The Smart Home: How Consumers Craft New Service Networks by Combining Heterogeneous Smart Domestic Products

Abstract

Service research suggests homes are becoming increasingly connected as consumers automate and personalize new forms of service provision. Yet large-scale empirical evidence on how and why consumers automate smart domestic products is lacking. To address this knowledge gap we analyze 13905 consumer-crafted, automated combinations of smart domestic products, totalling 1,144,094 installations, across 253 separate service providers on the Web service IFTTT.com. An exploratory network analysis examines the topology of the network and an interpretive coding exercise reveals how consumers craft different styles of human-computer interaction to co-create value. The results reveal the smart domestic product network is disassortative, imbalanced, has a long-tailed degree distribution, and that popular services have high centrality across all product category combinations. We show that popular combinations of smart domestic products are primarily motivated by utilitarian value seeking enacted through a preference for automated tasks outside of conscious attention, though more individualistic combinations are slightly more likely to be hedonistically inclined. We conclude by showing how these consumer-crafted forms of service provision within domestic environments reveal design redundancy and opportunities for service innovation.

Keywords

Smart Home; Internet of Things; Craft Consumers; Big Data; Service Design;

"The purpose of a computer is to help you do something else. The best computer is a quiet, invisible servant." (Weiser 1996)

Service research highlights the importance of smart technologies and artificial intelligence in transforming frontline service delivery (Huang and Rust 2018; van Doorn et al. 2017; Jörling et al. 2019). Early literature (Meuter et al. 2000; Bitner et al. 2002) describes self-service technologies (SSTs) situated in commercial locations (e.g. ATM machines in a bank, self-checkout services in a supermarket, or service robots in hotels) or alternatively accessed via telephone or online. However, as computing devices have become ubiquitous, always "on", and embedded in a widening range of products, the scope for "smart interactive services" (Wünderlich et al. 2013) or "frontline service technology infusion" (de Keyser et al. 2019), has blurred the boundaries for service encounter. The domestic environment has not escaped these pervasive technologies and the home is now the physical frontline for many forms of service innovation, where smart products compete for the role of "quiet, invisible servants" (ibid).

Service innovation research is an area of expanding interest (e.g. Gustafsson, Snyder and Witell, 2020; Helkkula, Kowalkowski, and Tronvoll 2018; Hollebeek and Andreassen 2018). This article focuses on "smart home" service innovation and its relationship to *smart domestic products* (SDPs). We follow Woodall, Rosborough, and Harvey's (2018) definition of SDPs "as technological interfaces that provide or support any type of home service and are embedded into domestic routines". SDPs – also called "smart home technologies" (SHTs, Wilson, Hargreaves, and Hauxwell-Baldwin 2017), or "smart home objects" (SHOs, Stojkoska and Trivodaliev 2017) - are "smart" because they differ from "dumb" or "operand" (Vargo and Lusch 2004) resources as technologies that act rather than waiting to be acted upon. Instead, they perform as independent relays or catalysts with the potential for facilitating long chains of causal connections between functions inside and outside the home. Connections may be between systems owned solely by

one consumer, between different consumers, or between consumers and service providers (e.g. companies, charities, or governments).

Recent literature reviews (Gram-Hanssen and Darby 2018; Marikyan, Papagiannidis, and Alamanos 2019; Alam, Reaz, and Ali 2012) have shown there are broadly four types of study currently deployed in smart home research. Gram-Hanssen and Darby (2018) characterise these as: *Conceptual* – where meanings are ascribed to "smartness", the "home", and the relation between technology and myriad actors; *Technical* – how distinct elements communicate with one another and how hardware/software is designed; *Prospective* – future smart home potential: what is possible, and how it might be configured for optimal benefit; and lastly, *Evaluative* – which smart devices are connected, and how smart homes work in practice. Of the four types, they note *Evaluative* is the least studied, primarily due to a lack of available data. These reviews highlight the lack of large-scale or longitudinal empirical research into how smart technologies actually work in domestic environments. We aim to address this gap using a massive observational dataset of consumer-led service innovation (1,144,094 instances) to investigate the value derived by craft consumers in smart home improvement. We evaluate (1) how such consumers connect smart domestic products into broader networks of service provision; and (2) how these connections translate into functionalities co-created from connecting heterogeneous smart domestic products.

We begin by surveying the literature on smart homes, smart domestic products, service innovation and craft consumers. Subsequently we discuss a*pplication programming interfaces* (APIs) as a means by which organisations provide modular access to services that consumers can modify. We then introduce online service platform IFTTT.com, the source of data for this study, to illustrate how consumers combine heterogeneous smart domestic products using APIs to create new forms of service provision. After this we outline our research approach which deploys: (1) an exploratory network analysis on the smart domestic product network; and (2) an interpretive coding exercise to analyze the types of human-computer interaction and the values expressed by consumers on IFTTT when crafting new forms of service provision. Our results are derived firstly

from a range of analyses focused on a topological analysis of a network of 253 separate services. Next, we explore why craft consumers connect smart domestic products in the way they do, by analysing the benefits that users derive from connecting devices via IFTTT. Our results are expressed as a series of "key insights". By combining both approaches our insights identify directions for SDP service research and design, and we present these in the final section.

Smart Homes and Smart Domestic Products (SDPs)

The term "smart" in natural speech is used to convey quick-wittedness or high intelligence (Cambridge Dictionary 2019). Transposing this term into the field of domestic service innovation implies the use of products beyond direct householder intervention. Human involvement is required for the installation of the products concerned, but once set-up these operate autonomously and are independent of the reflective mind. Such products take care of a wide range of domestic concerns ranging from energy use, comfort, leisure, healthcare, safety and security (Alam, Reaz, and Ali 2012). For "smart", in domestic terms, it is conventional to think of (a) smart homes - the context on which "smartness" is focused; and (b) smart objects (or products) - the technologies used to embed smartness in the home (Wünderlich et al. 2015). Beyond this though, the smart products within the smart home integrate with other smart contexts – smart grids, smart communities and smart cities - interconnected via the *Internet of Things* (IoT - Ashton 2009). The Internet of Things is a computer-mediated network of distributed artificial intelligence existing in parallel with the regular Internet. It has been estimated that by 2020, this network will comprise 25 billion separate smart products (Miranda et al. 2015).

A home becomes smart when it has "a high level of device connectedness within and beyond the home, along with a reliance on that connectivity for everyday operations" (Gram-Hannsen and Darby 2018, p.96). "Context awareness" (Gu, Pung, and Zhang 2015) is critical for interaction between a home and any smart products it contains, and Figure 1 demonstrates how context awareness can be configured. This illustrates an idealised smart home, showing both

classes of smart objects currently available and where these are typically located. Smart Domestic Products (SDPs), the term we use to denote these technologies, was first used in Woodall, Rosborough, and Harvey (2018). Other terms denoting this same phenomenon are "smart home technologies" (e.g. Wilson, Hargreaves, and Hauxwell-Baldwin 2017), "smart home objects" (e.g. Stojkoska and Trivodaliev 2017) or "smart home devices" (e.g. Robles et al. 2010). We use the word "product" rather than object, device or technology to indicate a strong relationship with consumer markets and to acknowledge these may be individual units or systems and may be virtual or physical. By deploying "domestic" rather than "home" we draw on the work of Elizabeth Shove and colleagues (e.g. Hand and Shove 2007; Shove 2003; Watson and Shove 2008) who use this to connect everyday practice with its location.

[INSERT FIGURE 1. HERE]

Smart homes can either be built deliberately or retrofitted post-hoc as smart products become embedded in older houses. The public perception of SDPs is largely positive (Wilson, Hargreaves, and Hauxwell-Baldwin 2017) yet according to Olick (2017), although 80 million smart products were sold worldwide in 2016 (a 64% increase on the previous year), evidence suggests few people are prepared to pay a premium for a either a built smart home or one that has been expensively converted. The increasing volume, therefore, is explained primarily by retail sales of individual units used by consumers to upgrade houses they occupy. The number of planned smart domestic spaces is much smaller than the number of homes where this iterative up-grading will, for many years, be the norm.

We refer to this iterative upgrading as *DIY* (Do-It-Yourself) *smartness* - following Gram-Hanssen and Darby (2018). This might involve the purchase of a single product (e.g. Amazon Echo, Nest thermostat, Ring video doorbell) or multiple products with no aim other than to deploy the novelty these products convey, allowing for "...more interaction, playing and personalising..." (p.100) of domestic technological potential. Alternatively, though, there are those for whom

"smart" potential becomes a challenge in itself, and for whom this challenge becomes an act of creativity (see, for example, Haraty, McGrenere, and Bunt 2017; Funk et al. 2018). This resonates with Campbell's (2005) notion of the *craft consumer*, someone who typically deploys skill, knowledge, passion and judgement within a context of self-expression, or self-transformation (Elliot 2016), that moves beyond mere personalisation of context and space.

SDPs are a special case of the wider category, human-computer-interface (HCI; Laurel and Mountford 1990) – a device or program enabling users to communicate with a computer. Woodall, Rosborough, and Harvey (2018) categorise SDPs via a 3 x 3 matrix typology; firstly, according to the form of HCI enacted (either *Supportive, Advisory*, or *Persuasive*) and secondly with the type of value derived from the SDP (defined as either *Transformative, Utilitarian*, or *Hedonic* value). Various HCI forms have emerged over the past two decades and can be divided according to the extent that they intervene into user consciousness. For instance, some interactions happen in the background, not requiring conscious attention to the changing environment (e.g. a light automatically dimming as a person leaves a room). These *supportive* interactions aim to get out of the way of the user, and in HCI literature are called "calm" technology (Weiser and Brown 1997). As Weiser (1991, p.94) noted "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it". Other HCI forms deliberately try to catch the user's attention to initiate an informed decision and are thus *advisory* (e.g. receiving a notification on a smartphone whenever motion is detected on a security camera). Finally, some HCI forms seek to deliberately manipulate users into acting, such that they are consciously aware, but nonetheless motivated to act in a way that they wouldn't without prompt (e.g. smart watches vibrating to ensure their owners move and burn calories). This form of HCI is referred to as *persuasive* computing (or "captology" - Computers as Persuasive Technology, Fogg 1998).

