)*	Amazon, Apple, Google, Roku	Sold direct to consumer or provided by telcos
DVRs *(e.g., Tivo)*	Tivo, Panasonic, Teac, Humax	Sold direct to consumer
Gaming consoles *(e.g., Playstation)*	Sony, Microsoft, Nintendo	Sold direct to consumer

The incorporation of DVR technologies into cable and satellite STBs had nothing like the disruptive effect on television advertising that television networks initially feared, but the functions associated with DVRs became an essential part of the next generation of STBs that developed in the 2000s, along with the pay-TV, EPG and other functions that had already developed in the pre-DVR era of STBs. Moreover, at the same time as these developments were taking place, governments across much of the world had organised, in collaboration with consumer electronics and IT industry trade bodies, a transition from analogue to digital television. This provided a boom in the television set industry, as older sets needed to be replaced by digital-capable sets – always part of the aim of digitalisation, as Galperin (2004) showed. It also created a boom in digital terrestrial STBs. Although it was possible for digital television to be transmitted to television via (new) rooftop and indoor aerials, the wider choice and convenience associated with multi-channel television, including the incorporation of DVR technologies, was only really possible through the development and marketing of STBs. For example, in the UK, the 'switchover' from analogue to digital signals in the UK (2008–2012) was dependent upon the earlier, successful establishment from 2002 to 2006 of Freeview, a joint venture between the BBC, satellite operator BSkyB (brought in for their marketing and technical expertise) and telecommunications company Crown Castle (later Arqiva), eventually joined by the other major broadcasters: ITV, Channel 4 and eventually Channel 5. While Freeview allowed transmission of free television channels to homes via new aerials, an important part of the arrangement struck by regulators and media organisations was that consumer electronics companies would produce specialist Freeview STBs at reasonable prices (Starks, 2013). These sold heavily to customers who did not wish to subscribe to cable and satellite, and eventually came to incorporate VOD and pay-TV capabilities. Freeview is still the main basis of television consumption in the UK, even as cable has spread by offering joint broadband-cable-telephone packages. The Freeview model was also adopted by Australia and New Zealand. Meanwhile, in the USA, STBs provide a very profitable income stream for cable companies, who charge users a monthly fee for their use, meaning that long-term subscribers may 'pay for' their STB many times over.

As STB markets grew in the 2000s, the number of consumer electronics companies involved expanded. Some of the most notable companies have been European (Thomson, Amstrad), some Asian (Huawei, Samsung, Skyworth), some North American (Echostar, Arris, Motorola). These companies, and a handful of others, have been responsible for supplying the vast majority of cable, satellite and IPTV receiver boxes to pay-TV operators worldwide, who

apply their own branding to the boxes and then install them in their customers' homes as part of their pay-TV subscription packages. As pointed out above, this is mostly a business-to-business (B2B) market, and this means it rarely attracts much attention from media industry observers, but it is nonetheless a sizeable and important market globally, with overall revenues estimated to be approaching US$20 billion (Technavio, 2017). This figure is expected to increase further, notwithstanding cable-cutting in some markets, due to the growing demand for pay-TV services in major emerging economies, especially China. Indeed, China's enormous appetite for STBs has made Chinese electronics giant Huawei the leading global supplier of IPTV STBs, even though its products are little used beyond East Asia (SNL Kagan, 2017). Meanwhile, Arris/Pace – the best-known manufacturer of STBs in Europe, North America and Australia – is losing market share overall because of the growth of both IPTV and the massive expansion of Asian markets. These divergent national and sectoral specificities complicate familiar industry discourses about the future of television devices. Notwithstanding industry discourses in Europe and North America that predict a "boxless" future, the experience of Huawei and other Asian STB manufacturers tells a different story, in which the STB is becoming more rather than less integral to everyday television viewing for much of the world's population, due to rising pay-TV adoption in emerging economies.

