3D PRINTING
Rights & Responsibilities:
consumer perceptions & realities

Emerging issues for online access, communication & sharing of 3D printer files

THE UNIVERSITY OF MELBOURNE

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Luke Heemsbergen, Robbie Fordyce,
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Authored by **Luke Heemsbergen, Robbie Fordyce, Michael Arnold, Thomas Apperley, Thomas Birtchnell, Bjorn Nansen**

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University of Melbourne
Website: 3DPrintinginfo.org
Email: nansenb@unimelb.edu.au
Telephone: +61 3 9035 5511

Australian Communications Consumer Action Network
Website: www.accan.org.au
Email: grants@accan.org.au
Telephone: +61 2 9288 4000
If you are deaf, or have a hearing or speech impairment, contact us through the National Relay Service: www.relayservice.gov.au.

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Executive Summary

Many people in Australia and around the world are creating, sharing and printing an assortment of real world objects from digital files they find and share online. They are able to do so through new and relatively inexpensive 3D printers that turn digital design files into real life objects that range from personal to professional, utilitarian to artistic. These abilities also come with new sets of responsibilities and risks that consumers identify, but need insight into. This white paper focuses on 3D printing from the user's perspective as they navigate risk and regulation around finding, sharing, modifying, and printing files.

It considers 3D printing as a social practice that is largely dependent on digital communication: consumers are enabled by the effortless connectivity the internet brings to find, modify and print files, whether at home, a retailer or a library. The paper is designed to interpret consumer concerns and practice and then leverage current expert legal opinion and case law to arrive at clear points for consumers to consider as they explore 3D printing.

Our findings suggest that while consumers are relatively naive to intellectual property regimes (IPR) and product safety, they bring their own understanding of risk and responsibility in the digital age. Our findings coalesce around six points that consumers should note as they consider their communicative and productive 3D printing practices:

1. Risk is often directed towards individual users for 3D printed goods. Protections consumers might be used to through state protection regimes are less certain to apply, or be easily enforced.

2. Australian law is necessary, but not sufficient to understand user experience online. Website terms and conditions and functional mechanisms like 'takedown' notices will often define user experience.

3. Copyright only serves artistic works as they are expressed in some medium - not their ideas or functional objects that users might design.

4. Patents protect novel functional inventions, but users must register for them.

5. Design and trademark law will evolve into important factors guiding 3D printing, but provide complex rights.

6. The power to create is decentralised with 3D printing. So to, is the power to control what is created, and how accountability and liability work.

This white paper is part of a consumer-oriented information project (available at 3Dprintinginfo.org) for 3D printer users. It focuses on the practices, rights and responsibilities of 3D printer users, and evaluates popular online file marketplaces and sharing sites.

The report itself is structured to first summarise the (social) history of 3D printing, then explain our approach to the research. The first main discussion section then draws on focus group research and

online data collection to explore consumer perceptions around 3D printing and how 3D objects are shared online. The second discussion section responds to these patterns by considering how current regulations interpret developments in 3D printing and what this means for consumers in practice. The final section offers some tentative user-inspired frames for future socio-economic models for 3D printing.

A note on terms:

While this report is targeted towards Australian 'consumers', 3D printing practices mean that consumers literally become makers, and often also tweak or remix what they find online. As such, we will call people that use 3D printers 'users'. This is meant to show that consuming and producing are common and tied practices of 3D printing that exist as cultural practices worked out in digital communication media.

A (Social) History of 3D Printing for Consumers

This section introduces the technical and social histories of 3D printing. It concludes by highlighting ways that researchers have come to think about how everyday 3D printing, decentralises the power to produce objects from industry by sharing designs across the internet. We approach this section - and the rest of our research - by acknowledging that 3D printing is a social practice. 3D printing is not just reliant on evolving technologies of 'additive manufacturing', it also depends on new patterns of digital communication between the many users and intermediaries who have a hand in designing and sharing the files required for 3D printable objects. That is to say that 3D printing is a practice that involves socially sharing information and sets of cultural techniques that sit atop the technology of additive manufacturing.

Technological History

The technological history of additive manufacturing is quite long. Currently, 3D printers involve a mechanical process where automated machinery uses a predefined design to create objects by laying down multiple layers of material to build up objects 'additively'. The idea of using machinery to automate the creation of objects with distinct designs can be traced to technologies of the early 19th Century, notably the Jacquard loom. This machine relied on punch cards with specific patterns of holes in them to automate the creation of intricately designed textiles. People could communicate designs by sharing punch cards that would re-create the same pattern to perfection across multiple garments or looms - the punch cards held the required design. By the late 19th Century, patents in America also described a systematic way for transforming two-dimensional topographical data into fully three-dimensional objects.

One hundred years later, computerisation and advancements in materials science in the 1970-80s led to the first industrial reference to 'additive manufacturing'. The process was described as a computer working from a digital design file to direct a machine to build objects layer by layer. Chuck Hall and Scott Crump patented some of the underlying processes that allowed novel forms to be created in small amounts of time. These inventors went on to found companies that grew into the two largest 3D printing firms, 3D Systems and Stratasys respectively. As those processes improved with time, additive manufacturing was used for industrial form, fit and function trials (Wood 1990), as well as by industrial designers, architects and engineers to prototype their new designs (Pham and Gault 1998). New technology in the 1990s, including being able to 'print' in metal, led to using additive manufacturing for limited production runs in aerospace, automobile and military applications, where customers demanded customisation and complex geometries over economies of scale (Hopkinson, Hague, and Dickens 2006).

Social History

An important social shift occurred as the patents on additive manufacturing expired, allowing new uses of the underlying technology in innovative consumer oriented projects. Patents work by giving an inventor of a new, useful, and non-obvious process or machine exclusive rights to stop anyone

else from using and profiting from their invention for a limited amount of time (usually 20 years). However, to be granted the patent, the inventor must publicly detail the invention. This way, after the patent term expires, anyone can use the invented product or process to solve technological problems in their own products. The 20 year lag is designed to give inventors financial incentive to invent, while ensuring that useful scientific advancements are shared by all. From 2010 to 2015, many useful additive manufacturing patents expired and this led to a proliferation of inexpensive mass-market 3D printers targeted towards hobbyists and enthusiasts (Moilanen and Vadén 2013).

The shift to consumer machines mirrored a shift in the economies of 3D printing, involving questions around how and why people were becoming interested designing, sharing, and printing 3D objects. The 3D printing consultancy Wohlers and Associates notes that in 2014, 86% of 3D printing revenues came from industrial applications, while 92% of the printers sold were for consumer purposes. So what's going on there? The data suggests that consumers and communities are finding uses for their printers different than charging others for prints.

Much of what is now designed, shared and printed is created through what Benkler (2002; 2006) describes as commons-based peer-production. This involves the re-use of others' contributions with minimal restrictions on that use. Such 'gift economies' or 'sharing economies' use the power of community-wide experimentation to quickly innovate and create new solutions. These economies usually consider attribution important, but usually do not understand ownership of designs to mean restricting others' ability to use them. They see restricting the use of designs as an economic cost that stifles innovation, especially in cases where the end uses of objects are not commercial. In this model, the re-use or re-mix of designs represent crucial enablers for 3D printing. The wheel (or any other widget found online) does not have to be re-invented by each maker, but instead can be modified to suit individual needs. This type of commons-based peer-production is premised on sharing designs in the 'commons' so that others can build from yours as you can build from theirs.

Creativity in the 3D printed commons means that often effort is put into personal objects, objects that are useful for users or their friends, artistic pieces, or even objects that replace things consumers would otherwise have to buy. Users are also experimenting, generating things that they didn't know they would be able to generate. Harvard University's Jonathan Zittrain (2007) calls technology that enables such experimentation 'generative' in that it can generate new and unpredictable outcomes, rather than being limited to building a specified subset of things. Users that experiment in this way find both offline and online spaces to do so. Offline, Schrock (2014) describes community-maintained workshops that allow individual tinkering, social learning, and collaboration as 'Hacker-Maker Spaces' (HMS). HMS are growing exponentially according to Kostakis et al. (2014), from around 40 globally in 2007 to over 1000 by 2013. Here academics understand 3D printing through a range of practices such as 'playfulness' rather than printing for a strict purpose (de Smale 2014), or the 'ambivalent emancipation' (Bosqué 2015) that results from throwing away the manual and focusing on activities such as repair over mere replication. Other approaches suggest a 'critical engineering' that encourages techno-political literacy, which questions the space between the production and consumption of technology to uncover how technology dependency shapes its users. Channeling these productive, but potentially disruptive, energies speaks to the societal opportunities and challenges of understanding 3D printing as social practice.

Online, the sharing of 3D designs usually happens through specific platforms or services that themselves become an important consideration in what gets made. Your Google searches end up somewhere! How these sites are designed, what their terms of service allow, how they curate objects, and what they restrict, are all important considerations that shape the cultures of 3D printing. They also shape the rights and responsibilities of those who hope to upload, download, modify or print out files. The typical concerns of Australians regarding these spaces, and how they come about, are outlined in the next section of the white paper.

