Rapid evidence assessment on labelling schemes and implications for consumer IoT security

PETRAS IoT Hub

John M Blythe
Shane D Johnson

Dawes Centre for Future Crime at UCL

Table of Contents

INTRODUCTION

In March 2018, the Department for Digital, Culture, Media and Sport (DCMS) released their policy review on *Secure by Design* for consumer "Internet of Things (IoT)" products. As their primary measure, they detail a voluntary code of practice for manufacturers to ship products with features that make them *Secure by Design*. They also proposed exploring the role of a voluntary labelling scheme to communicate important information to consumers that is otherwise invisible to them, or difficult to elicit, such as how data collected by devices is shared and the support period of the product. Alongside this, the British Standards Institution have announced a kitemark for consumer IoT devices that have been certified to comply with the DCMS code of practice [1]. There has also been community-led approaches to a IoT labelling scheme that covers a number of IoT challenges including security [2]. Furthermore, calls for a trust label [3, 4] or a security rating scheme [5, 6] for consumer IoT are not new but what does differ is the type and format of the proposed labelling scheme.

There are three different labelling formats that have been discussed. The first is a descriptive information label that would detail security-related information such a devices' support period. The second is "seal of approval" labels in which a product is certified to a standard. The third format is a graded scheme that allows more nuanced comparisons of security and to encourage consumer/industry behaviour change. However, what is not well understood is what type of label will likely: a) have the biggest impact in pushing manufacturers to ship products with better security and b) influence consumer choice.

To provide greater insight into the relative merits of different types of labelling, this report outlines a rapid evidence assessment[1], conducted as part of the Consumer Security Index project (funded by PETRAS Internet of Things Research Hub and the Dawes Centre for Future Crime at UCL), on existing literature exploring the efficacy of labelling schemes in established areas (food and energy efficiency[2]). We also discuss physical security labelling schemes in consumer settings (such as vehicle and home security) and existing work on privacy labels. The report ends with implications for the development of labelling schemes for cybersecurity in the context of the consumer Internet of Things.

---

[1] Rapid evidence assessments provide a more structured and rigorous search and quality assessment of the evidence than a literature review but are not as exhaustive as a systematic review (see https://www.gov.uk/government/collections/rapid-evidence-assessments).
[2] We primarily focus on food and energy labels as there is an established academic literature base on consumer behaviour and they are presented on the front of a product, whereas CE marks and other certification marks lack this research base.

1. Food labels

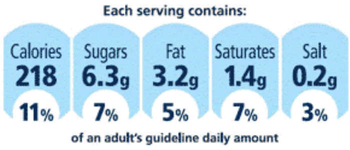

Figure 1. GDA label [7]

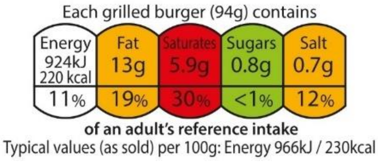

Figure 2. GDA label with traffic light system [8]

Figure 3. Binary health logo [9]

The aim of food labelling is to enable consumers to make healthier food choices and reduce levels of obesity in the general population [10]. The provision of food labels is currently regulated by the European Commission which requires pre-packaged foods to label their nutritional content (energy, fat, sugars etc.) per 100g or per 100ml (EC No 1169/2011). Manufacturers must present this information on the back of the packaging and can opt to include it on the front-of-pack (FOP), which in itself is not mandatory. Those opting for FOP labelling must provide portion values for four key risk areas (sugars, salt, fat and saturates) in line with legislation [11]. In this report, we specifically focus on FOP labelling.

The science of categorizing and communicating food nutritional content on FOP is referred to as “nutrient profiling”. Many different logos and labels exist across countries and these are underpinned by different nutritional profiles, but they share common goals. Kleef and Dagevos (2015) summarize the key objectives of nutritional labels. Firstly, they are intended to aid consumer understanding of the nutritional content of food - that would otherwise be difficult to discern- either within or between types of products. The aims of doing so are to improve decision making at the point of purchase, and as a consequence to enhance consumer health and diet. Secondly, they are intended to act as a lever to encourage food manufacturers to produce healthier products. And, thirdly, they allow government to promote health behaviour change without enforcement and without negatively impacting the food industry’s freedom to produce goods. It has been suggested that FOP labels should include three key features; that they are simple to use, outline nutritional information and are not unduly coercive [13].

Broadly, there are three types of FOP labels that a consumer may be exposed to. The first are Guideline Daily Amount (GDA) schemes (see Figure 1) that display the calories and information relating to the key risk nutrients and their relative percentage contribution to daily adult requirements. The second are traffic light schemes, such as that shown in Figure 2 which is approved by the UK Food Standards Agency. These also communicate information on risk nutrients but overlay that with traffic light colouring to help the consumer interpret the data more easily. The final type are health logos (see Figure 3), which are “seals of approval" (e.g. https://www.choicesprogramme.org/) granted when a product meets particular nutritional requirements and/or standards. Research has found that across the 27 EU member states, 48% of food products displayed some form of label with the three outlined above the most common formats [14]. However, there is variability in the design, colour and format of the schemes. The co-existence of multiple types of labels in the food market frustrates consumers, causing difficulty in comprehension and makes it hard to compare foods that have different FOP labels [15]. To reduce confusion and burden on consumers the UK Department of Health promote a combination of traffic light and GDA FOP [16], although there is still opposition at the EU level to adopt traffic light systems [17].