Strongly associated with the rise of the STB we have just outlined were two particularly important developments in terms of television's role as a social and cultural institution. First, in the global north, electronic programme guides (EPGs) became more and more embedded in people's viewing practices. EPGs came to be built into the software of television sets as well (i.e, it was possible to use an EPG without a STB) but more and more users used their STB interfaces to organise their viewing and recording. This fact has led some countries and jurisdictions to legislate that EPGs should prioritise certain content, for example national general-interest and public-service channels. In the United Kingdom, this involves a set of principles designed to ensure that public service channels are easily discoverable in the EPG interface – for example, reserving the first channel numbers within the channel list for PSBs, or the centre position in a screen of tiles or icons (Ofcom, n.d.). Different EPG rules apply in other nations regarding interoperability, accessibility, and 'must-list' requirements. The term that has increasingly come to be used for this group of issues is 'prominence'.

Second, digital cable and satellite STBs collected data on the behaviour, tastes and habits of television audiences, by allowing that information to be sent back 'upstream' to cable and satellite operators and the consumer electronics firms developing the hardware and software. As Evens and Berte (2014: 242–243) put it, STBs 'function as people meters and register all user actions, including linear and interactive viewing behaviour such as time-shifted viewing, on-demand video consumption and other kinds of interactive applications'. It was via the STB, not via internet or smartphone use, that datafication in its contemporary sense – the 'transformation of social action into online quantified data, thus allowing for real-time tracking and predictive analysis' (van Dijck, 2014: 198, citing Mayer-Schoenberger and Cukier, 2013) – entered into the media industries, although its ramifications are still rather poorly understood (Arsenault, 2017; Doyle, 2018). The transmission of data back to cable and satellite operators and consumer electronics firms had significant implications for the audience research industry (Buzzard, 2012: 129–149; Napoli, 2011: 75) but it also led to early

concerns over user privacy, as discussed by Carlson (2006) in his prescient article. The return of data 'upstream' also meant that digital cable and satellite STBs could generate personalised recommendations for viewers based on the data collected. Indeed, discussions of TiVo's recommendations represented an early appearance in popular culture of controversies over the accuracy or otherwise of algorithmic recommendation, as Cohn (2016) shows.

We examine the implications of these changes - battles over prominence and datafication - for understanding the distribution of power and control in the television industry, later in this article. In the next section of the article, however, we discuss how interventions by technology companies may now be starting to displace traditional STBs in favour of new (and often smaller) devices, such as the dongles and sticks that are increasingly used by viewers to connect to internet-distributed television, and we discuss what this means for television.

Television device ecologies: from set-top boxes to sticks, dongles, and streaming media players

The goal of many companies developing, manufacturing and marketing television hardware is to establish market power via the spreading of proprietary software and devices, and to accrue revenue and competitive advantage via the collection and analysis of data. This move is a key part of a hastening transition away from cable and satellite-led systems of multi-channel television towards a new television distribution model based on internet access. As a result, over the last decade a rather different market has emerged, including internet-connected TV streaming boxes, dongles, and devices, which are sometimes grouped together as *streaming media players*: the kind that can be bought from an electronics store then connected to a TV set via an HDMI cable. Popular devices in this category include Roku players, Apple TV, Chromecast, and Amazon Fire TV devices (Fire Stick, Cube, Recast, etc). Internet-connected Blu Ray players and game consoles such as Xbox and PlayStation, via which many users access streaming content, provide similar functionality. In the United States, for example, almost half of all households own an Xbox, Wii or PlayStation (Nielsen, 2017). These devices build on the software collection and analysis capacities developed by DVRs in the 2000s, and the later emergence of user-friendly networked streaming devices, notably Apple TV, from 2009 onwards. Each structures the television experience in a particular way, using its own interface and operating system, or a bespoke version of an open-source operating system (e.g., Amazon's Fire OS, based on Android).

Rather than placing any one of these devices at the centre of analysis, we find the broader concept of television "device ecologies" – a term used in computer science, design and human-computer interaction to refer to "collections of devices...interacting synergistically with one another, with users, and with Internet resources" (Loke and Ling, 2003: 559–560) – useful as a way to conceptualize their interrelations, which have vastly increased the number of possible device combinations needed to access internet-connected television. For example, when accessing internet television some households use only a smart TV; others will use a 'dumb' TV with attached STB or streaming media player; others will have a full range of peripherals including smart TV, streaming media player, STB, smart speakers; and so on. Each combination of devices introduces specific issues of interoperability and integration.