We have already hinted that patents have played an important role in technical side of 3D printing as a form of intellectual property. Intellectual Property Rights (IPR) considers how 'creations of the mind' are regulated for commerce, and are sometimes at odds with the creative desires of 3D printer users. At the same time, IPR help those who consider their designs to be their own, and wish to limit others using them.

Consumer Questions

Consumer concerns with 3D printing and IPR are more often defined through intellectual property regimes like copyright and trade dress rather than patent law, and these concerns will be detailed in the rights and responsibility section of this white paper. Regardless, consumers are increasingly becoming caught up in the opportunities and challenges of 3D printing as they confront questions of social expectations and legal practice. That means that hobbyists, artists, and home users of 3D printing are beginning to experience, question, and need guidance on both formal regulations and social norms that are emerging both online and offline.

The reality for most Australian consumers is that they do not consider how copyright, patent, and trade dress/design law - from international jurisdictions - might influence how and what consumers can create and what others can do with their own creations. Consumers also have questions about safety and liability regarding 3D printing. Finally, consumers do not currently have reliable information about which online intermediary that stores and shares their work presents the best choice for them.

Approach to Research

The histories identified above led us to consider how to best inform Australian consumers about their rights and responsibilities for 3D printing, as well as provide guides towards some of their concerns. The final and evolving product of our work is actionable consumer information, hosted at 3DPrintinginfo.org. The current section of this report details the research design and methodology we used to discover and respond to consumer concerns.

The design reflects and learns from a multi-year research arc on the socio-political aspects of 3D printing. Previously, the team deciphered normative academic and industry models of 3D printing practices through extensive literature review, expert interviews and participant observation of 3D printing workshops. We also scraped the website of the largest 3D printing intermediary, Thingiverse, to determine empirical patterns and cultural trends of hundreds of thousands of objects that people have uploaded to print (Fordyce et al. 2016, Heemsbergen et al. 2016).

Themes that emerged from that work applicable to the current project were diverse. They include the challenge of an inbuilt lack of centralised accountability for the decentralised rights and responsibilities that come with 3D printing; and an apparent naivety from those learning about 3D printing regarding their own rights and responsibilities for managing the sharing and printing of designs. Further, the research on objects shared online mapped the popularity of different types of things and how these were thematically 'tagged' by users. It uncovered relational networks shared between tags through Social Network Analysis (SNA). These methods allowed us to explore empirically what types of things consumers gravitate towards printing and why, as well as the common social practices of hundreds of thousands of users who create, share, and print 3D designs. We continue to analyse these data and new findings are reported in the sections below. Together, the previous qualitative and SNA research informs our understanding of 3D printing as a social practice, and allows us to infer how Australian consumers interpret 3D printing, with an aim to find out what their concerns are and what they still need to know to make informed choices.

The current project leverages the above structure to inform discussion for a number of focus groups with Australian consumers who identified an interest in 3D printing. We use the insights gained from the focus groups to narrow our attention to the applicable areas of law in regards to rights and responsibilities. We rely on expert legal findings that are based on jurisprudence and informed through a 'law in context' approach to consider how the law has and will interface with evolving commercial and consumer concerns, rights, and responsibilities. To do so we survey a large amount of recent legal scholarship, but ground our analyses from the concentrated findings of legal experts working in the field of 3D printing. Specifically, we leverage recent scholarship from Dr. Angela Daly (Faculty of Law, Queensland University of Technology), forward looking socio-legal narratives concerning 3D printing discussed with Adam Holland (The Berkman Center for Internet and Society, Harvard University), and the works of Michael Weinberg (currently IP & General Counsel at Shapeways) who wrote extensively on 3D printing and the law for the non-profit organisation Public Knowledge, and explicit advice from IP Australia.

Our focus groups' sample frame was a major Australian city. We purposively narrowed our respondents to those that had some interest, but not much experience with 3D printing by clustering advertising at city libraries and businesses with 3D printing facilities, services, or classes advertised. We asked potential respondents to fill in a brief survey outlining their level of knowledge and experience (n: 37), and excluded those scoring above a specific threshold. The remaining cohort of participants was stratified according to self-reported 3D printing experience to ensure some level of homogeneity in each focus group. We did not code for any other demographic traits, however, during the focus groups a wide diversity of ages, backgrounds, professions, and skill-sets were observed. We seemed to have found a diverse, albeit urban, sample (n: 24) of 'everyday Australians' that had expressed mild interest in 3D printing. We also included an additional set of two professional respondents from the advertising industry who had worked on 3D printing campaigns. Their voices gave additional data towards how 3D printers are sold to consumers, and what barriers remain for further adoption - including consumer fears and risk assessments. A total of four focus groups took place from November through December 2015. All data from the respondents in this report has been anonymised and pseudonyms are used.

We selected focus groups, as opposed to individual interviewing, not only for reasons of efficiency, but because the method allows insight to how knowledge around 3D printing is created and solidified in social settings. These moderated discussions allow us to locate tensions between beliefs and practices that emerge discursively, while also considering how jointly producing an account in a socially organised manner shapes normative beliefs (Smithson 2000). In other words, we are interested in when and how respondents changed their views (Reed and Payton 1997) about 3D printing as we talked through its opportunities and concerns together. Our approach to running multiple focus groups also hoped to attain saturation (Clarke 2005) of different concerns, questions and misunderstandings that consumers might have - we kept listening and probing until no new ideas emerged across the many themes repeated across groups. Our limited sample may not have heard all concerns, nor does it represent the Australian public at large, but we do feel that the knowledge gained shows concerns indicative of diverse consumers that wish to embark on 3D printing use. The next section introduces some of these insights and concerns.

Perceptions & Reality

This section reports on empirical data of how everyday Australians understand 3D printing, and how thousands of users online are actually using 3D printing today. We first summarise and interpret our focus group respondents' knowledge of 3D printing, their aspirations for and their concerns with practices that involve copyright to safety, and their own insights and conclusions on 3D printing. Our empirical focus then shifts to quantitative metrics, where we use hundreds of thousands of 3D printing design objects available for view, download, and remix in statistical and social network analysis. These analyses are based on data we gathered from what is believed to be the largest (public facing) 3D printing object repository online, Thingiverse.

Focus Groups

Focus groups began with a writing task designed around free-word association for 3D printing. We were consistently surprised with the diversity of responses given by our respondents. Within the diversity of objects, desires and concerns, themes included creativity, personalisation, prototyping, jewellery and other artistic crafts, medical advances, home and auto repair and more general aspiration for the future that bled into futurism and theories of technological change. Beth, a lighting designer noted that "technological change has always been … at first kind of strange and weird and uncanny and different, and then it just becomes normalised". She identified 3D printing as something similarly revolutionary, and that would be normalised soon enough.

Interestingly, most of the free association words used did not reflect practice or technology per se, but instead 3D printing outputs: things. It seemed that despite our decision not to introduce 3D printed objects to the group (which could kick-start yet bias their understanding and expectations of what prints can be), objects were still the key metaphor from which consumers understand and identify 3D printing.

As the focus group conversations were guided to perceptions of access and any barriers to use, some common themes emerged. First was an understanding that while prices were coming down and 3D printers were "much more available now" than even a few years ago, the barrier to entry of owning one – and the rapidity with which the technology was improving – meant that users were mostly happy to use libraries and retail locations to print. The exception to this was thinking through personal objects that they might be embarrassed to print in public. A couple of respondents reflected on when photo-development shifted from retail locations to the home (i.e. digital cameras and inkjet printers) they started taking photos of things that they wouldn't have taken to the shop to get developed. Other respondents argued that something similar to printing photos at home had not yet happened for 3D printing. The needed literacies and ease of use were not there yet. We quizzed respondents on their 3D printing literacy, asking what specific steps were required to print, and there were indeed some gaps of knowledge toward the practicalities of readying digital designs into printable objects. This included both software based competencies and manual work required to 'finish' additively manufactured objects once they had printed. Underestimating the technical-mechanical requirements of turning digital into physical still presents a barrier to the wider profusion of 3D printing in society.

As we continued discussion on the social and economic potentials of 3D printing there were some broad consensus shared across groups. These included, an ethic of sharing designs, including the caveat that as the complexity of designs (or their uses) increased, so too did consternation around intellectual property - both in terms of infringement and protecting user creations. Charles, an engineer in his mid 30s summed up his understanding of how things would go by stating that, “If you want something more complex, or more detailed or more beautiful or more current you'll pay…If you want something that is not - you will be stuck with what's available.” This stratified approach to what is available and how online is indicative of the complex economies that already surround 3D printing practices.

Such stratification was balanced by an understanding that the value of communicating 3D objects online came through sharing them. One respondent, interested in replacement turntable parts, offered that “[3D printed things’] value is in their use, not in there…rarity or anything… [to me the incentive to create], is to be able to share it”. Ubiquitous sharing, however, brought its own concerns. There was a strong consensus from our respondents around the need for protection from larger corporations and designers from using individuals’ designs without permission, or for profit. Other concerns included quality control of 3D printed good - comparing what could be made at home to a specialist shop and assessing material and safety issues, potential to download viruses attached to 3D files, and the legality of printing off potentially illicit objects at home. Here, the interface between law and practice showed some considerable gaps, which we highlight below.