[INSERT FIGURE 2. HERE]

The vertical axis of Woodall, Rosborough, and Harvey's (2018) typology comprises three archetypal value forms. Two of these, *hedonic* and *utilitarian* are widely deployed in the marketing literature (e.g. Babin, Darden, and Griffin 1994; Chitturi, Raghunathan, and Mahajan 2008; Das, Mukherjee, and Smith 2018). For SDPs, utilitarian value relates to the perceived benefits of delegating routine, domestic endeavours (e.g. Brich et al. 2017). Hedonic value, by contrast, relates to outcomes that delight, surprise or excite. The third form refers to outcomes for personal or social well-being and is named *transformative* value (Blocker and Barrios 2015). This relates to agendas described in Mick (2006) but is used here specifically in relation to the domestic environment. When Woodall, Rosborough, and Harvey's (2018) two dimensions are conjoined (Figure 2) they create a matrix that helps illustrate the wide variety of smart possibilities. Combinations can be applied both to individual objects with smart utility and also to the broader smart service systems into which these might be integrated. The matrix helps identify innovation possibilities for service designers, who can implement combinations of value and HCI (e.g. TS, UA, HP) to suit potential market opportunities.

Service innovation and the craft consumer

Service innovation is "the creation of new value propositions by means of developing existing or creating new practices and/or resources, or by means of integrating practices and resources in new ways" (Skålén et al. 2015). This definition configures service innovation as a practical accomplishment, and in the context of DIY smartness brings the home-owner sharply into focus, someone who both (co)creates and consumes the smart services they develop. The "working consumer" (Cova and Dalli 2009) trope has a well-established provenance within service research. This emerges from different academic traditions, but generally describes the consumer as either "dupe" or "hero" (Slater, in Campbell 2005, p.23/24), meaning we either control, or are controlled by, our consumption habits. Over the past 40 years researchers have drawn attention to the overlap of production and consumption in customer experiences (e.g. Toffler's [1980]

"prosumer"; Firat and Venkatesh's [1995] "postmodern consumer"), while others have shown how the productive potential of market actors might be harnessed (e.g. Prahalad and Ramaswamy 2000). Similar ideas appear in Vargo and Lusch (2004) where a shift from a product-, to a service-dominant marketing logic (SDL) has become influential. Using a broadly service-for-service exchange analogy, SDL posits service innovation resulting from the integration of diverse shared resources, either operant (with power to act) or operand (to be acted upon), to form value in the shape of varied service benefits. Service innovation is perceived primarily as customer driven, with information and digital resources increasingly relevant to how value is understood and distributed within markets (Barrett et al. 2015). A later shift in emphasis from co-*production* to co-*creation* (Vargo and Lusch 2006) acknowledges some weakness in earlier arguments.

The distinction between co-creation and co-production is highly relevant to this study, as these frame the consumer in different roles (Hilton, Hughes, and Chalcraft 2012). For example, as a "more general concept" (Galvagno and Dalli 2014) co-creation suggests even passive consumer/supplier interactions (e.g. sitting on a train) are collaborative in that all service experiences are moderated by both consumer character and the involuntary inflections that configure them. Co-production, in contrast, implies a service does not happen in any substantive sense unless the consumer participates in its performance and completion (e.g. Etgar 2008). The latter has pejorative implications if consumers become non-remunerated part-time employees for a firm – i.e. the "dupe" - undertaking for free, activities for which others would traditionally have been paid (e.g. Cova, Dalli, and Zwick 2011; Humphreys and Grayson 2008; Ritzer 2016). This might be putting together a furniture kit or self-swiping groceries at the supermarket. Alternatively, though, this could provide opportunities for the consumer (as "hero") and where prosumption/co-production is envisaged as "more proactive and critically engaged" behavior (Knott 2013) enabling rather than constraining the consumer and facilitating the co-creation of value in the process (Chandler and Chen 2015). This is reflected in Campbell's (2005) notion of the *craft-consumer*, an exemplar case of the creative prosumer for whom consumption is

characterised by participation, skill and mastery: "the assumption here is that individuals consume principally out of a desire to engage in creative acts of self-expression" (p.24).

Craft consumers are those who typically find pleasure in creative practices such as cookery and gardening, and who both design and build – in the broadest sense - that which they consume (Campbell 2005). Campbell suggests, "the craft consumer is a person who typically takes any number of mass-produced products and employs these as the raw materials for the creation of a new "product"… typically intended for self-consumption" (p. 27/28). For "product" we might say "outcome", given that both services and experiences are now the *lingua franca* of contemporary consumption practice (e.g. Bolton et al. 2014; Carú and Cova 2006). Elliot (2016) suggests craft consumption is reflexive and thus transformational, heightening engagement and social relatedness. Craft consumption is similar to craft production in that people are expressing a preference to do work for themselves rather than pay others to do it for them (Cole 2018; Kosnik 2018), and both can have function and meaning in consumers' everyday lives. Also typical of the genre is home-improvement work, and both Watson and Shove (2008) and Wolf and McQuitty (2011) show how painting and decorating fit into and help distinguish this category. Of increasing interest, though, is how DIY work transcends traditional boundaries taking opportunities made available via the Web (Beer and Burrows 2010; Novak and Hoffmann 2019; Paltrinieri and Espoti 2013). We address this in the section that follows.

The Research Context: If This, Then That (IFTTT)

Ethnographies within service and design research have long shown that technologies are appropriated and adapted in ways that designers had not previously intended. Appropriation is a learned behavior that supports resource integration (Hibbert, Winklhofer, and Temerak 2012) and is widely seen as necessary to consumer engagement (e.g. Chandler and Lusch 2014). Indeed, two recent service research papers have called for further study into how service innovation can be triggered by changing resource integration and co-creation roles (Helkkula, Kowalkowski, and

Tronvoll 2018; Jaakkola and Alexander 2014). And yet, as Dix (2007) notes, designing for forms of appropriation and innovation based on the unexpected seems an oxymoron. How can service providers facilitate something they cannot yet imagine consumers will want? One increasingly popular approach is to make available *application programming interfaces* (APIs) for products that consumers can access and configure. APIs specify how software components should interact, and these enable the features of respective smart products to be digitally modularised (e.g. turning a light on or off) and thus algorithmically accessible at the behest of consumers. APIs afford the potential for creating modularity in service design, allowing consumers to craft their own new forms of service provision and tailor an experience to suit their personal needs and taste (DIY).

An API is a means by which the technical features of an SDP can be interacted with remotely, and potentially, combined with other technologies to create chains of events which "trigger" each other and enable vertical integration of functionalities (Chase 2013). For example, when a person leaves home to go to work their mobile phone can use geo-positioning to sense they have left and create a trigger causing their digital thermostat to reduce ambient house temperature, saving money and conserving fuel without user intervention. IFTTT, an acronym meaning "If This Then That", is one of several *online automated task services* (OATS, Hoy 2015) used for combining APIs from popular software applications and hardware devices. IFTTT, the most popular of these services (Desolda, Ardito, and Matera 2017) refers to user-designed connections between applications as *recipes*; that is, a distinct set of ingredients and contextual factors to be adhered to: if a specific "trigger" happens to X then outcome Y ("action") follows.

IFTTT recipes represent a vast cosmos of user-led innovation in service design and innovation outside of the realm of traditional market research-led product development cycles (Ovadia 2014). Indeed, though some savvy companies are now creating recipes for consumers, the majority are designed and publicly shared by consumers. This newly emerged platform has huge potential, giving imaginative prosumers almost limitless opportunity for co-creating DIY smartness. The list of IFTTT smart product APIs (also called *channels*) and associated recipes is

thus constantly growing. Many recipes represent highly individualised personal projects, while others have proven useful to tens of thousands of other people. Figure 3 illustrates the structure of IFTTT recipes and reveals the implicit network structure that forms between channels. The topology of the network (the way in which its constituent parts are arranged and interrelated) gives the most immediate empirical evidence of how consumers appropriate smart domestic products and craft/co-create new forms of service value beyond the original designers' intent.

[INSERT FIGURE 3. HERE]

Research Questions

The IFTTT recipe database contains a wealth of behavioral data on consumer-led service design, yet research on this form of craft consumption is lacking. Although studies exist in computer science and human-computer interaction journals that focus on technical characterisations (e.g. Mi et al. 2017; Ur et al. 2016) or privacy (e.g. Fernandes et al. 2017; Surbatovich et al. 2017), the services literature has not yet examined how these services form value for users. For instance, how people decide what devices to connect and the functionalities they co-create have not to our knowledge been studied. Our research design combines topological network analysis and a subsequent interpretive coding exercise of a longitudinal dataset. Our aim is to understand how a community of craft consumers practice service innovation and value co-creation in an emergent context (IFTTT) facilitating DIY domestic smartness. We set the following research questions:

RQ1 - How do IFTTT recipe developers connect smart domestic products to co-create value within a broader network of service provision? Here we explore the topology of the SDP/IFTTT network. This is in response to calls to address the lack of empirical evidence on how consumers craft new service design by integrating heterogeneous products in the home (Gram-Hansen and Darby 2018; Marikyan, Papagiannidis, and Alamanos 2019; Alam, Reaz, and Ali 2012). Findings have clear implications for how service providers think about important but paradoxical considerations of innovating by "designing for appropriation" (Dix 2007).