The appearance of such devices raises important questions for cultural and media policy regarding the prominence afforded to particular content and services in the interface and/or operating system of each device. Until the 2000s the STB was for most users the only device aside from the TV set that could be configured to exercise 'curatorial' control over linear television content, by contextualising, highlighting or otherwise drawing the user's attention to particular channels and programmes. This was made possible through EPGs and digital cable and satellite STB home screens. Various business strategies emerged during the 1990s to monetize these interfaces. Today, the proliferation of streaming devices extends this tradition of commercial intervention. Streaming media players are explicitly designed with the capacity to promote, recommend and 'surface' particular content and services at the expense of others. A key goal for many of the major players in this market is control over user attention, experience, and discovery--in addition to control over hardware, which is a necessary but insufficient stage in the longer game.

Unlike the cable or satellite STB, the streaming media player is a retail product and associated service sold direct to consumers, and the dominant players in the global market for such players are information technology companies: especially Apple, Google, Amazon, and Roku. This marks a significant departure from the rather contained, business-to-business market of STBs, in which specialist manufacturers like Arris and Pace were dominant. In the new economy of television hardware, Apple, Google and Roku have been able to successfully market their own devices and/or operating systems as cheap and user-friendly replacements for cable and satellite STBs, with pay-TV subscribers encouraged to access their subscriptions through OTT apps. At the same time, Apple and Roku are also signing deals with pay-TV operators to replace their aging STB inventory with more consumer-friendly boxes: for example, Canal+ (France), Salt (Switzerland) and Verizon and Charter (United States) currently offer their new pay-TV customers an Apple TV device– configured as an IPTV STB and pre-loaded with all the operator's apps and linear channels – rather than a traditional STB manufactured by a specialist company like Arris or Sagemcom.

Specialist STB manufacturers, increasingly concerned about competition from Silicon Valley firms, have been reducing in number through acquisitions and mergers. For example, the STB manufacturer Technicolor acquired Cisco Connected Devices in 2015, while Arris acquired Pace for US$2.1 billion in 2016. Increased competition is not restricted to STB hardware. Operating systems are also emerging as a key battleground between traditional STB manufacturers and information technology firms, especially Google. Google's open-source Android TV operating system has been adopted widely by device manufacturers at the expense of older proprietary systems, fueled by the 2018 release of a dedicated Android TV 'operator tier' (allowing pay-TV operators to customise the device home screen and user interface to their own specific requirements). At the time of writing, at least 20 well-known pay-TV operators and telcos have adopted Android TV as their STB platform (Irdeto 2019). Together, these industry shifts have had the effect of bringing the formerly niche STB business further into the sphere of consumer technology and software.

TSoftware is crucial here. As Evens and Donders (2018) have argued, future profitability in television industries is increasingly linked to a strategy of "platform power" associated with control over operating systems, interfaces, and digital marketplaces. In other words, the software dimension of television's device ecology becomes crucial as a site of control and leverage. Android – which, in its various mobile OS, Android TV and operator tier versions, now commands an estimated 40% global market share of the connected TV operating system market – is a prime example here (IHS Markit, 2018).[5] Other major players in television software include Samsung and LG, which control their own operating systems (LG's webOS, initially developed by Palm and Hewlett Packard, and Samsung's Linux-based Tizen OS), and Roku, which licenses its Roku OS smart TV operating system to Chinese TV manufacturers such as Haier and Hisense, which then rebadge and customise the OS before installing it in their TV sets.