“Everyday” understandings of IPR across the groups held some unique traits. First, there was a general naivety towards what intellectual property was, not to mention how IPR worked from codified laws or in relation to 3D printing. Respondents’ own communicated practices around IPR, however, were quite developed and resonated around a few key themes. First, the reality of sharing online, and the impracticalities of restricting copying was widely agreed on. One highly educated respondent offered “I would just assume that once you put it up there … you kind of cede all your rights, but I don't know”. Most respondents also felt that protection from IP infringement in the digital space was difficult if not impossible, (un)ironically citing their friends movie watching habits, and the historical pattern of MP3 sharing. Second, was concern about how such realities would negatively affect users. IPR and law in general were understood to be designed for those already in power. “Law is there to protect those who have enough money to operate within that legal system” noted one respondent. The third theme was contextual specifications of with whom and for what it was OK to share designs online. It seemed that respondents felt ethically positive towards sharing with friends or with specific communities, but less so around sharing designs with strangers. There was not consensus around why people would share work with “strangers”, but there was consensus that sharing work within a community of interest (eg. a turntable forum online) was preferable to offering it to “strangers”.

Finally, thinking through how knowledge was constructed around 3D printing in conversation offered some valuable observations. Usually, discussion first focused on what we will call the ‘virtuous’ practices of 3D printing such as replacement parts, medical breakthroughs, new personalised design, and other positive externalities of sharing created objects across society and in otherwise disconnected domestic spaces. Some participants started with an authentic naivety surrounding what we’ll call ‘nefarious’ practices. Group knowledge of these only came into being

when discussion of normative regimes of culture and law began to reference copyright restrictions, the production of “knockoffs”, and illicit creations. This shifted conversations about what can be made, to what should be made. In these instances, hegemonic normative structures such as complying with the law governed conversation even though participants were not sure what these structures said about specific cases of 3D printing.

Counter to this was discussion on ownership of digital goods, where respondents grappled with what their views of IPR and sharing meant for the meaning of ownership. Although consensus wasn’t met, there was recognition that value of designs in digital abundance came from spreading them, rather than restricting how they were spread. Jon, a respondent with a technical background in computers summed up the discussion by saying “Ownership is a tricky one because I think ownership [with digital good] looks different … like attribution might be ownership”. Another respondent interjected that recognition of a user being the creator makes it “more likely to earn off the next one where you get commission for that” project. These views of ownership and propriety may highlight how consumers caught in shifting models of production are making sense of them, and what they attach value to.

A second set of observations came from how discussion progressed about safety and liability. All groups tended to come to a consensus around users bearing the brunt of safety risks outside of market mechanisms for both practical and normative reasons. These conversations started with the concern about who to hold liable in decentralised systems, with most respondents only expressing a need to direct liability after they were presented with situations that pointed out the complexity of doing so.

However, through continued conversations about sharing and decentralising design and manufacture, respondents tended to arrive at two linked positions. The first was that the market (buying a design from someone online) ought to offer some forms of what we identified as ‘retributory’ accountability to liability issues. By ‘retributory’ we mean structures that allow refunds, sanctions, and other eristic means of finding resolution above the parties involved. The second position considered exchanges outside the market and converged on what we consider ‘reciprocal’ understandings, which focussed on the limited capacities afforded by individual relations between users. This means that respondents understood that objects gained for free are to be used at the users own risk. At the same time, they felt that user generated metrics for designer reliability and quality could solve some of the problems that ‘retributory’ systems of commerce do not. When pressed about the risks of nefarious uses of 3D printing, the advertisers we spoke with quipped that other generative technologies (naming laptops and cameras) do not come with warnings about “the dangers of finding al-Qaeda websites or shooting child porn - that would be absurd.”

To summarise, the focus groups suggested that respondents were naive to the law yet felt their own knowledge contributed towards realistic limits of how digital production practices would play out. They identified a need to inform both how the law in practice (may) apply in relation to 3D printing, and how the practical experiences of encountering IPR might differ. They also offered insight into how risk is conceptualised and assessed in regard to different ways of acquiring objects, and how risk is mitigated differently by communities that function inside and outside of the market. Ownership was another concept that was tested by the discursive social interactions of the focus group, attempting to find new meanings in economies of digital abundance. While these discussions

speak to everyday perceptions, we now turn analyses to common uses of 3D printed designs that are shared online. Such patterns offer further insight into how 3D printing affects everyday consumers, and therefore what relevant laws and practices can help guide better choices online.

Online Objects, Shared

Thingiverse is an online repository for 3D printed objects uploaded by users. It reports to be the largest such website and is designed to foreground the objects themselves, rather than the users who create them (Fordyce et al. 2016). Our analysis of the objects on this website allows insight to 3D printing practices through two methods: basic descriptive statistics and a Social Network Analysis between objects based on how users have categorised them with 'tags.' We should point out that there are no options for users in Thingiverse to charge for their work. This site shares designs under various IPR licences tied to the creative commons, as well as other 'free culture' licensing schemes and the ability to place creations directly into public domain. While this serves as a self-selection bias for users and their practices, that Thingiverse is the largest repository suggests that many users' cultural practices identify with this assumption. This preference of sharing was further confirmed by our focus group data.

Our snapshot of Thingiverse data allows us to compare 3D printing patterns to previous analysis of 3D printing file sharing that was carried out in 2008-2013 (Mendis and Secchi 2015). The most striking trend is the exponential growth of items uploaded to 3D printing sites. There were more objects available for download on Thingiverse in 2015 than across the 17 sites (including Thingiverse) measured by the UK's IPO office in 2013 (Mendis and Secchi 2015: 27). This loosely correlates with IPO's claims that the number of files uploaded roughly doubles every year, considering their methodology seems to only look at public items. The IPO measured 40 Million items downloads across 17 sites from 2008-2013. Thingiverse's total downloads alone now count at over 80 Million. Note that from 2013 to 2015, user count only increased 26% - it seems users are starting to upload and download more things.

What is striking within our own data of the 330,000 objects that were visible in Thingiverse for analysis is the distinct patterns concerning how users interacted with objects, and chose how to share their work with others. First, a minority of items are viewed very frequently, while most are barely viewed at all (Mean views: 6038, Std. Dev.: 3801). An even more intense pattern applies to what gets downloaded. Much like the world wide web, there is a 'longtail' (Anderson 2004) of downloads that suggests very few things get downloaded a lot, while there are many, many, many things that get very few downloads, but fill a need nonetheless (Mean downloads: 264, Std. Dev. 1179).

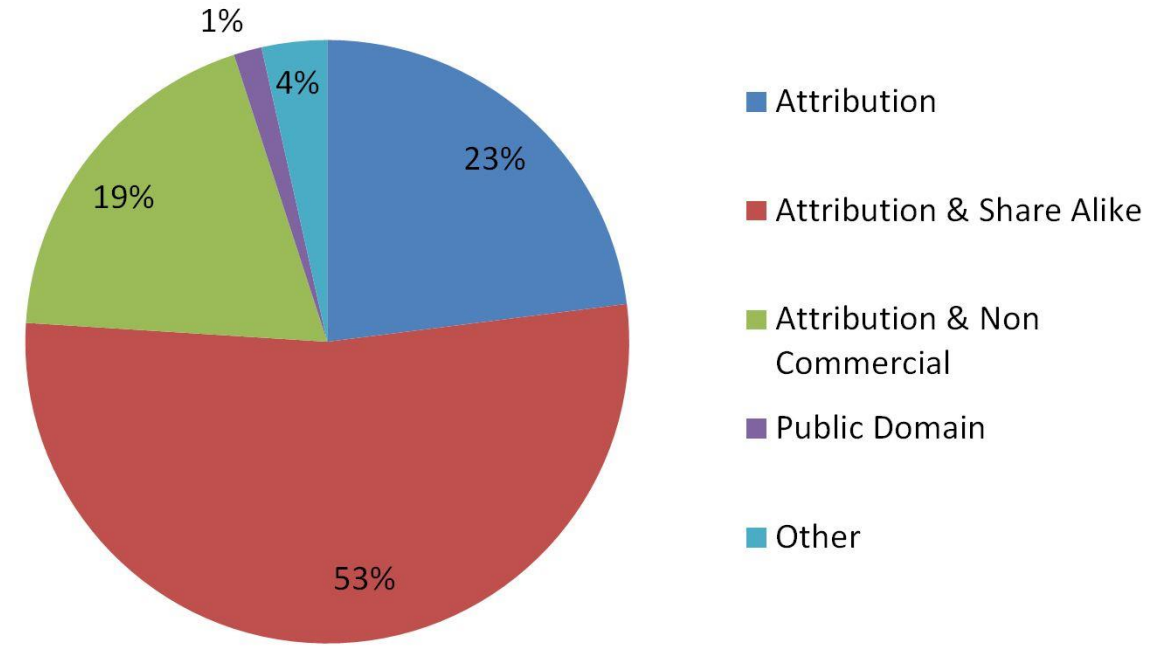

Figure 1: Licence choice for objects on Thingiverse, 2015 n:355,880

The IPR licences users choose on Thingiverse vary and correlate to ratios of views and downloads. We have coded user choice into four basic categories from the 12 licence choices available at Thingiverse. Figure 1 suggests that a majority of objects are designed to be modified, but that the authors want attribution to be carried through to any new transformative iterations of that object. This 'attribution please' majority is probably closer to 75% of objects, as the "attribution only" licence speaks to the same concerns, but is open to new authors claiming authorship of transformative works. These licensing patterns are a shift from the work of the UK's IPO office, which suggested that through 2008-2013, 65% of users did not assign any licence at all to their work and left it "vulnerable and open to infringement whilst losing the ability to claim authorship" (Mendis and Secchi 2015: 43).