RQ2 - What functionalities do smart home craft consumers co-create by connecting heterogeneous smart domestic products? This question is not focused just on how SDPs are connected but examines also the concomitant motivational states underlying device connectivity and new forms of service provision. We draw on Woodall, Rosborough, and Harvey's (2018) typology to categorise IFTTT recipes according to archetypal value forms and the means of human-computer interaction which enable these. The findings can help contribute to understanding how service innovation can be triggered by consumer-led resource integration (as called for by Helkkula, Kowalkowski, and Tronvoll 2018, and Jaakkola and Alexander 2014).

Research Methods

Much of the previous work on SDPs has focused on attitudes to these products and on the social practices that apply (see Marikyan, Papagiannidis, and Alamanos, 2019). Though this work is valuable we propose that to understand fully how SDPs are deployed in practice requires the analysis of large-scale historical and behavioral data. Such data can be used to inform abductive reasoning and theorisation about the emergence of smart craft consumption and associated new service development (Gram-Hanssen and Darby 2018). Abductive work is not the norm in marketing research, which has been dominated by hypothetico-deductive approaches (Hofacker, Malthouse, and Sultan 2016). However, there is growing interest in abductive reasoning (e.g. Antons and Breidbach 2018) given the emergence of "big data" that can provide unprecedented and naturalistic insights into behavior exhibited by consumers and service providers alike.

Data Collection

Both research questions are pursued via analysis of a large-scale dataset acquired by scraping the IFTTT homepage for all recipes in its library. This repository captures details of craft consumer behavior played out in natural settings. Ur et al. (2016) originally scraped this data and we are indebted to them for making their results open-access. From an aggregated dataset comprising

295,156 recipes and 259 channel APIs, we checked each channel to determine whether they could be categorised as SDPs based on classes outlined in figure 1. Once the list of SDPs was collated, we filtered recipes to only include those used as either a trigger channel, and/or an action channel. This process was necessary to isolate the smart home subgraph for IFTTT and permit further analysis specifically on products used to modify the domestic environment. We retain non-domestic channels where they trigger a smart domestic action channel (e.g. phone GPS measurement triggering central heating in the home when a person leaves work) or when a SDP triggers a channel outside the home (e.g. push notification sent to a mobile phone when a thermostat records a temperature above a specified limit). Once filtered, the network comprised 253 individual channels and 13905 recipes, accounting in total for 1,144,094 IFTTT installations. Craft consumers in this context fall on a continuum – at one extreme are those for whom smart recipe generation is the object of engagement; whilst at the other extreme are those for whom smart home development is the primary aim. The first we describe as *Developers*, and the latter as *Downloaders*. For Developers, recipe configuration provides value as an act of co-creation in itself, and for both them and Downloaders further value is co-created by modifying their homes.

Methods of Analysis

IFTTT data is analysed using two separate, but empirically associated methods. Firstly, we perform a range of exploratory network analyses designed to identify the patterns of connection co-created by recipe developers. Secondly, we undertake an interpretive coding exercise to explore how these patterns emerge as functionalities deployed by craft consumers to co-create smart domestic contexts. Each method is now discussed in turn:

Exploratory Network Analysis

The first analytical phase of our study is *exploratory network analysis* (De Nooy, Mrvar, and Batagelj 2018). Analytical software used included *Ucinet, Pajek, and Python Networkx* (See

Batagelj and Mrvar 1998; Borgatti, Everett, and Freeman 2002; Borgatti, Everett, and Johnson 2013). Network vizualisations came from a modified version of *Gephi* (see Bastian, Heymann, and Jacomy 2009). The IFTTT recipes are modelled as a directed network where nodes represent channels and edges are recipes crafted between them. A sequence of global and local network measures surface both the relative position of SDPs within the network *and* the structure of the network in its entirety. The measures are: (1) *Basic structural measures*; examining the geodesic distance and giant connected component (i.e. which devices have been combined in recipes and what structures are formed in the aggregate SDP network); (2) *Degree distributions*; revealing how similar in popularity are those products connected into recipes; (3) *Centrality measures*; indicating the relative positional "importance" of SDPs facilitating connections between other products. Centrality denotes the extent to which a node contributes to network structure by virtue of its position within the network (Kang et al. 2011). We include measures of betweenness centrality, closeness centrality, and also PageRank centrality to find which devices are connected to other highly connected devices through recipe development. And (4) we address *Degree Assortativity*, to determine whether devices that are similar form connections with each other (as in "birds of a feather flock together") or whether devices with few connections tend to link to highly connected devices. In directed networks each node *i* is characterised by an incoming *k* in-degree and an outgoing *k* out-degree. Assortativity can therefore be defined by four x degree correlation functions (in-in, in-out, out-in, and out-out; Barabási 2016) using the Pearson correlation coefficient between degrees found at the two ends of a link. Collectively, these sub-questions address the structural elements of value-forming potential within the network.

Interpretive Coding Exercise

Research question two concerns the functionality that craft consumers derive from connecting SDPs. To answer this, we designed an interpretive coding exercise for analysing (1) how IFTTT users characterise their value-related motivations for creating recipes, and (2) the form of human-

computer interaction enabling such value. The most frequently downloaded recipes were firstly selected for analysis from the initial pool of 13,905. Analysis showed that the number of recipes with 100 or more downloads was 1170, representing 89.93% of all SDP-related activity on IFTTT. This "most popular" subset represents the activities of those users we describe as Downloaders. A second area of interest was recipes representing the activities of those users closest to the Developer end of the distribution (1-99 downloads) and comprised 11,835 different recipes but only 10.07% of overall downloads.

Given the broadly logarithmic character of the download distribution we treated the 100-plus downloads dataset as broadly homogeneous and below 100 as heterogeneous. This latter group we sub-divided into five bins – 1 download (2992 recipes), 2 to 24 downloads (7918 recipes), then 25-49 (1109 recipes), 50-74 (454 recipes) and 75-99 downloads (260 recipes). Although we had no strong evidence on which to base an associated (and thus, testable) hypothesis concerning relative differences in character between recipes at different points along the Developer/Downloader continuum, we believed adopting this position would offer good potential for exploratory analysis. Taking one download recipes as a bin of its own was clearly justified given the comparatively high number of recipes at that level.

Two coders, PhD marketing students, were recruited and trained to understand the IFTTT-SDP dataset. The first phase was thus preparation for coding. Each recipe contains details across a number of fields: (1) author-entered *description* (what the recipe does and why it is useful); (2) *trigger channel* (which API causes the recipe to occur); (3) *trigger description* (which specific channel feature initiates the recipe); (4) *action channel* (which API is activated and thus causes the channel to act); (5) *action description* (which specific action channel feature is activated). Based on an analysis of 150 randomly selected recipes, the principal authors created a coding protocol to assist coders in interpreting the functional motivation and HCI style evident in each recipe. The protocol was designed to maximise inter-coder reliability, and from this a decision tree was developed (Figure 4). Following Woodall, Rosborough, and Harvey's (2018) SDP

typology, the decision tree guided coders to characterise each individual recipe in each of the two parts of the IFTTT-SDP database (Developer-focused and Downloader-focused) based on (a) the nature of technology-human relationships (HCI Judgement) and (b) perceived value-type.

[**INSERT FIGURE 4. HERE**]

Working independently, coders were given an initial batch of 500 recipes to evaluate from the Downloader-focused dataset. We adopt Krippendorff's α to determine the level of inter-rater reliability. This method was used because it allows for uniform reliability standards and is insensitive to number of values per variable, number of observers, sample size or missing values (Krippendorff 2004). The intercoder reliability for both HCI and Value-type judgement in this first phase was 0.76 and 0.79 respectively (80% similarity). Krippendorf (2004) suggests an acceptable level of reliability occurs above α >=0.667, and given our objective was to maximise sample size for subsequent analysis, these results provided confidence to continue.

In a second phase, coders were given the remaining recipes (670) from the Downloader-focused dataset for independent coding. Krippendorff's α for this second task was 0.79 and 0.80 for HCI and Value sides respectively, figures at, or close to, the expected norm for a "good" inter-coder reliability test (e.g. De Swert 2012). Combining the two phases there were 974 (from 1170) perfect matches between the two coders (83% similarity). The result presented strong evidence for (a) robustness of the decision tree; and (b) good inter-rater reliability between coders. This left only 176 unresolved recipes. Investigations suggested that in this relatively small but significant sub-sample decisions had proved difficult because although the IFTTT website readily identified function to be performed, it was not always clear why the user *wished* the function to be performed. Thus, there were instances where coders disagreed whether HCI was advisory or persuasive, and Value was transformative or utilitarian. In order to achieve 100% concurrence between coders (to maximise sample size for the next stage of the analysis) therefore, coders were asked to collaboratively re-code the 176 recipes they had independently disagreed on, either for

the HCI side, the Value side, or both. As these were public/shared recipes we adopted a Downloader perspective and a decision protocol based on "most-likely" Developer intent.

The SDPs within these recipes were also manually labelled into broader categories based on manufacturers' descriptions to distinguish normal application as either inside or outside the domestic boundary - i.e. is each smart product designed for a domestic environment (or not) and what is the device designed to do (for example, heating, lighting, security, entertainment, etc)? The purpose of labelling was to determine direction of causality for SDP-related recipes: are SDPs primarily *acted upon* by channels triggered outside of the home; do SDPs act as a trigger to *act upon* channels outside of the home; or do SDPs *act within* the home itself by forming an internal subgraph of connections between devices. Labelling also provides further contextual depth for examining the relationship between categories of heterogeneous products - i.e. which aspects of service provision are combined when consumers craft new recipes.