Once there is a substantial user base locked into a particular TV operating system, revenues can be extracted in several ways. The most common strategies include taking a commission on app store revenues, and selling advertising space on the device's homescreen and remote control. For example, Roku offers its partners "a variety of ad placements, particularly native display ads, on the Roku home screen and screen saver" and even sells "branded channel buttons" (e.g., the Netflix or Hulu button) on the Roku remote control (Roku, 2018: 6). For platform providers like Roku, the "real estate" of the user interface is both a commodity that can be sold to the highest bidder and a vital element of platform power. The prime positions on the interface can be actively marketed to content providers, pay-TV companies, app developers, social media platforms, or other entities wishing to capture user attention via the TV screen. Conversely, companies that choose not to pay for a prominent position must rely on users actively searching for and installing their apps, and will not benefit from the preferential placement and 'nudges' that apply to partner apps. This leads us to the policy implications of this issue of prominence, and the related issue of datafication.

Prominence and datafication in television's new device ecology

Prominence

Among the groups most affected by the above issues of prominence are public-service media (PSM) organisations, who are concerned that the cultural policy regulations that have been built into broadcasting law in many nations – including priority channel placement and EPG prominence for PSM – have no direct equivalent in the streaming environment. This has led to concern that the central, protected position of PSM within the television distribution system is being eroded. BBC Director-General Tony Hall has recently called for new laws to create "proper, protected PSB [public-service broadcaster] prominence on the first page for ANY significant device - be it a set top box; smart TV; or a games console sold in the UK".

UK Channel 4 CEO Alex Mahon has provided some vivid examples of the cultural consequences of inaction on smart TV prominence:

When you turn on a smart TV the device is entirely geared towards operating through its own user interface and hub. The positions on those screens are governed by the auction of spots and by negotiation with the manufacturers.… Which news gets promoted to you first? Is it the BBC, is it Channel 4, or is it Russia Today? Or is it a clickbait fake news farm? The truth is it's completely up to whoever owns that platform and they're free to sell that spot off to the highest bidder. (Alex Mahon, cited in McDonald 2018)

These comments by Mahon and Hall underline the policy significance of television's device ecology, as opposed to just individual services or apps. Prominence is a multidimensional problem for content providers, with multiple layers of intermediation at work simultaneously. This is because prominence is determined not only by the interface design of individual services/apps, but also by the interfaces of other connected devices, including smart TV sets and streaming devices, through which those apps/services are accessed. For example, a viewer accessing BBC content through an Apple TV is likely to use the Apple TV home screen recommendations to directly select individual shows, at least some of the time. In this scenario, the user's choices would be structured by the differential integration of as many as three different platforms: the iPlayer app, Apple's tvOS operating system, and, possibly, the operating system of their smart TV. However, the successful integration of these various software systems is not guaranteed, and is subject to each operator's partnership agreements, commercial priorities, security requirements, app store policies, interoperability, and other factors both technical and commercial in nature.In each case, prominence is determined by opaque layers of intermediation – platforms within platforms, like a series of Russian dolls. Each has the power to differentially promote or block the recommendations pushed through by the next platform. Cultural producers who wish their content to be easily discovered need, then, to understand how each of these intermediaries work, their integration with other apps and operating systems, the opportunities for paid prominence, and the relative disadvantage or other consequences of not participating in such arrangements.

Datafication

Another key issue foregrounded by attention to television device ecologies is the role of data collection and analysis in the new television industries. We indicated earlier that STBs, through their incorporation of upstreaming data, were in the forefront of introducing to the television industry the kinds of tracking of audience or user behaviour that have been the cause of considerable concern with regard to the marketing and advertising industry (Turow, 2011), smart TV and speaker manufacturers (e.g., Samsung, Vizio and Alexa devices 'spying' on users), and of course in relation to the GAFA tech oligopoly (Foer, 2017: 183–204). Another way of putting this is that STBs brought about the early onset in the television industries of the datafication referred to and defined earlier, including analysis of people's behaviour, attitudes and emotions. Jose van Dijck (2014) has criticised the widespread acceptance, among researchers and policy-makers, of datafication as a desirable and even necessary part of the contemporary communications environment, and she has coined the