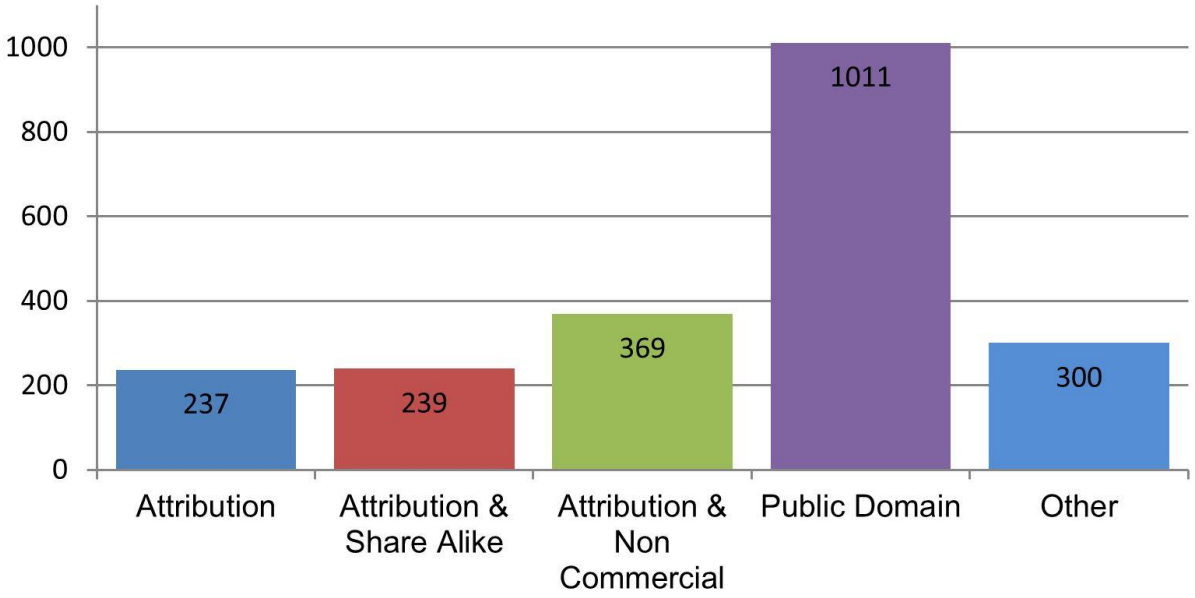

Figure 2: Average Downloads per Object by Licence Type on Thingiverse, 2015 n:355,880

A large minority (19%) of objects are categorised as only being open to re-use and re-design in non-commercial uses, while only 1.5% are offered up as part of the public domain - where no attribution or commercial restrictions apply. That being said, the small fraction of public domain objects see a statistically significant bump in downloads - 270% more per object than the next most productive licence. Otherwise, there are similar ratios of views to downloads across licences: things that get viewed, get downloaded (See figure 2). Thus we can say licence choice manages the visibility of objects for users in ways that indirectly has them selecting what to download. Content here takes a back seat to licence, although further analysis is required to understand if this is an affordance of Thingiverse's specific user experience design, or a larger IPR related trend.

Social Network Analysis of Thingiverse

Our application of Social Network Analysis (SNA) to 3D printing is, as far as we are aware, a novel and unique approach to understanding 3D printing practices. Our research generally follows Rogers (2013), to posit that the researcher must think through any corpus of data in its own digital terms and adjust research strategies accordingly. This means that sometimes instead of focusing on the user, we focus on objects, and how they get used. In this way, SNA methods are useful for providing macro-level information about large sets of data, where the data contains relational information. We use SNA to map social patterns within 3D printing on Thingiverse through how users have tagged objects, and how these tags relate between objects. Tags may indicate hobbyist usage, or particular aesthetic or functional purposes, brand identities, or measurements for ideal printing, and so on.

Category	Example Tags	Socio-cultural Use implied
Dimension/geometric	3D, 2D, cube, Z-Axis, 40mm	Item designed with specifications
Representational	Art, animal, moon, halo, knot, scan	Item's function is likely representational
Hardware	Makerbot replicator, RepRap	Item designed for specific printer
Software	Sketchup, blender, TinkerCAD	Item designed using specific software
Date/time	2013, 2014, July, Christmas	Item produced on/for that date/holiday
Printer materials	ABS, PLA	Item intended to be printed in this material
Purposive	Holder, screwdriver, sensor, tensioner, food, wearable	Item is designed as a functional object
Qualitative/Affective/Emotional	Cool, awesome, love	Item evokes subjective evaluation
Brands	Nike, Warhammer, Canon, GoPro, iPhone, Arduino, LEGO, Pokémon,	Item mirrors the aesthetics of these brands, or adds to or replaces proprietary parts
Subcultural	cookie, robot, baixar	Tag has context to a specific subcultural group that has origins outside of 3D printing

Table 1: Common Categories of tags on Thingiverse

We created a map of tags that shows the relationship between different types of 3D printing practice and identifies themes and clumping behaviours. This allows us to infer practices different to what users had shared in previous interviews or in our focus groups. For instance, we detected a particularly wide array of braille-tagged objects that were not visible through other research methods. We coded the numerous tags into categories of use, which are detailed above in table 1, and suggest the themes in which users interact with 3D printing practices as they share their work. Finally, patterns around re-mixing objects to new objects suggested that most users remixed objects only once - most transformative work stopped after one iteration. This was mostly due to the design of Thingiverse's interface, but also because users tended to remix in order to personalise objects. Note that objects that were scanned by users in real life and then added into the site were almost always marked private and were not available for analysis: we knew they were there, but couldn't see them individually. Work on these data is ongoing and new insights will be published in academic journals in the near future.

What we can learn from our SNA work relevant to this project is that the social uses of objects shared online are extremely varied, even if many objects uploaded are rarely shared. Users employ 3D printing for purposes that seem to include both purposive and aesthetic outputs, and do reference the intellectual property of others (mostly through brands) in a high degree - while this does not overshadow 'substantial non-infringing uses' that seem to be employed by the users of Thingiverse and expressed in the some of the prominent tags given to objects.

Rights & Responsibilities

This section discusses the rights and responsibilities of consumers involved with 3D printing by matching the concerns and patterns enunciated above with insights into legal and cultural practice. We approach legal issues from a lens that asks what consumers need to know, but maybe don't understand, about intellectual property rights (IPR) as well as safety and liability insofar as they will affect practices of printing and sharing online. We cannot offer a comprehensive review of the law here; the issues are emergent, cross jurisdictional, largely unproven in case law, and of varying importance to actual 3D printing experiences. We can, however, leverage what experts in digital IPR think are the most germane issues related to 3D printing, and how they consider these have been and will be tested in the consumer space. From this scholarship we infer that while there are consumer protections that Australians will call on, such as Australian Consumer Law, their efficacy in the 3D printing space is yet unproven and significantly influenced by factors external to Australia.

The Law, 3D Printing, and you

Legal rights and responsibilities are discussed here through three themes. The first considers what the letter and practice of IPR law says about 3D printing. It offers detailed assessments of the frameworks and regimes that determine rights and restrictions that may be applicable to 3D printing. The second theme maps how these multiple points will play out for consumers in the short to medium term. It gives pointed advice for consumers across copyright, patent, design and trademark law. It also suggests that while coming legal challenges may target individual consumers, secondary infringement cases are where potentials of use concerning printing and sharing 3D files will be decided. The third theme reflects on these realities in terms of safety and liability, and is concerned with how interpretation and implementation of consumer rights by bodies like the ACC evolve in practice.

Note that the legal perspectives on 3D printing mostly consider the economic repercussions of sharing abundant digital-physical goods that are produced in 3D printing practices. Digital goods behave differently than physical ones in an economy. Delong and Froomkin (1997; 2000) suggest that digital goods differ in three key ways: digital goods are not excludable - this means copying files is easier than stopping the copying of files; digital goods are not rivalrous - this means digital copies do not spoil the original or stop new copies from being made; digital goods are less transparent - this means digital goods are actually less interchangeable for consumers than physical ones because digital goods can involve continued service relationships with the provider that evolve in ways controlled by the provider. As an example, think of the real case where George Orwell's book '1984' was downloaded by Kindle users across the globe. Downloading 1984 didn't take away the opportunity for someone else to download another copy, but Amazon can and did use their ability to remove some of these eBooks from peoples' kindles based on business relationships and copyright jurisdiction issues that customers were previously unaware of (Stone 2009).