Finally, we asked coders to evaluate the Developer-focused dataset, using the same methods used for the Downloader-focused dataset (independent evaluation followed by collaborative coding to resolve differences). A sample size of 120 was selected for each sub-group bin. This enables a small to medium effect size (index of 3.2, Cohen 1992) to be observed with 80% power when considering per cell/aggregate cell changes in one-vs-rest proportions. In practice this means if differences (increases) in cells with proportions closest to 0.5 exist they will be observed with 80% power. The coders achieved 91% coding similarity on this additional 620-recipe sample before collaboratively resolving those outstanding. Our research design, focused on two primary research questions, is summarized at Table 1.

[INSERT TABLE 1. HERE]

Findings

Research Question 1

This question is concerned primarily with the topology of the IFTTT-SDP network and describes key insights derived from exploratory network analysis using a range of software tools designed for that purpose. Table 2 provides a description of the network by identifying key characteristics.

[**INSERT TABLE 2. HERE**]

Key Insight 1: A small number of channels capture a large share of installations. The SDP network exhibits long-tailed degree and weighted degree distributions.

The smart domestic product network has highly right-skewed degree distributions and weighted degree distributions. Figure 5 (a and b) shows that some SDPs have gained many more connections than others, in both numbers of separate product connections (recipes), and numbers of installations associated with those connections. Channels such as Nest thermostat (out-degree 86) and Phillips Hue lightbulb (in-degree 153) have accrued many more connections to other channels when viewed comparatively. The long-tailed nature of the degree distribution is similar to other social, biological, and technological networks examined by previous research (e.g. Albert and Barabási 2002; Dorogovtsev and Mendes 2002).

[**INSERT FIGURE 5. HERE**]

In response to previous calls for research (Gram-Hansen and Darby 2018; Marikyan, Papagiannidis, and Alamanos 2019; Alam, Reaz, and Ali 2012) these results help to provide an answer to the question of how smart domestic products are connected at scale rather than examining individual practices. A small group of channels have captured a disproportionate share of the recipes (and associated number of installations) within the broader connected SDP network and can be seen organized by degree weight and device class in Figure 5 (c).

Key Insight 2: SDP classes tend to have one dominant service provider that connect to many other product classes. Services with high weighted degree (installations) are also the most central in the network

There is a single giant connected component within the SDP network, meaning all channels are connected through recipes into one broader system. The maximum geodesic distance of the SDP network is 5 (number of "hops" needed to cross the full diameter of the network). Though the network has a relatively low density at 0.034 (see Table 2), topological measures illustrate that the network is closely connected (average geodesic distance 2.246) and that consumers craft recipes between product categories without restriction. If the network had more than one component this would reflect a fragmentation of connectivity between particular devices types, but not so here. The results demonstrate clearly that consumers enact a wide variety of connections between SDPs, rather than being restricted by arbitrary classes of devices.

Any given device can be connected to any both practically and theoretically. However as shown in Table 3, although consumers may be willing to combine SDPs without prejudice, network topology nonetheless centres around those devices with more installations. Table 3 illustrates that the same devices are similarly ranked across weighted degree and centrality scores (betweenness and PageRank). There is positive correlation between installations and betweenness centrality scores ($r = .73$, $p < 0.5$) and degree and closeness centrality scores ($r = .81$, $p < 0.5$). As the installations of central nodes increases, probability of connecting to other highly connected nodes also increases, and vice versa. Results suggest there is no privileged central position in the network based just on product classes, as might for instance have been expected of those devices designed explicitly to act as smart home hubs or controllers, e.g. Amazon Alexa. Instead, there are clear leaders within different product categories (e.g. lighting, heating, electricity, security) and each of these leading devices possesses high degree, weighted degree, and centrality scores, respectively. These results provide a clear response to the calls for analysis on how consumers integrate heterogeneous products (Alam, Reaz, and Ali 2012; Gram-Hanssen and Darby 2018).

[INSERT TABLE 3. HERE]

Key Insight 3: Consumer-crafted recipes tend to connect popular channels with less popular channels. The connected smart home network has a disassortative overall network structure.

Table 2 presents measures of degree assortativity for the SDP network (degree correlation functions). Negative results indicate that nodes with few connections tend to link to highly connected nodes, whereas positive values indicate nodes with similar connectivity tend to connect to each other. The SDP network has a weakly disassortative structure, much like other technological networks such as the Internet and the World Wide Web (see Newman 2002).

We suggest that SDP network disassortativity is the result of multiple pressures: (1) *technological convergence* - the phenomenon whereby two or more independent devices become integrated (Caviggioli 2016); for example the smartphone combines technologies from previously disparate devices (e.g. telephones, cameras, computers, GPS, and fingerprint scanning) within one unified product; (2) *monopolies* - in some instances there is only one product available with particular functionality and API from which to craft new recipes, e.g. pet tracking (Whistle Smart Collar); and (3) *first mover advantage* (Magnusson et al. 2003) - previous service research has shown that companies that involve users in service innovation can gain a competitive commercial advantage (e.g. Chesbrough and Crowther 2006). SDPs ease appropriation by enabling their APIs to encourage user "plugability and configuration" (Dix 2007, p.2). Those SDPs that first bring an API to market receive the first customer-created recipes, subsequently receive greater exposure than later entrants, and thus benefit from a preferential attachment effect, a phenomenon seen in many other socio-technical networks (Jeong et al. 2003).

Key Insight 4: SDP network connections are largely imbalanced at both channel and category level meaning value is initiated both inside and outside the DIY smart home.

When channels are categorised according to location within or outside the physical domestic boundary, notable imbalances in causal relations are visible (see Table 2). Only 25.3% of recipes

involve combinations of SDPs within the physical domestic boundary, whereas 74.69% of recipes involve channels outside of the boundary. 60.05% of recipes involve external triggers where a channel outside the boundary acts upon an SDP and 14.63% involve an SDP acting upon a channel outside of the home. Notable imbalances in the direction of causality are visible at a class and device level too. Figure 6 is a heatmap showing normalized trigger/action relations between classes of channels. The results demonstrate the imbalance that most channels maintain, primarily acting as either trigger or action channel. This imbalance holds for the majority of classes.

For example, two external classes "Smartphones and ubiquitous computing" and "Spatiotemporal indicators and events" have the biggest effect as triggers on SDPs, and yet the converse relation is far lower when examining how SDPs trigger channels in these categories. Similarly, Figure 6 reveals that the "Lighting and Shading" SDP category has garnered action support from all categories and yet rarely acts as a trigger. Indeed, lack of reciprocity between classes is most evident in lighting (e.g. Phillips Hue is the most popular action channel with 582137 installations, yet never acts as a trigger) and in products designed for command - e.g. Alexa (out-degree entirely) and Logitech's Harmony (in-degree entirely). Service providers should thus carefully consider how classes of SDPs interrelate more broadly into the service ecosystem in order to create opportunities for strategic alliance through service design.

[INSERT FIGURE 6. HERE]

Research Question 2

This question concerns functionalities co-created by combining heterogeneous smart domestic products in IFTTT. We interpret recipes and develop key insights using both Developer and Downloader samples of the IFTTT database. We use Woodall, Rosborough, and Harvey's (2018) smart service innovation matrix to categorise functionalities rather than stand-alone products.

Key Insight 5: Consumer-crafted combinations of SDPs are primarily motivated by utilitarian value forms and a preference for supportive human-computer interaction

The 1170 recipes taken forward for the interpretive coding exercise at the Downloader end of the recipe distribution constitute 8.41% of the recipe corpus (13905 total) but represent 1,028,938 downloads, equivalent to 89.93% of the total (1,144,094). Table 4 shows the number of recipes for all combinations of HCI /value and is divided (beyond the first column showing the nine possible smart context categories) to give a descriptive analysis related to (a) the Downloader segment of the IFTTT population, and (b) the Developer segment of the population (see Insight 6). The Downloader results (derived from recipes downloaded 100+ times) reveal that the *Utilitarian/Supportive* combination, at 66.4%, was the most popular type of recipe for IFTTT users. This was followed *by Utilitarian/Advisory* at 23.4%.

The results further show that Utilitarian-focused recipes account for 91% of recipes (66.5% US + 23.4% UA + 1.3% UT, representing 89.6% of download share) while there are only 2% for Transformational value-type (1.6%TS + 0.4%TA, representing 2.1% of total download share). The relative lack of Persuasive recipes (just 15 recipes – 1.3% of download share, and all for Utilitarian value-type) suggests that though smart products are frequently designed to manipulate owners into acting (e.g. smart watches vibrating to ensure their owners move), when consumers craft their own recipes the target of automation is generally another device rather than themselves. We therefore do not deny the possibility of hedonic/persuasive recipes but suggest these outcomes are less likely associated with craft consumers who connect products through IFTTT. Figure 7 provides illustrative examples of coded recipes mapped onto the SDP Matrix.

[INSERT FIGURE 7. HERE]

Key Insight 6: For one-download recipes there is a small but statistically significant reduction in utilitarian focus and a compensating increase in hedonism

So as explore whether the Developer corpus of recipes differs in character to the Downloader corpus, we performed a range of comparative tests between the 100+ download bin and the 1, 2-24, 25-49, 50-74 and 75-99 downloads bins. We used Fisher's Exact Test for Count Data for testing the null of independence of rows and columns in a contingency table with fixed marginals (Agresti 2002). This was preferred to a standard "t" test given the low download incidence in some cells. The number of replications in the Monte Carlo test was set at 6 million. We then used the False Discovery Rate adjustment on computed p values (Benjamini and Hochberg 1995) to account for the multiple hypotheses testing involved. We then compared data in the contingency tables (3 x 3 Value/HCI) at matrix, axis and cell levels.