term 'dataism' to refer to both a) the pervasive belief in the efficacy of digital tracking and quantification as a means to objective knowledge, and b) extensive trust in the institutions that 'collect, interpret, and share (meta)data culled from social media, internet platforms, and other communication technologies' (van Dijck, 2014: 198). By contrast with recent discussions of social media, search and e-commerce, there has been little sustained critical comment in television studies on the potential problems associated with the gathering of data about television audience members, nor has there been much reference in critical studies of data about the presence of data-gathering in the television industry. While critical researchers have been alert to the dangers of accepting industry hype about the ability of television institutions to 'personalise' recommendations in such a way to enhance audience rewards and pleasures (Athique, 2018; Hallinan and Striphas, 2016; Johnson, 2019: chapter 6), there has been less discussion of the implications for contemporary society of television data audience capture. Instead, many analysts seem to have largely accepted the television industry (and indeed the social media industry's) account of its data gathering and analysis as part of a trade-off, in which users implicitly consent to surveillance in exchange for improved user experience and access to free services. A focus on television software and hardware devices such as STBs helps to correct these tendencies in recent scholarship, and draws attention to problematic ways in which data are increasingly central to contemporary media industries.

As noted above, Carlson's early research on TiVo was prescient in noting that 'while TiVo is able to utilize its data collection platform to create a new revenue stream, perhaps more importantly' its market research reports 'aid in promoting a two-way flow of information model as the future of television' (Carlson, 2006: 103). Carlson also noted that the 'new aptitude for data collection' caught the attention of privacy advocates who strongly criticised the company for its failure to provide a clear privacy policy. Later generations of STBs have extended this capacity. By 2009, market researchers were claiming that the STB was set to provide the television industry 'with a vast ocean of granular insights' (Bhatia, 2009) on TV viewing, allowing them to know the audience in far more detail than via panels. New intermediaries appeared to offer services that would integrate data from STBs with 'other enterprise master data' to provide analysis of viewership trends (Infosys, n.d.), including in markets such as India where market research had previously been limited (Bansal, 2017). As one trade magazine puts it, 'while Nielsen ratings remain the central currency for measuring TV audiences, the process of gathering second-by-second data from millions of set-top boxes has rapidly become an alternative option that can help programmers and their advertisers learn much more about their viewers - and target them' (Baumgartner, 2015: 8). This 'granularity' initially involved, for example, seeking to understand patterns of channel switching (Shabbab, 2006). However the data-gathering capacities of STBs and other devices (including smart TVs) have expanded massively in recent years to include the user's pause/rewind behaviour, search and browsing voice control commands, and information on other connected devices in the household wifi network. The uses of these data are various, but include what many in the advertising industry see as the 'holy grail' of advertising: fully addressable TV ads, which can be targeted to individual, known viewers rather than bought on the basis of demographic segments inferred from program types.

Of course, the sheer amount of data provided by analysis of 'second by second' viewing across literally millions of devices provides considerable challenges for market research and data analytics. The number of intermediaries involved in the value chain of TV datafication (including platform providers, data brokers and specialist software firms) continues to grow, and the relations between them are frequently conflictual, leading to 'overlapping surveillance enclosures … characterized by a proliferation of different monitoring networks with varying capabilities for information capture' (Andrejevic, 2012: 93), under the control of many different entities. In this respect, the almost unimaginable quantity of 'big data' also serves as a means for data analysis companies to promote themselves as having access to some magical methods of making sense of such vastness, creating the investment bubble that we have seen in recent years. The widely-circulated formulation, 'data is the new oil', apparently coined by data analyst Clive Humby, directs attention to the fact that not only is oil valuable, it also requires considerable work to process it (Marr, 2018). There remains great uncertainty about whether such big data really provide meaningful insights, but there is great fear about the dangers of being left behind, across many industries, including television.