In the 3D printing world, imagine that you use a mobile app to design a doorstop, which you name Holdör, and make it available for download on the app's built in 3D printing file sharing service. The number of people that download Holdör does not affect whether others can. In fact, once it is downloaded by someone else, it probably becomes easier to create rather than restrict new digital

(and physical!) copies. But, if the website that hosts your Holdör goes down, or decides to no longer let you view, download, or modify your own work, there is not much you can do. There are many reasons user creations might disappear from such a service, and we will now shift focus to explain some in relation to law.

To do so requires looking beyond Australian law. While this white paper is written for an Australian audience, there are overlapping legal regimes and international agreements that come into play once you consider the multiple jurisdictions and IPR regimes involved, as well the market forces that define much user experience. We split out these complex concerns of IPR and 3D printing into copyright, patents, and design/trademark law – the latter two are different, but hold similar concerns for domestic users. We start with copyright as it is most applicable. Before we do, we need to acknowledge at the outset that while the findings here are built off existing legislation, legal precedent and scholarship, this white paper should not be interpreted as legal advice.

Copyright & 3D printing

Copyright covers any creative 'works' (like sculpture, songs jotted down on paper or recorded, and other art) and is automatically granted in almost all instances. Copyright is not about ideas, but instances of their expression – the material 'thing' that is created. Infringing copyright, or reproducing creative works without permission, is not theft - it is infringing copyright. This means that the penalties for infringing copyright in Australia are civil not criminal, unless the infringement is for commercial advantage or profit. Also note that there are not laws specific to 3D printing for copyright in Australia, as 3D printing practices will be interpreted under current laws.

Specifically, the Australian Copyright Council (2015) suggests that 3D design files will be covered under copyright 'in some situations' as artistic works, a category that covers, for example, sculpture, craft work, and architectural plans. 3D designs that are printed and show craftsmanship and some aesthetic appeal will also fall under copyright protection, according to the Australian Copyright Council. However, the Australian Copyright Council is only one voice in the coming debates around copyright and 3D printing. It's voice represents current copyright holders. So, how can consumers determine when the 'situations' the Copyright Council hopes apply, actually apply?

International agreements on trade that function to at least somewhat harmonise IPR mean that precedents in other countries show where Australian consumers – and all 3D printer users – should focus their expectations. Also, while courts across the globe are not harmonized, judges have been known to borrow from each other's' ruling with some frequency (Slaughter 2009). This might happen in future 3D printing cases.

Legal scholarship in the UK and USA suggests that while the files of 3D printing works will probably be protected under copyright, the design-idea of the file (rather than its actual code) will probably not be - unless the printed object is artistic in nature (Copyright, Designs and Patents Act; Simons; Bradshaw et al. in Daly 2016: 26-27). So if someone uses your banana peeler design to make a bigger functional banana peeler, your copyright probably will not apply to the object. However, their new design file might infringe on your old one. But only if they use a "substantial part" of your design, and this has to be decided in the courts. Further, while The Australian Copyright Council suggests copyright covers three-dimensional reproductions of two and three dimensional works, US case law suggests it is – as might be guessed - complicated. For instance, Daly (2016: 28) cites cases against

the Australian Copyright Council's advice where 3D costumes based on two-dimensional designs have been insufficiently original to be granted their own copyright.

And there is more: Section 77 of Australia's (1068) Copyright Act suggests that if a work of artistic craftsmanship is 'applied industrially', copyright might no longer apply and the designer would have to register for relevant design IPR, which has lesser time protections (covered below). The Australian Copyright Council suggests this will be applied at 50 3D prints (Australian Copyright Council 2015) but this has not been tested and indeed 3D printing breaks the domestic/industrial production assumptions. Finally, while there are fair use and fair dealing exceptions to copyright, we do not cover them here as the latter applies to dealings including parody, criticism and research in Australia, while the former is interpretive from a US context – there is not yet precedent for 3D printed works in either.

Yet, how all of these details apply to 3D printing experiences is another question all together. Despite its warnings, the Australian Copyright Council (2015) recognises that designs that users find on the internet will probably be subject to the terms of use from the site users find them on. These private terms modify the above laws, by making specific contract between user and service provider. They decide the policy that addresses how designs, objects, user data, etc. on that site will be shared with others. The terms form private regulatory schemes that may restrict users from asserting their otherwise assumed rights. So what does all this mean for users dealing with 3D printing and copyright?

What copyright means for users

In terms of actual 3D printing practice, the two most common sources of authority encountered by users are terms of service and an American copyright law called the Digital Millennium Copyright Act (DMCA). Empirically, there is a high probability that 3D printing sites agree to govern copyright through the DMCA and write their terms of service to match it. The DMCA implements international IPR agreements in the US context. It offers protection from liable to online service providers (i.e. a 3D printing website, Google, etc.) as long as they remove content from their sites that rights holders claim infringes their copyright. Australia's Digital Agenda Act amendment to the Copy Right Act provides similar frameworks. Consumers and makers of artistic works on the internet usually encounter the DMCA law through what is called a 'takedown notice', which means authors or their agents ask service providers to 'takedown' or delete a file or links to files that seem to infringe their copyright. How service providers react to these notices is up to them, but it is in their legal and financial interests to immediately abide by the notices.

A systematic analysis of 50 million takedown requests suggests that DMCA takedown notices do work well to remove specific files from specific sites. The process can easily be scaled electronically for efficiency while offering rights holders an avenue to take down content that 'bypasses judicial oversight over copyright disputes' (Seng 2014; 3). However, each notice is targeted towards a specific site; it is very difficult to scrub the entire internet.

Note that, if a user feels that a request to take down their works is unwarranted, there are processes of redress for DMCA takedowns. However, these are often cumbersome and are not as efficient as the takedowns themselves; services must assume copyright is being infringed to keep their own 'safe harbour' from liability. It is up to users to prove the takedown notice incorrect (Daly 2016; 41-

42). So while copyright law and 3D printing have complex links, there are some key points users can keep in mind:

-Copyright is for creative and artistic works, not ideas or functional objects.

-Terms of Service on 3D printing sites matter, and might restrict the protections of your own country's IPR.

-The legal difference between printed objects and their design files are subtle, and each holds their own restrictions.

-The Digital Millennium Copyright Act is often invoked for digital copyright disputes and this happens outside the courts, which makes for efficient, but possibly unfair, outcomes that can remove content from sites.

-If an artistic work is 3D printed 'industrially', Australian copyright protections may no longer apply - the design should be registered.

Design, Trademarks & 3D Printing

Design in IPR considers how things look and/or are shaped, in terms of how brands uniquely resonate with customers, helping identify products' origin and value. Trademarks in Australia are defined through recognisable signs and expressions that identify products and services as coming from a particular source/company/brand, and in Australia can be a shape as well (IP Australia 2016). These are different 'areas' of law, but from a user's perspective, we can consider them together. Australian law describes design as what makes a product look as it does, including features of shape, configuration, pattern or ornamentation of a product. Industrial design rights, trade dress, the rough equivalent of what are called design patents in the US, are all types of IPR that consider design. A famous example of design law in-practice is Apple's insistence that Apple owns design rights to the curvature of iOS app squares and the corners of Apple laptops. Apple has won design patents on 'rectangles with round edges' after Johnny Ives showed their curvature employed the design finesse of resolving tangency breaks using a Bézier surface. Ives' rectangles with round edges are unique, or at least that is what they successfully argued in court. Note that design patents (US law) last only 14 years, compare to copyright's seemingly indefinite extensions (currently at life of author plus 70 years).

In Australia, designs must be registered to receive relevant intellectual property protections, while other jurisdictions have mixed requirements. Daly (2016: 35) suggests that sharing 3D printing designs (that are not trademarked) on file sharing sites for non-commercial purposes falls within an 'implicit exception to infringement' of design rights in Australia. Other jurisdictions have explicit, similar exceptions, including features that have to do with technical function, home use, or as the UK has it, a 'must fit' exception (Registered Design Act 1949 in Daly 2016: 34). This means that if a specifically shaped widget is required to fix your fridge, design rights protections cannot be used against you for making the needed part snuggly fit in place. Daly goes on to argue that design law is less clear for file sharing websites themselves. These sites might turn a profit by hosting design for non-profit use, while it is also unclear if use of these sites is private or public. As such they could run afoul with design IPR. Further, home prints, as opposed to going to a neighbourhood print shop that

profits off your print, might stamp out the private/personal exception to design IPR that are, depending on the jurisdiction, explicitly or implicitly available.

What Design and Trademarks mean for users

Design and Trademarks seem to be less of a concern for users, and less useful for rights holders - assuming the goal is not trying to sell things that look like other peoples' things. Even scanning objects that clearly involve other peoples IP for personal, private use should not infringe due to the exceptions mentioned above (Daly 2016:88). For instance, even the most identifiable creative works can have their IPR reduced when design is considered over copyright. Star Wars met this fate in 2011 when the Supreme Court of England (Ainsworth v Lucasfilm) decided that 3D Storm Trooper helmets designed for the original Star Wars film, but manufactured in England without the consent of Lucasfilm were not artistic works. The court instead interpreted them through their intended use as props. This meant that under US law design rights applied (for 15 years) rather than copyright (life plus 70 years), and means that you can still buy such memorabilia.