At the matrix level (all nine cells, value-type vs HCI) we found a significant difference (adjusted $p = 0.019$) between just the one-download sub-sample (Developers) and the 100+ sample (Downloaders). At the axis level (comparing both value-type and HCI independently) we found significant differences on just the value-type axis, firstly between the one-download sub-sample and the 100+ sub-sample (adjusted $p = 0.045$) and between the one-download sub-sample and the 75-99 sub-sample (adjusted $p = 0.019$). Given that at both matrix and axis levels we found differences between the one-download sub-sample and the 100+ sample only, and because the difference between the one-download sub-sample and the 75-99 sub-sample implied the Downloader category was likely wider than first envisaged, we focused cell-level tests on one-download and 100+ downloads only. Here we converted data into "category of interest" vs. rest counts and again ran Fisher's Exact Test for Count Data, this time testing for an alternative of either "greater than" or "less than" for observed direction of difference in download proportions.

Now disregarding the HCI axis we focused just on cells in the value-type axis and evaluated for difference at individual value categories. This led to an observation of differences in both utilitarian ($p = 0.041$) and hedonic value ($p = 0.019$). For utilitarian value there was a lower proportion in the one-download sub-sample than in the 100+ sample (83.3% vs 91.2%) and a corresponding increase in the hedonic category (15% vs 6.8%). There were no observed

differences for the Transformational category. We then evaluated cells using both axes, this time to evaluate for differences at the smallest (HCI x value) increment. Here we identified a significant difference in proportions ($p = 0.019$) for the hedonic/supportive cell only with a higher proportion (9.2%) in the one-download sub-sample than in the 100+ sample (3.1%). Given, though, we had previously found no significant differences in the HCI axis we concluded the difference was a function of the Hedonic aspect of the cell. Evidence at the cell level suggests, therefore, that although Developers are *significantly* more diverse in their activities than are Downloaders, they are not *substantially* so. We reproduce comparative data from the one-download sub-sample at the Developer headed columns in Table 4.

[INSERT TABLE 4. HERE]

Key Insight 7: When SDPs trigger themselves ("Self-loops") recipes are primarily motivated by a failure to support utilitarian needs and thus highlight opportunities for service innovation

34 channels are involved in 403 self-loop recipes, i.e. triggering themselves to act (i.e. "daisy chaining" – e.g. Blaauw et al. 2014) or triggering a second copy of the same device so these act in concert in the home; for example, one lightbulb turning on if another one does. The number of self-loops rises further to 628 recipes when analysis is conducted at class level (e.g. "Heating and Climate Control") rather than individual channel level. Why should consumers need to use a recipe to link a sensor and an actuator over the Internet that exist within close physical proximity? Self-looping demonstrates that consumers are recrafting device functionality, but also that SDPs have been designed for appropriation by "support not control" of features (Dix 2007, p.2).

Of the 628 self-loops in the dataset we coded 65 at class level (e.g. a security device triggering another security device) of which a subset of 37 were at single device level (e.g. Nest thermostat triggering itself). The value-type coded for these recipes was Utilitarian regardless of installation count, and occurred in the following combinations: *Utilitarian-Supportive*: 58; *Utilitarian-Advisory*: 6; *Utilitarian-Persuasive*: 1. Self-looping is driven by the failure of SDPs

to provide Utilitarian value in their basic configurations. Two interesting implications are apparent: (1) self-loops at channel level show redundancy and therefore opportunity to improve SDP design; and (2) self-loops provide insight into how people want to pair features from competing technologies together. They therefore show where future technological convergence could assist existing consumers (combining features from previously separate competing devices to craft new forms of service innovation and assert functional superiority over rivals).

Evidence of self-loops provide excellent insight for designers looking to capitalize on consumer intelligence for co-creating new functionality. For instance, some recipes instruct smart thermostats to measure room temperature and create an IFTTT alert, which then triggers the same device to adjust the room temperature in response to the alert sent over the Internet. Self-looping recipes highlight redundancy, inefficiency and possible design flaws that customers are trying to overcome. Self-loops therefore draw attention to the barriers experienced by users during resource integration (Helkkula, Kowalkowski, and Tronvoll 2018; Jaakkola and Alexander 2014). Attentiveness to self-looping recipes is likely to lead to improved design suggestions for individual devices and also provides opportunities to plan for further technological convergence between previously heterogeneous sensors and actuators.

Key Insight 8: In the smart DIY eco-system Developer and Downloader agendas are aligned: utilitarian recipe design in IFTTT meets service innovation needs in the home

According to Funk et al. (2017) those wishing to customise their homes for smart capability are most likely to do so using trigger-action programming via websites such as IFTTT. And although this is clearly not the only option available, this offers those with relatively limited programming skills the ability to practice smart-focused craft consumption both for personal and for wider advantage (Ovadia 2014). The results of our coding exercise mirror those of Brich et al. (2017) who conducted a longitudinal study of 12 households in search of insights into end-user programming needs in home automation. They identified respondent preferences for

"…automation that would spare them tedious everyday tasks like turning things on or off…" and by contrast note they expressed, "…comparatively little interest in automating entertainment and access control." (p. 20). Developers may initiate individually focused recipes of all types for personal need but can then choose to either make these private or share them as opportunities for further open innovation. And although there were slightly more Hedonic recipes in the Developer data subset they perhaps choose primarily to make public those recipes most likely to be "useful" and that allow other DIY smart-home craft consumers (most likely Downloaders) to improve domestic experience by banishing the mundane to a state of unconscious enactment.

We note Haraty, McGrenere, and Bunt's (2017) research into Developer communities and how results signpost wider community needs. They found Developers were reluctant to upload overtly personal or complex customisations, and by contrast wished to share those likely to prove more generally useful. In much the same way that academics look to produce outputs that expand their reputation and/or citation count, Developers were conscious that popular customisations represented a route to both community- and self-approbation. The objectives of Developers and Downloaders, therefore, appear to be aligned. We note, though, these may also provide opportunities for Downloaders to co-create – if they should wish it - value that has a different (e.g. hedonic or transformative) core. In co-creating essentially utilitarian output in IFTTT Developers may be offering Downloaders the freedom to co-create whatever value they wish in the home. For example, the "action" on some recipes is to push a Wemo-switch. And whilst the most-likely-case scenario here is to turn on a table lamp, air conditioner or instigate similarly practical purpose, these could just as easily initiate music or a medical support system. The most innovative IFTTT recipes, therefore, could be those that – through their truly utilitarian nature (potential to provide the greatest happiness to the greatest number) - maximise the opportunities for others to co-create value of their own choosing. Those recipes with most downloads, therefore, could either be responding to a prescribed Utilitarian/Supportive need with mass appeal, or alternatively offering non-prescribed utility with wider open innovation potential.

Discussion

Implications for Theory

We respond to questions posed by Helkkula, Kowalkowski, and Tronvoll (2018) and Jaakkola and Alexander (2014) regarding the ways customers are involved in resource integration. They suggest resource integration cannot be understood simply as the output of a product and user dyad, and our results evidence this. In IFTTT a broader constellation of people, products and ideas act via the Internet of Things to trigger service innovation that blurs the distinction between operand resources, operant resources and indeed questions such a simple binary. IFTTT facilitates a range of functionalities that characterise contemporary smart consumption in the home. As an engagement platform (Ramaswamy 2008) it enables consumers to integrate their ideas with those of organisations and other users for engagement and shared value (Hollebeek and Andreasson 2018). As a platform for open innovation (Chesbrough 2003) it encourages common purpose creativity outside institutional boundaries. Its users exhibit characteristics of prosumers (Toffler 1980), co-producers (Etgar 2008), brand communities (Muniz and Schau 2005), participatory web cultures (Beer and Burrows 2010) and, as we argue earlier in this paper, they are typical of Campbell's (2005) craft consumer.

RQ1 and RQ2 results illustrate how Developers use IFTTT to co-create value for themselves but also to create opportunities for other consumers whose focus is customising the home. In this respect IFTTT is typical of Helkkula, Kowalkowski, and Tronvoll's (2018) process-based service innovation archetype. Insights 1-4 illustrate the broad range of recipes crafted by consumers, but insights 5-8 also demonstrate that utilitarian value-seeking is important as inspiration for new, and frustration with old, forms of service design. In Campbell's (2005) account craft consumption entails transformation of commodities (in our case SDPs) into personalised or humanised "objects" (for us, heterogeneous SDP combinations) that create new service forms. This "ensemble activity" frees people to consume in expressive new ways and to "acquire control over … consumption experiences" (Addis and Holbrook 2001, p.52). Whilst our

evidence suggests this is undoubtedly the case – IFTTT recipes reflect individual and/or domestic proclivities, providing opportunities for "doing" enhanced smartness (Gram-Hanssen and Darby 2018) – we also note that firms are beginning to "piggy-back" these consumers, planting their own recipes, infiltrating social networks and nudging users towards preferred smart configurations. IFTTT users accelerate proliferation of Internet of Things infrastructure, aiding its mass reach and paradoxically also submitting themselves to manipulation. It is perhaps the case, therefore, that just as post-industrial fragmentation bought with it the inevitability of a consumption/production customer paradigm, digitalised prosumption (Paltrinieri and Esposti 2013) has entangled "hero" and "dupe", again subverting consumption hopes.

Further, although consumers might look on occasion to introduce either novelty (Hedonic value) or wellbeing (Transformational value) into their smart homes - reflecting, perhaps, the prevailing wisdom of the "experience economy" – our evidence suggests the experiences that consumers frequently want are those that minimise effort and are "ordinary" rather than "extraordinary" (Carù and Cova 2003). Shove (e.g. 2003) suggests the key objectives for domestic practice are 'comfort, cleanliness and convenience' with products (smart or otherwise) increasingly deployed "as essential ingredients in the effective accomplishment of everyday life" (Watson and Shove 2008, p.69). Removing annoying tasks from the field of consciousness ("supportive" or "calm" technology, Weiser and Brown 1997) appears the key aim for most.