What is often not recognised is that STB data has been as important to these trends in the television industry as social media analytics and internet-distributed television. There has been a remarkable degree of media and academic interest in Netflix's gathering and collection of data about its users, with almost mystical powers attributed to the company's strategies (e.g., Steiner, 2013). But since the rise of the STB, cable and satellite companies have had access to huge amounts of data. In the era of datafication, many have started to seek out ways of 'monetising' those data, by working with partners to sell on information about users to advertisers and other parties, for example audience research market leader Nielsen's agreement with leading US satellite provider DISH to integrate their respective data sets. It is surprising that even those researchers who have astutely analysed recent developments in audience research, such as the increasing use of social media analytics as a way of supplementing or even replacing panel data (Kosterich and Napoli, 2016) or the increasing concern with measuring 'engagement' rather than audience size or 'exposure' (Nelson and Webster, 2016) have, beyond fleeting references, paid less attention to the now-pervasive use of STB data. Research that has drawn important attention to the problems and dangers involved in processes of capturing and analysing user data in the digital communication environment (e.g., Andrejevic, 2007) has understandably focused on the power of large tech corporations to combine data sets from multiple user activities and devices. But television remains a hugely significant way in which people spend time, and its relevance to datafication debates has been so far under-appreciated. When data surveillance researchers have turned their attention to television (e.g., Lee and Andrejevic, 2014), the focus has been on the use of streaming services and game consoles, and how new 'second screen' technologies would permit surveillance. These are indeed important issues, but the humble STB, so embedded in ordinary use, represents a way in which data capture was already integrated into television. As Andrejevic has noted, the dangers of such surveillance include, but also go beyond, questions of privacy, to those of opacity and even exploitation, where our own activities are incorporated into a political-economic system where convenience and ubiquitous availability are placed ahead of all other notions of the good, with very little

understanding on the part of ordinary citizens about how information about them is being used, and with minimal consultation or democratic regulation.

Conclusions

This article has sought to correct the neglect of television hardware (now of course thoroughly dependent on computer software) in studies of television and the television industry. Many analysts understand devices almost entirely as products of the information technology sector, but we have highlighted the crucial role of the consumer electronics sector in shaping television as a social and cultural institution. Focusing on one of television's most ubiquitous and yet poorly understood objects, we have shown the historical importance of the STB, and how most functions of contemporary internet-connected streaming devices have a precedent in this neglected device. We have argued that the STB endures as a central intermediary in the television device ecology, even as its capabilities are redistributed and dispersed across a wider variety of consumer products, including streaming media players and smart TVs. We have also observed how technological and market boundaries around the STB are changing, as are the companies competing in those markets. Finally, we discussed two important cultural and social implications of these transformations: the ability of STB-like devices to shape the prominence of different kinds of content, and the extensive data-gathering capacities built into such devices.

The key features of the story we have told here – technological disruption, shifting market boundaries, industry consolidation, and an altered landscape in which specialist equipment manufacturers, consumer electronics companies and 'Big Tech' now compete – are not unique to television. However, the undiminished cultural significance of television to public culture in every nation makes it a special case, and it means that the stakes of the industrial transformations we have described here are especially high. In showing how the STB has been reconfigured over the years by changes in policy, technology, and industry structure, we hope to have provided a contribution to understanding the infrastructures of television in the multiplatform era, and a different way of thinking about television's many "black boxes". A lesson for research on media technologies more generally is that the most ubiquitous objects are sometimes neglected, and that attention to such overlooked devices can cast light on historical continuities that an excessive focus on transformation sometimes obscures.

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[1] Apple has recently announced a new subscription service, TVPlus, which is expected to be integrated into Apple's TV platform in the near future.

[2] Trade books and business histories also occasionally deal with set-top boxes (e.g., Horsman, 1997; Robichaux, 2003). Although important research has addressed the place of television sets in the home as 'domestic technologies' (Morley 2002, Chambers, 2016), and Chambers (2011) has addressed TV set design, there has been very little media studies scholarship on the business of television sets or the place of sets within TV infrastructure.

[3] Parsons (2008) identifies International Telemeter's dual heterodyne cable converter box – first demonstrated publicly in 1966 – as among the first generation of television's set-top boxes.

[4] The meaning of 'IPTV' (internet protocol television) varies according to national context. In this article, we use IPTV to refer to internet TV distribution via managed networks, as opposed to 'over the top' distribution using the public internet.

[5] This figure includes both TVs installed with Android TV, Google's dedicated operating system designed for smart TV sets, and generic streaming boxes installed with Android mobile OS.