This American-turned-English case also suggests that users are clear to scan the originals or design and then print their own Star Wars memorabilia too. Going even further, Weinberg (2016) suggests that virtually all scans will fail on copyright grounds due to a lack of originality, and suggests access is the only form of control. This means that, as our respondents intrinsically knew, once you upload something, it's gone.

That being said, the current state of trademarks and design in 3D printing also offers incentive for the "expansion of intellectual property laws to further … restrict the continued use of new and emerging technology" (Scardamaglia 2014). This is already apparent in the tone of advice legal firms' offer in unsolicited commentary on how to protect designs from being copied in a 3D printed world - even when the practices they outline are in some instances manifestly legal. Future concerns – including law firms looking for new markets - should not, however, offer a chilling effect for current user practices.. As such, there are only a few clear practical points for users to think through regarding concerns around design, trade dress and trademark.

-Design and Trademarks concern IP that is separate from artistic and inventive function but speak, respectively, to what makes a product look the way it does and to its origin.

-Using others' trademarks as your own and others' design to make profit is infringement.

-Users can make objects that use trademarked shapes, or are based on un/registered designs if they don't sell those objects, but third parties like 3D printing sites might not be able to legally host these designs.

Patents

Patents give IPR to inventions that are new, useful, and non-obvious technical solutions or processes that help solve a (usually industrial) problem. They require registration and have shorter terms than copyright - usually around 15 years. Australia offers 20 year standard and 8 year 'innovation' patents. The latter offers a rapid certification and is easier for incremental advancements to be recognised, but is not actually assessed until there is an infringement case.

On the one hand, patents are not very applicable to domestic uses of 3D printers. There is little chance of infringing a patent through printing creative works (see copyright above!). On the other hand, users that make objects to solve common household problems could technically infringe a patent; even if they are unaware the patent exists. Note that in Australia and the US there are no exceptions for individuals infringing a patent for personal or unwitting use. The UK does have an exception for private, non-commercial purposes as well as experimenting to invent and Australia has an 'experimental uses' exception as well (Daly 2016: 30).

The other aspect of patent IPR important to 3D printing practices is that users cannot patent things if they are already publicly available. This means that if an object that provides a new, useful, and non-obvious technical solution is uploaded to a 3D printing website before patent applications are applied, it will probably not be able to be patented.

What patents mean for users

3D printing sees continued innovation and increased consumer choice of printers as patents around additive manufacturing itself expires. At the same time, there is no remit for Australians to make objects in their printers that are patented unless they seek a licence from the inventor. Finding out which objects online infringe on active patents is difficult. However, like most IPR regimes, enforcement of patents usually only comes up when there is demonstrated loss to the affected party; accidentally infringing on someone's patent to solve an issue at home shouldn't lead to trouble with the law even if it is technically against patent law. Here is one last brain teaser that shows how 3D printing forces IPR to play catch up – and creates complex situations. Consider that granted patents are publicly viewable. This means a user can look one up, and based off the descriptions, create a computer design of the invention for 3D printing purposes. If the user 'makes' the design, she infringes on the patent. However, she now owns the copyright of her CAD file, and might be able to block the patent holder from releasing a similar work under copyright (Holland 2009: 41). Here's what users should remember:

-Patents pertain to useful inventive things or processes that have functional uses.

-Patents need to be registered before users make their inventions public.

-Infringement at home might happen without user knowledge, but there is no way or want to regulate this.

The above has set out how issues around copyright, design and trademark, and patents affect domestic 3D printing uses. The report now shifts to consider previous experiences of IPR meeting new technologies, to think about who will be liable to be targeted for infringements – and in the legal sense of the word - how liability will be considered in the decentralised production system the 3D printing engenders.

Accountability, Liability & Safety

This section shows how there is an inbuilt lack of centralised accountability for the decentralised rights and responsibilities that come with 3D printing. This means that there is no easy answer on how to manage risks that are present, control what can be made, or decide and enforce who to hold to account for breaches in IPR or product safety expectations. Note that this section conflates two

separate areas of law - liability in terms of product safety, and being held liable for infringements as mentioned above in the IPR section. Legal scholars (and courts!) see these as two very distinct things. However, this section discusses both together, as from the perspective of domestic 3D printer users, they form similar issues and constraints to practice and risk.

We will first consider decentralising production and contributory infringements to IPR, and then transition to how users should think about safety for prints that do not live up to expectations. Note that there are (many!) use cases of 3D printing outside the scope of this report and its focus on domestic 3D printing. These include regulated medical devices - where medical practitioners would design, use, or fit to a user's body 3D printed goods; firearms and firearms parts that users make without license; and other restricted weapons that users decide to make. It is our view that creating firearms without a licence is clearly a criminal offence, and not a focus of consumer activity. However, we will briefly introduce recent Australian developments regarding firearms and 3D printing as a way to relate the challenges of decentralised consumer responsibility and liability in general.

3D printing decentralises responsibility and liability to a significant degree. In terms of manufactured goods, instead of a hierarchy and traceable supply chain from manufacturer to seller to consumer, 3D printing practices tend to rely on decentralised economies of production. Many actors contribute in sometimes small or unknown ways that make designs and products that users want to make. Then there are intersectional concerns such as is the design at fault, or the material that is used to make it, or the specific printing process. Determining how these relate in a causal way is very difficult. Further, the jurisdictional issues touched on above, as well as the importance of private terms and conditions, provide increased complexity for following paths of liability.

Trying to control what people can print through regulation and active censorship regimes is far from an ideal solution. The efficacy of centrally restricting what can be printed is suspect for many reasons. There is a long precedent for heated public debates about digital 'lock and limit' policies for technology, including from recurring debates tied to encryption (for example Apple v FBI in 2016 and older debates around the Clipper Chip in the 1990s - see Froomkin 1995). The example that is most applicable however, might be the 34 year old 'Betamax' decision (Sony Corp. v Universal Studios) that allowed consumers to buy a technology called video cassette recorders (VCRs) that were capable of saving and copying analogue TV shows and movies for later use - despite the potential for VCRs to be used to contribute towards copyright violations.

Aside from policy decisions, the technical aspects of trying to restrict what is printed are difficult to enforce. Hardware manufacturers we spoke to in previous research do not want restrictions built into their devices. At the same time, online operators do not want new responsibilities for user uploads or downloads when the internet has grown and sustained itself under 'safe harbour' provisions like the DMCA that limits platform liability. Finally, deep packet inspection of all communications over the internet to seek out 3D designs is politically contentious, and can be defeated by encryption.

Meanwhile, new laws that try to stem the spread of dangerous designs seem to be misdirected efforts. For example, in 2015, New South Wales (NSW) amended its Firearms Act to, among other things, include a clause that says "A person must not possess a digital blueprint for the manufacture

of a firearm on a 3D printer or on an electronic milling machine" or face a maximum penalty of imprisonment for 14 years. This means the possession of the blueprint rather than the weapon is the crime. The logic of this approach breaks down when typing 'M16 blueprint' into any online search service like Google, DuckDuckGo, or even Bing. The accessibility and ease of finding files that are meet NSW's criteria of 'technical drawing of the design of an object', makes the law very hard to enforce. Moreover, if files are located in an American cloud service, are their users in possession or control? NSW law on computer crimes (Sections 308A and 308F, Crimes Act 1900 No 40) is somewhat unhelpful here, as access has a different legal definition than "possession or control of data" – looking up a blueprint on Google, or streaming it may be different to hosting it on your server or someone else's.

In a seemingly mild rebuke to the NSW law, the Australian Commonwealth's own report on 3D printing firearms suggested that while "it seems that current laws pertaining to firearms would apply equally to 3D printed firearms and firearm parts" some consolidation towards uniform regulation should be considered (Commonwealth of Australia 2015: 23). The report also suggested that the overreactions to limiting 3D printing were not sound policy: "The committee … does not accept that banning the individual use of 3D printers or introducing a character test for ownership is either necessary or practical." This stems from 3D printers being generative technologies. Printers have the capacity to make firearms, and infringe IPR, however, they are also capable of many other uses. The legal language that has tested IPR (not firearms!) issues in the US states that such 'dual use' technologies need "merely be capable of substantial non-infringing uses" (Sony v. Universal) to not restrict their functions.

Adam Holland (2009; 26) argues that 3D printers fit this description and more. He notes the stated purpose of copyright as written in the US constitution is:

> "To promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries" (U.S. Const. art. I, § 8 in Holland 2009).

He suggests that there is a strong argument that 3D printing will provide significant and measurable promotion of the progress of science and useful arts, and that any restrictions placed on 3D printing will have to balance against this potential. Liability concerns of the technologies involved in 3D printing (including sharing networks built into 3D printing experiences) is thus balanced against the benefit gained by society through their use. But where does liability sit? A cynical legal student might quip that liability usually ends up resting in the deepest pockets. However, in a decentralised production environment, there are many pockets, most of which are very shallow. How does this affect risk of liability for home users (that aren't intent on printing guns)?