Practical and Managerial Implications

To our knowledge, the results provide the first large-scale empirical demonstration that popular consumer-crafted combinations of smart domestic products are primarily motivated towards utilitarian value and a preference for automated tasks performed without conscious attention of users. Our Results section highlighted eight key insights emerging from the research and we now outline the practical and managerial implications arising from these findings.

Digitalised craft consumption opens opportunities for the creative mind, but results suggest automation tends to happen for more mundane reasons. IFTTT users opt primarily for utilitarian benefits that are "functional, instrumental, and practical" (Chitturi, Raghunathan, and Mahajan 2008, p. 49). Trigger channels typically initiate the switching on-and-off of essential home-based functions (e.g. turn on heating before arriving home), or to notify message arrivals (e.g. make a light flash to indicate new email). In this respect users are essentially conservative and their "smart" DIY endeavours frequently no more stirring than those conventional home-based DIY activities identified by Watson and Shove (2008) and Wolf and McQuitty (2011).

The findings have clear implications for service design. The SDP network is imbalanced, disassortative, exhibits a long-tailed degree distribution, and shows popular services have high centrality across all product category combinations. The topology therefore illustrates that SDPs should not considered standalone services, but members of broader ensembles deliberately "designed for appropriation" (Dix 2007). Design thus suggests products be conceptualised as part of a service eco-system (e.g. Akaka and Vargo 2015), a market array characterised by multi-directional resource integration and networked service provision. One key managerial insight arising from our findings concerns service innovation and value propositions. Results show how consumer-crafted service forms within domestic environments can point companies to design for new co-creation opportunities. Skålén et al. (2015, p.156) suggested that "service innovation must be conducted and value propositions must be evaluated from the perspective of the customers' value creation, the service that customers receive". In the same vein, Barret et al. (2015) argue that service innovation is perceived primarily as customer driven and believe that contemporary businesses should adopt an active engagement with practices in designing for service as an influential approach to innovation. The findings from digitalized craft consumption reveal how firms can serve their customers more effectively and enhance value-in-use.

Limitations and Future Research

The results provide unprecedented insight into how consumers craft new forms of service from heterogeneous products. However, there are limitations to the study. Our dataset derives from recipes made public by consumers on IFTTT. Though IFTTT is the preeminent service of its kind it is nonetheless a single case and results should be compared across other platforms also (see Desolda, Ardito, and Matera 2017). Another limitation is that recipe creation is a simple process not requiring user programming knowledge. Thus, a smaller sample of more technically competent users may possibly pair channels without resort to an intermediary service provider, thus circumventing IFTTT. This specialised group of users is not captured by the IFTTT dataset, so the prevalence of this practice is unknown. These limitations require further scrutiny to address the demographic, psychographic, and behavioral profiles of people who connect SDPs.

The results of both parts of the study can help guide future research. A temporal evaluation of the smart domestic product network topology could provide insight into whether further technological convergence might affect network disassortativity; i.e. devices with multiple features may monopolise connections within the home. It would be interesting to monitor the relative number of health-care related SDPs in the database on an ongoing basis. The lack of Transformative/Persuasive recipes is likely due to the relative absence of products available that are explicitly linked to healthcare at home and this will likely increase in future.

The lack of health-care products on the market with public APIs integrated into IFTTT is perhaps a consequence of privacy issues that arise when linking products into public networks, as shown in previous technical research (Fernandes et al. 2017; Surbatovich et al. 2017). Further insights could be gained by surveying individuals who engage in craft consumption. While speculation abounds regarding consumers' different styles to craft value, primary data collection would help shed light on this. On a related note, another interesting research direction would be to use longitudinal data to study how IFTTT and its adherents evolve. Our study inherits some of the limitations of cross-sectional research methods (Rindfleisch et al. 2008), and longitudinal study would contribute to enhanced understanding of developing behavior.

As discussed in the methodology section the coding of some recipes was resolved via discussion. Issues arose because in some cases it proved difficult to choose between persuasive and advisory categories on the HCI side of the SDP typology and between transformative and utilitarian on the value side. In both instances the most common issue was lack of clarity on user intent. For the bulk of recipes this was not problematic, and the observed preponderance of utilitarian/supportive functionality within the recipe corpus is not in question; we believe our 'most-likely' protocol to be effective. However, when researching beyond the database (within and amongst users of smart domestic functionality) a more nuanced representation of user value could be determined by introducing a "preventive" category into Woodall, Rosborough, and Harvey's (2018) typology "y" axis. This would help capture instances where users were neither seeking enhanced well-being (Transformative value) nor just Utilitarian value, but instead wished to prevent deterioration of existing well-being. This could apply, for example, to maintaining versus losing weight, or to notifications concerning deteriorating versus dangerous weather.

For persuasive versus advisory categories collaborative resolution proved easier. The coding procedure showed that IFTTT users were unlikely to exert unwelcome pressure on themselves. However, given the increasing prevalence of firm-generated content on IFTTT, and the invasion of "smart interactive services" (Wünderlich et al. 2013) into the home, this might not always be the case. We thus hypothesise a further HCI category for consideration in the broader context of SDP service design. We call this *perfidious* rather than "persuasive" HCI, characterised as advice but with persuasive intent. Thus, a user-initiated alert may merely imply time to wake up, or time to watch TV; but if firm-initiated could imply time to "watch that ad", or to "buy more stuff". We suggest, therefore, that in research contexts where intent can be clearly defined, a four-by-four rather than three-by-three typology would provide a more nuanced characterisation of smart functionality and user motivation. If the best computer truly is a "quiet, invisible servant", we should nevertheless scrutinize who they are said to serve.

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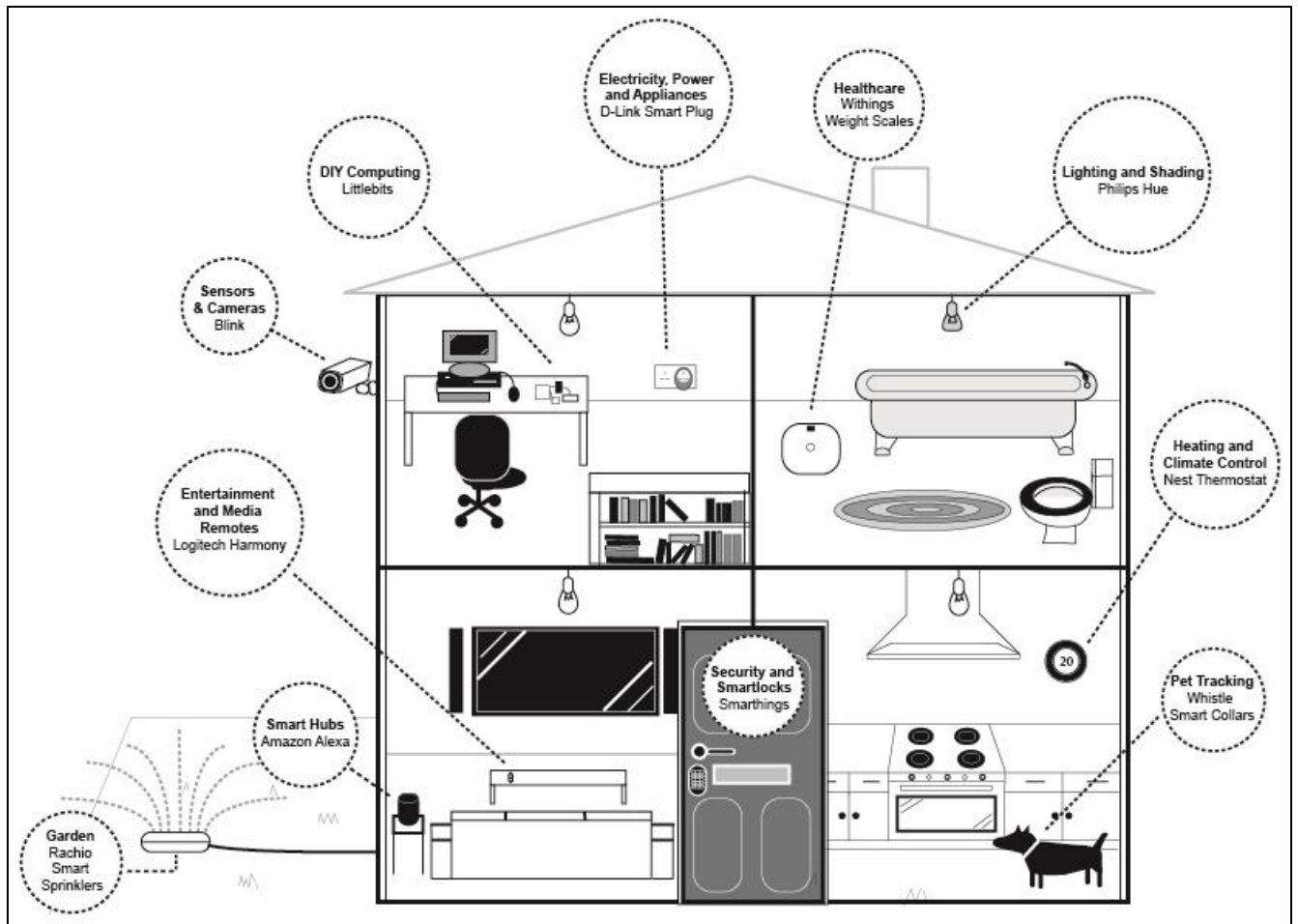
Figure 1: An overview of smart domestic product classes with examples

INTENTION / VALUE-TYPE	Supportive	Advisory	Persuasive
	Calm technology (Weiser and Brown, 1997): designed to sustain existing behavior	Technology designed to help customers determine their own behavior	Captalogical technology (Fogg 1998): designed to change or create new behavior
Transformative Focus on personal or social wellbeing	**TS**	**TA**	**TP**
Utilitarian Focus on daily/routine domestic endeavor	**US**	**UA**	**UP**
Hedonic Focus on the provision of hedonic benefits	**HS**	**HA**	**HP**

Figure 2. A matrix of smart service innovation opportunities

Recipe	Trigger	Trigger Channel (API)	IFT.........TT	Action Channel (API)	Action
Turn My Phillips Hue® Lights On When My iSmartAlarm® is Triggered	**Contact Sensor**	**iSmart® Alarm**	IFT........TT	**Philips Hue®**	**Turn on lights**
	Description: The Trigger fires when an iSmartAlarm Contact Sensor is opened if the system is armed.			**Description:** This Action will turn on your hue lights.	
Set Ecobee® to 'home' when any family member arrives home	**First family member arrives home**	**Life360® GPS Tracker**	IFT.........TT	**Ecobee® Thermost**	**Set comfort profile until next transition**
	Description: This Trigger fires every time the first family member arrives at a place you specify.			**Description:** This Action will set the thermostat into a hold using the settings from the specified comfort profile.	
If I leave my house then close my garage door	**You exit an area**	**iOS® Location**	IFT.........TT	**Garageio®**	**Close garage door**
	Description: This Trigger fires every time you exit an area you specify.			**Description:** This Action will close the garage door you specify. If already closed, the door will remain closed.	