What is important for users is that legal experts suggest that cases regarding liability of IPR will probably shift from targeting individual users to overarching technologies and products (Holland 2009). This will happen through targeting what's called contributory infringements that forecast secondary liability. Contributory infringement technically refers to patents and trademarks in law, but is also used as a concept in court cases that deal with copyright - sometimes called secondary liability in the US or indirect infringement. It means that someone or something materially

contributes to or facilitates infringements carried out by another party. Here, rights holders hope to target nodes that spread their IP or enable its infringement, rather than the users who consume it.

A similar pattern emerged as sharing MP3s became a widespread practice. The music industry was not having much luck suing its own fans for infringing on copyright, so they decided to - much like the Betamax case mentioned above - target intermediaries using contributory infringement provisions. Here the deep pockets were not users but the firms that connected them. Services and the underlying technologies tied to firms such as Napster, Gnutella, KaZaa, LimeWire, Scour, Grokster, Madster, and eDonkey2000 were all challenged for being responsible for contributory infringement of copyrights, and held liable. These cases were not about particular songs, or as in the Betamax case about a particular movie. Instead, Holland (2004: 464) reminds that in all of those cases, the question presented was whether the sale or distribution of copying/making equipment to the general public violates any of the rights afforded under copyright laws. The targets in 3D printing practices will be 3D printing technology manufacturers, distributers or service providers. Moreover, 3D printed designs are much more complicated in regards to IPR than direct copies of songs so harder to target effectively in court. For instance, we have already seen the failure of targeting individual users for violating IP in 3D printing spaces, and the questionable claims around those IP claims. In 2013 HBO targeted a user who created a 3D Iron Throne design, which he modelled off the popular show Game of Thrones. This caused media coverage about the uncertainty of the claim and the object was put back up online. In 2016, the site in question (instructables.com) still has the original file hosted as well as multiple copies available for download - including some that would suggest transformative works such as Iron Potty Throne and Iron Merkin creations.

What Accountability, Liability & Safety means for users

As corporate liability targets shift from users to other firms' technological enablers of holding intermediaries liable, it is important to consider how users can think about asserting their own rights in regard to liability and safety. To begin this discussion, note that while mapping multiple 3D printing services and organisations in the course of our research, we found every single one has Terms of Service that push liability onto consumers. That is to say that issues of product safety and consumer protection are made all the more complex in 3D printing. As rights and responsibilities are more widely distributed in 3D printing economies, liability protections that have historically relied on large well placed firms managing risks through insurance no longer work (Daly 2016: 66). That is to say that 3-D printing severs the long established identity between manufacturers and sellers with enterprises – it's the home user that is now making products (Engtstrom 2013).

Further, consumer protection law in Australia and most other jurisdictions is premised on market relationships. If users do not purchase 3D models, but instead share them, they may not be entitled to many consumer protections. But there is not agreement across jurisdictions about this. The legal language for Europe suggests that producers are not liable if their product was not manufactured for economic purposes or distributed in the course of business. The language in the US, a much more litigious country, suggests liability rests on those who are in the business of selling or otherwise distributing products that are deemed defective and harmful.

Enforcing liability from small "micro-sellers" (Berkowitz 2015) that are not just individuals sharing goods, but also not full-fledged corporate entities with deep enough pockets, requires rethinking

compensation and proofs of defects. Stanford Law School Professor Mark Lemley (2015: 512) suggests one alternative might include reversing the logic of suing individuals for damages by instead offering new social assistance schemes for those users who suffer personal injuries from 3D printed products. Whether these costs are built into taxes on 3D printers, or spread through society is a political question.

Although this might sound farfetched as a cultural solution, there is precedent when looking back at IPR law. Canada enacted a 'private copying levy' for blank media including audio cassettes, CDRs, and for a few years, even iPods. This levy was distributed to artists in case their rights were infringed through private copying. A similar liability levy could be created for 3D printing materials, although this would require new forms of consumer and/or creator protections that would be challenging to organise and enforce.

Australia has a very well developed consumer protection regimes, but its efficacy in holding 3D print designers to account is unclear. On the one hand, Australian Consumer Law is often channeled through the Australian Competition and Consumer Commission, and provides strong protections for consumers, past what other consumers can extract out of transnational companies. For instance, an Australian Judge recently ruled that 'goods' covered by ACL include computer software, and that where a foreign company is 'making representations to Australian consumers' about its goods, it can be held liable for consumer guarantees. This was a big deal for internet commerce in Australia and might set precedent for other software related purchases, such as those found in 3D printing services.

However, the nature of 3D printing sites means that they might be classed as intermediaries not sellers of the goods, and finding the publisher will be next to impossible - or overly costly. Further, our research suggests that most 3D print designs that are downloaded are shared - not paid for. Combining this with many terms of service making users waive their rights, means the law in this matter might not always be very helpful. Finally, many users who upload objects often offer explicit warnings that their designs are offered as 'use at your own risk'. This flies in the face of tort law in Australia. Usually, for the law of negligence (tort law) to apply in Australia you don't have to be in a consumer/seller relationship. Broadly, note that these laws are used by people who have been injured or otherwise sustained loss or damage due to the negligence of someone else. So for example if you're giving away a toy targeted at children and it has components that are a choking hazard, it is 'reasonably foreseeable' that this might harm a child and you'll be at least partially liable if a child ends up choking on it. However, if you are finding, downloading, and using a design from an online site, consumer protections might not apply, and tort law would be hard to enforce: users waive some right in the terms and conditions of website use, while tracking down the progenitors of negligent objects could be very difficult. An official review of Australian Consumer Law (ACL) formally started in 2016 and some submissions are pointing out the gaps that pertain to 3D printing, as well as possible solutions. For instance, a private safety advocate Gail Greatorex (2016) suggests adding product design to the product safety provisions for mandatory standards and bans, mandatory reporting, and recalls. As of yet there are no Australian safety provisions for designs.

Further, if the site has terms and conditions that waive rights to product safety and liability for negligence, there will be an uphill legal battle to try to gain back any protection, or be awarded damages. To put it another way, while mapping multiple 3D printing services and organisations in

the course of our research, every single one has had something in its Terms of Service document that negates liability and pushes risk to its users.

Therefore, it's important to remember that:

-Risk is worn by the user of 3D printed goods in ways consumers might not be used to.

-It will be very hard to sue for damages if a 3D printed object is defective due to design, especially if it was not paid for.

-Terms and conditions of websites often make users wave their rights concerning safety and liability, and enforcing (Australian) legislation will probably be difficult.

Summary

This section discussed the rights and responsibilities of consumers involved with 3D printing by matching the concerns enunciated by consumers in the course of our research with insights into legal practice. We approached legal issues from a lens that asks what consumers need to know, but maybe do not understand, about intellectual property rights (IPR) and safety and liability insofar as they affect practices of sharing and printing 3D objects. We did not try to offer a comprehensive review of the law, but instead leveraged experts opinion towards digital IPR's most germane issues related to 3D printing practices. It seems that there are some clear guidelines for rights and responsibilities across copyright, design, and patent law, as well as how users should approach safety and liability. There are questions yet to be resolved around how protections such as Australian Consumer Law will be effective in the 3D printing space.

Forward Looking Models

This section briefly considers forward looking models of sharing and making 3D goods online, based off the above state of law, our respondents focus group data, and the SNA of actual sharing going on online. It briefly discusses the needs for a 'better than free' model of 3D printing, before suggesting a few potential avenues to find one.

The idea that the consumer 3D printing industry had to offer consumers choices that are 'better than free' resonated through discussion, and we found quite reflective of the practices at hand. This is the idea that copying and production (illicit or otherwise) will happen in economies of abundance. The challenge is to provide value to and with consumers that surpasses the ease of finding a substitute good in a way that has negative externalities for rights holders.

Most of our respondents suggested that if the market (for IP objects) did not provide reasonable solutions for their needs, they would explore other options. They identified their needs to include the ability to repair, domestic use of patented objects, what they deemed fair use of design IP, and in some extremes, even the willing infringement of intellectual property rights for everything from experimentation to saving money. Rather than accept that 3D printing would thus be destined to center on underground or illicit practices, respondents were vocal at exploring a variety of new solutions that surprised our research team in their ingenuity.

There were numerous ideas to answer better than free. Some participants suggested that sharing 3D printing files would work in a similar way to what is available to clip art on the internet. While there is an abundance of free clip art of varying quality and utility, there are specific designers, services and subscriptions that paying users gravitate towards. This model also includes variations such as the 'walled garden' model where, like Apple's successful iTunes and App store, curated quality content at low prices and high ease of use, proves to be better than free. Our respondents did allow that any stratification between free and paid goods also suggested that at the margins, there would always be want and access to illicit materials and ways of getting them, regardless of laws on books or enforced.

Another interesting idea that came out of discussion was a structure that mirrored the online success of Threadless, a t-shirt company that uses co-design and crowd-sourced feedback loops to create unique textiles. In this model, many designs are submitted each week and voted on by users. The top handful of designs are then produced and added to the Threadless collection (selling in physical and online stores), with 20% of royalties going to the original creators. The 3D printing equivalent might innovate this model by having centralised designers tweak user-uploaded models to ensure quality of build etc., and then give them back to the community at a price that is mutually beneficial to designers and a central company - which would also be responsible to manage liability issues, etc.

Other models of sharing 3D printing already exist online that stratify IPR along varying price points. For instance, one online website we researched offered to 'steam' files directly to your printer at a highly reduced price compared to downloading. The caveats included that the items would only be able to be printed once, and were not able to be modified. Here we see the IPR markets removing

the generative nature of 3D printing through mechanisms of convenience and price. The extent that users will take up such compromises as 3D printing continues to expand in popularity will be both an empirical and normative question. We hope that reports such as this one can provide data and analysis that helps users consider the impacts of such tradeoffs.

Conclusion

This white paper mapped user perceptions and empirical use patterns to improve consumer knowledge and protection for making, sharing, and printing objects. It introduced the ways everyday Australians who are interested in 3D printing form their understandings around 3D printing practices, which are centered on communicating designs online. It offered data from focus groups around consumer perceptions and from sharing practices through a SNA of hundreds of thousands of objects on Thingiverse, a large 3D printing website. We found user concerns were expressed through a naivety of IPR law, while being informed by knowledge of digital practices that consumers were already accustomed to. This included new realities of the value of ownership and authorship for digital goods, as well as the practical experiences of digital copies being somewhat beyond control once shared. Our SNA suggested varied uses of 3D printed objects that are communicated between consumers and strong evidence of potentially infringing, transformative and unique productive objects being shared online. It also suggested that sharing is exponentially increasing year on year, even if the user base itself is growing more slowly.

Responding to these trends we outlined expert legal scholarship and proven case law that was meant to fill in some of the gaps consumers might have with regard to IPR and 3D printing. These gaps centred on copyright, patent and design and trademark law - as well as their differences. From these detailed accounts we inferred points of interest for 3D printing users, which should hopefully speak to some of their concerns as enunciated above. We further distil this information into an accessible resource at 3Dprintinginfo.org, which houses informational material for interested users about how to start 3D printing in a responsible manner.

The report concluded with some nascent ideas towards how users see 3D printing models evolving in socio-economic terms. These try to enable the new cultures of sharing and leverage the current laws that afford free expression and commerce on the internet. These ideas and implementations will continue to evolve as 3D printing continues its exponential growth curve. We look forward to helping chart the paths that may come from and for consumers, and hope that this report offers some tangible insights that can affect the capacities required to make informed choices around the rights and responsibilities of 3D printing.

Authors

Luke Heemsbergen

Luke Heemsbergen recently completed a PhD at the University of Melbourne. Luke researches how technology and the political collide to shape our lives. His work on 3D printing has appeared in The New York Times, Phys.org, and various academic publications. Before a career in academic research, he consulted in both the public and private sectors in Canada.

Robbie Fordyce

Robbie is a PhD candidate at the University of Melbourne. He employs critical media theory to research a wide variety of the experiences online. His current research areas include video games, critical political-economies of internet culture and, of course, 3D printing.

Thomas Apperley

Tom (UNSW) is an ethnographer that specializes in researching digital media technologies. His previous writing has covered broadband policy, digital games, digital literacies and pedagogies, mobile media, and social inclusion.

Michael Arnold

Michael is Associate Professor and Head of Discipline (The University of Melbourne) in the History and Philosophy of Science Programme. His on-going research activities involve studies of contemporary technologies and daily life.

Thomas Birtchnell

Thomas is a senior lecturer (University of Wollongong) interested in the interface between sustainable development and grassroots innovation. Before Wollongong he worked at the Centre for Mobilities Research (CeMoRe) at Lancaster University.

Bjorn Nansen

Bjorn is a Lecturer in Media and Communications (The University of Melbourne). His research interests include media adoption, children's media use, and interface studies. He currently holds an Australian Research Council funded Discovery Early Career Researcher Award (DECRA).

References

Anderson, C. (2012). Makers: the new industrial revolution: Random House.

Australian Copyright Council. (2015). 3D Printing & Copyright -INFORMATION SHEET G128v01. Retrieved from http://www.copyright.org.au/acc_prod/Search?SearchTerms=3d%20

Benkler, Y. (2002). Coase's Penguin, or, Linux and" The Nature of the Firm". Yale Law Journal, 369-446.

Benkler, Y. (2006). The wealth of networks: How social production transforms markets and freedom: Yale University Press.

Berkowitz, N. D. (2015). Strict liability for individuals? The impact of 3-D print- 146 ing on products liability law. Washington University Law Review, 92(4), 147 1019–1053.

Bosqué, C. (2015). What are you printing? Ambivalent emancipation by 3D printing. Rapid Prototyping Journal, 21(5), 572-581.

Clarke, A. (2005). Situational analysis: Grounded theory after the postmodern turn: Sage.

Commonwealth of Australia. (2015). Ability of Australian law enforcement authorities to eliminate gun-related violence in the community. Canbera: Legal and Constitutional Affairs References Committee.

Daly, A. (2016). Socio-Legal Aspects of the 3D Printing Revolution: Palgrave Macmillan UK.

de Smale, S. (2014). Building Material: Exploring Playfulness of 3D Printers. Transactions of the Digital Games Research Association, 1(3).

DeLong, J. B., & Froomkin, A. M. (2000). Speculative microeconomics for tomorrow's economy. Internet publishing and beyond: The economics of digital information and intellectual property, 6-44.

Engstrom, N. F. (2013). 3-D printing and product liability: identifying the obstacles. University of Pennsylvania Law Review Online, 162(35).

Fordyce, R., Heemsbergen, L., Apperley, T., Arnold, M., Birtchnell, T., Luo, M., & Nansen, B. (2016). Things, tags, topics: Thingiverse's object-centred network. Communication Research and Practice, 2(1), 63-78.

Froomkin, A. M. (1995). The metaphor is the key: cryptography, the clipper chip, and the constitution. University of Pennsylvania Law Review, 143(3), 709-897.

Heemsbergen, L., Fordyce, R., Apperley, T., Arnold, M., Birtchnell, T., & Nansen, B. (2016). 3D Printing: Civic Practices and Regulatory Challenges, 2: Melbourne Networked Society Institute Research Papers, University of Melbourne.

Holland, A. (2009). IP As You Know It Is Dead: The IP Implications of Cheap 3D Rapid Prototyping and the Radical Democratization of Manufacturing. Available at SSRN: http://ssrn.com/abstract=2787260. Retrieved from http://ssrn.com/abstract=2787260

Hopkinson, N., Hague, R., & Dickens, P. (2006). Rapid manufacturing: an industrial revolution for the digital age: John Wiley & Sons.

Greatorex, G. (2016). Submission by Gail Greatorex. Australian Consumer Law Review 2016. Product Safety Solutions, Canberra.

IP Australia. (2016). Design Basics. Retrieved from https://www.ipaustralia.gov.au/designs/understanding-designs/design-basics

Kostakis, V., Niaros, V., & Giotitsas, C. (2014). Production and governance in hackerspaces: A manifestation of Commons-based peer production in the physical realm? International Journal of Cultural Studies.

Lemley, M. A. (2015). IP in a World without Scarcity. NYUL Rev., 90, 460.

Mendis, D., & Secchi, D. (2015). A Legal and Empirical Study of 3D Printing Online Platforms and an Analysis of User Behaviour.

Moilanen, J., & Vadén, T. (2013). 3D printing community and emerging practices of peer production. First Monday, 18(8).

Pham, D., & Gault, R. (1998). A comparison of rapid prototyping technologies. International Journal of machine tools and manufacture, 38(10), 1257-1287.

Reed, J., & Payton, V. R. (1997). Focus groups: issues of analysis and interpretation. Journal of advanced nursing, 26(4), 765-771.

Rogers, R. (2013). Digital methods: MIT Press.

Scardamaglia, A. (2014). Flashpoints in 3D printing and trade mark law. JL Inf. & Sci., 23, 30.

Seng, D. (2014). The State of the Discordant Union: An Empirical Analysis of DMCA Takedown Notices. Virginia Journal of Law and Technology.

Schrock, A. R. (2014). “Education in Disguise”: Culture of a Hacker and Maker Space. InterActions: UCLA Journal of Education and Information Studies, 10(1).

Slaughter, A.-M. (2009). A new world order: Princeton University Press.

Smithson, J. (2000). Using and analysing focus groups: limitations and possibilities. International journal of social research methodology, 3(2), 103-119.

Stone, B. (2009, 18 July). Amazon erases Orwell books from Kindle. New York Times, p. B1.

Wood, L. (1990). Rapid prototyping. Uphill, but not moving. Manufacturing System, 8(12), 14-18.

Weinberg, M. (2016). 3D Scanning: A World Without Copyright*. Retrieved from Shapeways: http://www.shapeways.com/wordpress/wp-content/uploads/2016/05/white-paper-3d-scanning-world-without-copyright.pdf

Zittrain, J. (2007). The future of the Internet. London: Allen Lane.