Figure 3: Illustrative examples showing structure of IFTTT recipes

HCI Judgement

Does the recipe require a person to consciously respond or react to, the IFTTT output?

The goal is achieved without the person doing anything

No

Yes

Does the IFTTT output explicitly try to change the behaviour of a person to achieve a preconceived goal?

Yes

No

Supportive
No response required from anyone

Persuasive
Person must respond in the way indicated

Advisory
There are multiple ways to respond – person has options

Re-check

Doesn't seem to fit either of these?

Value Judgement

Is the recipe obviously created for pleasure, excitement or joy?

Yes

No

Is the recipe likely to substantively improve physical or mental health?

Yes

No

Hedonic
Creates joy, pleasure, excitement

Transformative
Improves health (though doesn't minimise harm)

Utilitarian
Maintains *status quo* or performs routine task

Re-check

Doesn't seem to fit either of these?

Figure 4: Decision Tree developed by the authors for HCI & Value judgement

RQ	Method	Measurement			Sample	
		Focus	**To determine…**	**Level**	**Unit of analysis**	**N**
1	**Exploratory Network Analysis**	Network structure	…which products have been combined in recipes, and what structures they subsequently form as part of the aggregate SDP network	Macro	SDPs and external services	253 Channels
		Degree distribution (in and out)	…how many other services have each SDP been connected to through recipes	Micro	SDPs and external services	13905 Recipes
		Weighted Degree Distribution (in and out)	…how many recipe installations is each SDP involved in	Micro	SDPs and external services	1,144,094 installations of recipes
		Centrality	… the relative positional 'importance' of SDPs facilitating connections between other devices.	Micro	SDPs and external services	13905 Recipes
		Assortativity	…whether SDPs that are similar form connections with each other	Macro	Aggregated SDP network	13905 Recipes
		Classes of devices within network	…how broader classes of SDPs interact with other services inside and outside of the home	Meso	Device Classes	11 SDP and 6 External classes
2	**Interpretive Recipe Coding**	Recipe character: most popular downloads	…how IFTTT consumers combine HCI styles and value forms to craft new service innovation opportunities	Meso	Recipe Descriptions	1170 (1,028,884 Downloads)
		Recipe character: all other downloads	…how popular recipes differ in functional terms from recipes with fewer downloads	Meso	Recipe Descriptions	620 (115,210 Downloads)

Table 1: An overview of the selected research methods, measurements, and samples deployed for each research question
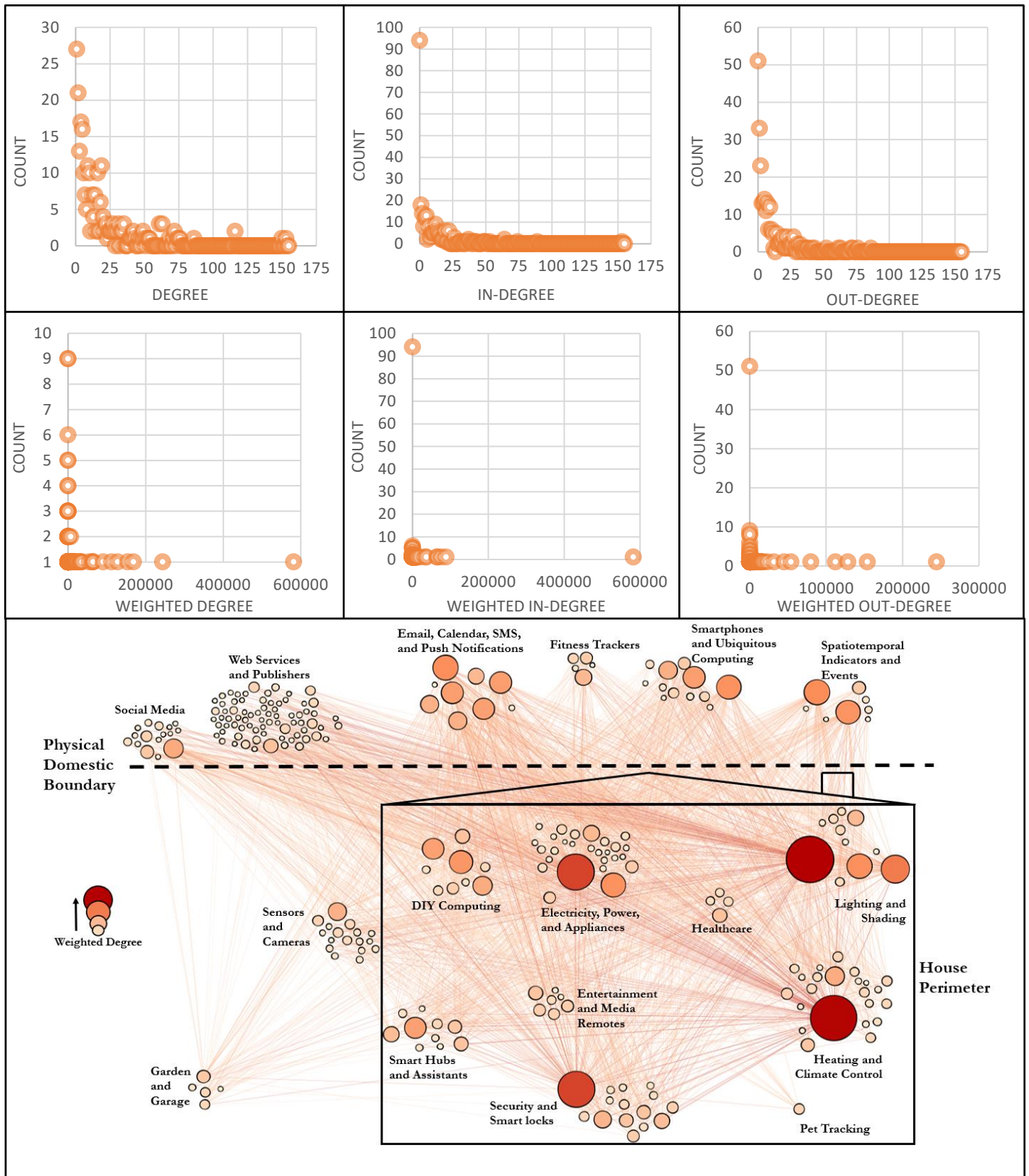
Figure 5: (a) Top row: SDP Network Degree Distributions; (b) Middle row: Weighted Degree Distributions; (c) Bottom row: Directed network showing connections between smart domestic products with nodes scaled according to weighted degree (total sum of recipe installations)

Topological Characteristics of the SDP Network

Channels (Nodes)	253
Recipes (Edges – Unique Recipes Implemented by Users)	13905
Total Sum Weighted Degree (Number of recipes implemented)	1,144,094
Average weighted degree (average no. of implementations per recipe)	82.28 (SD 675.99)
Average degree (average no. of connections between unique channels)	8.775
Self-Loops	403
Number of unique channels with reciprocal trigger/action relations	66
Total number of reciprocal relations between trigger/action channels	148
Connected Components	1
Maximum Geodesic Distance (Diameter)	5
Average Geodesic Distance	2.246
Graph Density	0.034

Assortativity Measures	**Correlation Coefficient**
Degree Assortativity (Undirected)	-0.324
Input-Input Degree Assortativity (Directed)	-0.132
Input-Output Degree Assortativity (Directed)	-0.001
Output-Input Degree Assortativity (Directed)	-0.319
Output-Output Degree Assortativity (Directed)	-0.116

Interaction Types	**Recipe Count**
Internal/Internal (SDP triggers another SDP within the home)	3519 (25.31%)
External/Internal (Channel outside the home triggers SDP)	8351 (60.05%)
Internal/External (SDP triggers channel outside the home)	2035 (14.64%)

Table 2: Topological Characteristics of the Smart Domestic Product Network, Assortativity Measures, and Interaction types for SDP channels

	Trigger Channel Degree (Weighted Out-degree)		Action Channel Degree (Weighted In-degree)		Combined Channel Degree (In + Out Weighted Degree)		Betweenness Centrality		PageRank Centrality	
	Channel	Instances	Channel	Instances	Channel	Instances	Channel	Score	Channel	Score
1	Weather	244400	Philips Hue	582137	Philips Hue	582137	Philips Hue	18989.0	Philips Hue	11.0
2	Amazon Alexa	154034	Nest Thermostat	88692	Weather	244400	Nest Thermostat	9268.8	Nest Thermostat	7.6
3	Date & Time	128417	WeMo Switch	75634	Nest Thermostat	168851	WeMo Switch	4242.5	WeMo Switch	5.7
4	iOS Location	112281	IF Notifications	65207	Amazon Alexa	154034	SmartThings	3404.9	SmartThings	5.1
5	Nest Thermostat	80159	LIFX	64369	Date & Time	128417	Weather	2905.9	LIFX	4.2
6	SMS	53869	Harmony	36568	iOS Location	112281	littleBits	2859.9	Weather	4.2
7	Email	44769	Google Drive	33300	WeMo Switch	90742	LIFX	2358.5	WeMo Light Switch	3.9
8	ESPN	31995	WeMo Light Switch	19792	IF Notifications	65207	Date & Time	1930.8	iOS Location	3.8
9	Gmail	23437	SmartThings	11970	LIFX	64369	iOS Location	1782.4	Date & Time	3.8
10	Facebook	18728	Email	10393	SMS	62816	Particle	1551.6	littleBits	3.7
11	Nest Protect	15592	Ecobee	10369	Email	55162	WeMo Light Switch	1530.3	Android Location	3.4
12	WeMo Switch	15108	WeMo Lighting	10368	Harmony	36568	ORBneXt	1461.9	WeMo Insight Switch	3.3
13	Android Location	14805	Wink: Shortcuts	10033	Google Drive	33300	Android Location	1457.6	Amazon Alexa	3.3
14	Android Wear	14047	SMS	8947	ESPN	31995	Amazon Alexa	1392.9	SMS	3.1
15	Ecobee	11854	WeMo Insight Switch	8843	WeMo Light Switch	30576	Blink	1335.3	Blink	3.0
16	WeMo Light Switch	10784	Blink	7708	Gmail	26292	Comcast Labs	1168.8	Particle	3.0
17	SmartThings	10050	Manything	7605	Ecobee	22223	SMS	1111.2	Google Calendar	2.8
18	Android SMS	9405	Honeywell Total Connect	6857	SmartThings	22020	Email	945.1	Email	2.8
19	Space	8462	Comcast Labs	6761	Facebook	18834	Google Calendar	920.0	Gmail	2.7
20	UP by Jawbone	7119	Wink: Nimbus	6182	Android Wear	15644	WeMo Insight Switch	876.7	IF Notifications	2.6
21	Netatmo Weather Station	6880	iSmartAlarm	6014	Nest Protect	15592	Gmail	843.0	Comcast Labs	2.5
22	iOS Reminders	6322	Phone Call	5041	Android Location	14805	Twitter	809.2	Android Device	2.5
23	littleBits	5745	Google Calendar	4323	WeMo Insight Switch	13136	Manything	807.8	Manything	2.5
24	Android Device	5599	littleBits	4006	Manything	12460	Wink: Nimbus	749.4	Twitter	2.4
25	IFTTT	5283	Scout Alarm	3063	WeMo Lighting	11027	Android Device	687.0	Ecobee	2.2

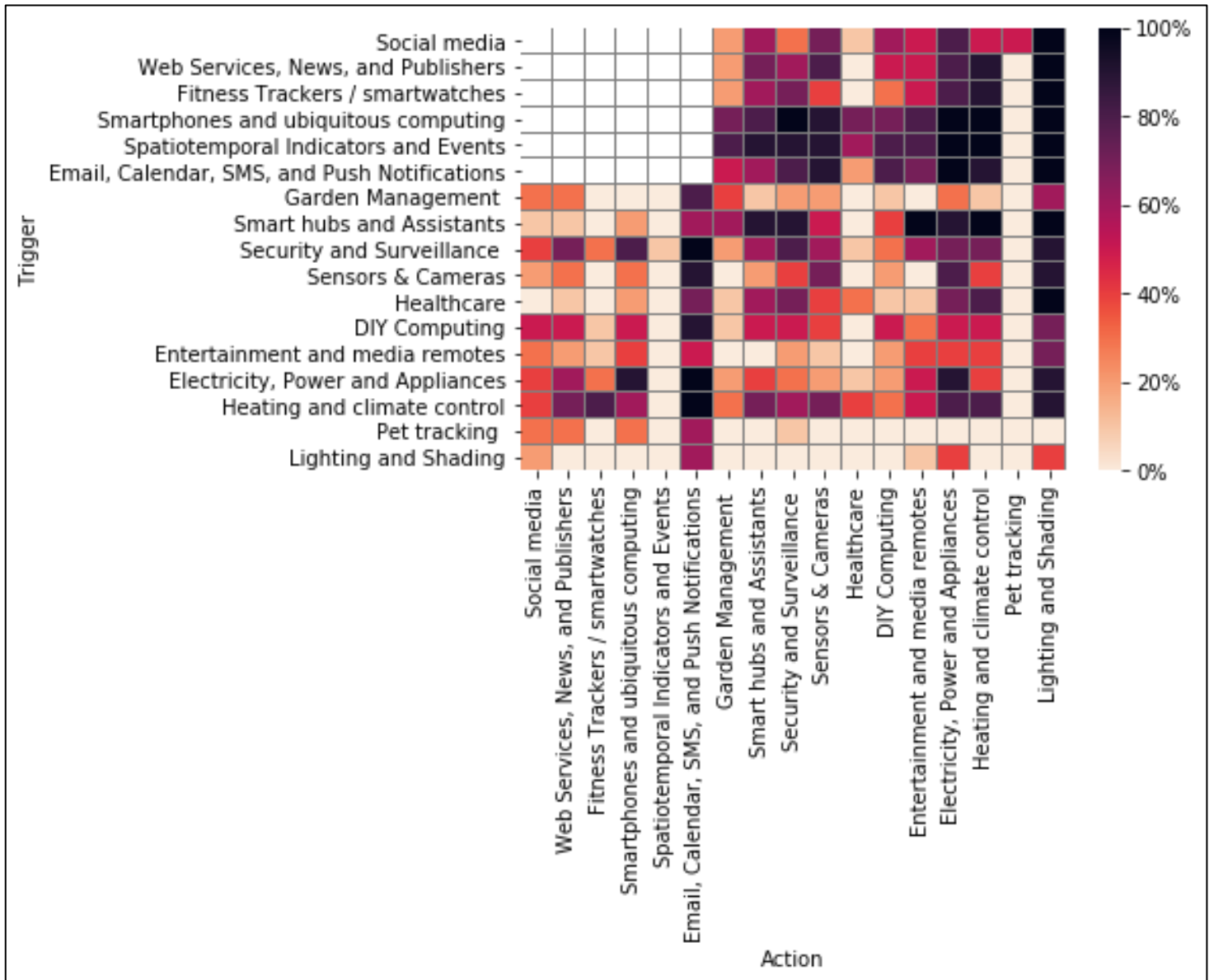Table 3: Ranked nodes according to degree and centrality statistics

Figure 6: Heatmap showing normalized Trigger/Action class relations.
Note: External/external relations are excluded from the SDP subgraph and are therefore shown as void.

HCI/Value combination	'Downloader' sample (Recipes with 100+ Downloads)				Developer sample (1 Download recipes)	
	Recipes in sample		Downloads in sample		Recipes/downloads in sample	
	Frequency	Proportion	Frequency	Proportion	Frequency	Proportion
Transformative | Supportive	19	1.6%	14,079	1.4%	0	-
Transformative | Advisory	5	0.4%	1,001	0.1%	1	0.8%
Transformative | Persuasive	0	-	-	-	1	0.8%
Utilitarian | Supportive	778	66.5%	695,933	67.6%	80	66.7%
Utilitarian | Advisory	274	23.4%	215,278	20.9%	18	15%
Utilitarian | Persuasive	15	1.3%	12,198	1.2%	2	1.7%
Hedonic | Supportive	36	**3.1%**	48,414	4.7%	11	**9.2%**
Hedonic | Advisory	43	3.7%	42,035	4.1%	7	5.8%
Hedonic | Persuasive	0	-	-	-	0	-
Totals	1170	100%	1,028,938	100%	120	100%

Table 4: Aggregate descriptive statistics for recipes involving different HCI/Value combinations for both 100+ downloaded recipes and once downloaded recipes. Note: Downloader category has a one to many relationship between number of recipes and downloads, whereas the Developer category always has one download per recipe.

INTENTION VALUE-TYPE	Supportive	Advisory	Persuasive
Transformative	*"Simulate natural sunlight on wake up"* **TC** = UP by Jawbone **T** = New sleep logged **AC** = Philips Hue® **A** = Change Color	*"Connect Fitbit® to Xfinity® – step goal"* **TC** = Fitbit® **T** = Daily step goal **AC** = Comcast Labs **A** = Send notification	*"Walk or BURN!!!"* **TC** = Fitbit® **T** = Daily step goal **AC** = Nest® Thermostat **A** = Set temperature
Utilitarian	*"Log my dog's daily activity to a Google® spreadsheet"* **TC** = Whistle Go® **T** = Daily Activity Summary **AC** = Google® Sheets **A** = Add row to spreadsheet	*"If there's rain tomorrow then update your Nimbus dial"* **TC** = Weather **T** = Tomorrow's forecast calls for **AC** = Wink: Nimbus® **A** = Set dial label	*"Netatmo® CO² above 2000ppm, change Hue color to Red* **TC** = Netatmo® Weather Station **T** = Carbon dioxide rises above **AC** = Philips Hue® **A** = Turn on lights
Hedonic	*"Turn all my lights orange for Halloween!"* **TC** = Email **T** = Send IFTTT an email **AC** = Phillips Hue® **A** = Turn on Color Loop	*"If ESPN has breaking news for my home team, play my team's fight song"* **TC** = ESPN **T** = Breaking News for Team **AC** = Littlebits® **A** = Activate Output	N/A

Figure 7: Example recipes – smart service innovation by IFTTT craft consumers