1.1 EFFECTIVENESS

Amongst other things, the success of any of the food label will be limited by the consumer's attention at the point of purchase. Consumers are often rushed and focus on trading off brand, price, convenience and taste when making product choices [18]. They are more likely to pay attention to food labels when they are shopping for children, trying to lose weight or purchasing a product for the first time [19–21]. There are also individual differences in the interpretation of food labelling which impacts on their effectiveness, including nutritional knowledge and health status [22, 23], as well as a range of socio-demographic factors including education, gender, age and socio-economic status [24, 25].

Nevertheless, a statistical meta-analysis of seven randomized controlled studies exploring the effectiveness of the three types of FOPs labels found that they increase healthy product choice by 18%, indicating that they do empower consumers to choose healthier food [26]. In fact, even the mere presence of a label may be beneficial, a phenomenon known as the "*feature-positive effect*" which suggests that seeing a label is more informative – and likely to influence consumer choice - than not seeing a FOP label at all [27]. However, there is little consensus regarding the most effective FOP labelling approach out of GDA, traffic light systems and health logos [17].

Research on GDA has been mixed with early work indicating that consumers cannot identify the nutrient content [28]. However, more recent work suggests that the label helps consumers to identify healthier products [29]. Despite this, whether consumers can use this information to self-regulate their overall daily diet is unclear [30, 31]. Comparatively, the traffic light system has received greater support with a number of studies demonstrating that it facilitates more healthy food choices [28, 32, 33]. In the recent meta-analysis discussed above, it was found that traffic light schemes were marginally more effective in increasing health food choices compared to other labelling schemes [26]. Research which monitors consumer eye tracking has also demonstrated that they guide consumer attention towards important information [34]. However, they can also cause consumer confusion with one study showing that 40% of participants failed to identify the healthier product when comparing two products with traffic light labels [35].

Health "seal of approval" logos are thought to be more useful in shopping scenarios where consumers are unwilling to dedicate lots of time to reading nutrient information [17] and research has shown that when directly asked what they are prefer, consumers choose them for their simplicity [36]. They have been found to reduce the duration that the consumer has to spend examining packaging as the format is recognizable and acts as a cognitive shortcut [37]. However, research has found that they are rated lower for comprehension and credibility compared to the traffic light scheme [36]. In a study comparing multiple FOP schemes, "Seal of approval" labels have been found to be easier to understand according to consumers, but the results showed no difference in objective understanding [36]. Other research which tested a combination of traffic light and health logos showed that in the absence of traffic light colours, health logos reduce attention to the packaging [37]. The traffic light colours attracts consumers attention, inhibiting the likelihood they will use cognitive short cuts in buying decisions [37]. An issue with health logos is that consumers may not detect that it is absent and understand what this means [12]. Moreover, unless the label is ubiquitous and obligatory on all foods, their absence does not indicate (a lack of) risk.

Furthermore, they do not allow consumers to distinguish between the relative healthiness of different foods, but rather lead them into categorizing food into "good" and "bad" categories [38]. This can be misleading since those that meet a minimum standard cannot be differentiated from those that excel, or those that only marginally fail to meet the criteria. It has been argued that this may lead to dichotomous thinking [12] and research has shown that consumers wrongly assume that a product with a health logo is healthier than one with a traffic light or GDA label [39]. These misinterpretations are not unique to health logos as consumers also overestimate the severity of amber and red colours on traffic light labels [40]. When information is summarised in a health logo, however, valuable health information is lost and misinterpretations are likely to occur [12] and these health "halo effects" are stronger for these types of labels [39]. For example, food labelled as "fitness" snacks causes consumers to eat more than if labelled as a "trail mix" [41].

There are clear benefits to a FOP label in aiding consumer choice, with each format offering its own strengths and limitations. Consumers state a preference for a binary label, however this may lead to poor decision making and research suggests that traffic light systems help people make better judgements and are marginally more effective in driving healthy product choice.

2. Energy Labels

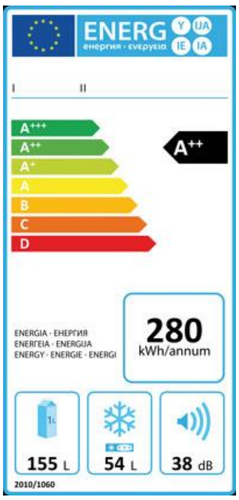

Figure 4. Energy Efficiency label

EU Directive 92/75/EC was introduced in 1995 and was more recently updated as Directive 2010/30/EU. It outlines an energy consumption labelling scheme to be displayed on electronic products when offered for sale or rent. This scheme rates the energy efficiency of a product from A to G, with A being most efficient and G being least efficient. These markers are paired with a colour cue to indicate performance with greener products (e.g. A) indicative of greater performance then red (e.g. F). In 2010, A+, A++ and A+++ grades were introduced to keep up with advances in energy efficiency standards. The energy efficiency is rated according to a specific product category covering a range of products including washing machines, refrigerators and light bulbs. However, its implementation is only mandatory for certain classes of products (e.g. refrigerator, dryer, televisions). Currently, failure by a manufacturer or dealer to comply with the regulation or to intentionally provide misleading information is an offence that can lead to financial sanctions. Compliance with the regulation lies with both the product supplier and the dealer that sells it.

In order to comply with the directive, companies must provide the labels for free to dealers, include a performance table in brochures and associated documents, and make the technical documentation available to the UK Office for Product Safety and Standards if requested, and retain it for five years after the manufacturing of the product has stopped [42].

Between 2009 and 2010, only one-third of EU member states conducted market surveillance activities to monitor compliance with the directive. However, this increased between 2009-2013. Product testing is the most common form of compliance monitoring, but this is expensive. Reliable indices of compliance across EU states are not easy to estimate, as the level of compliance varies by state, product and year. However, in a European Commission study, 5%-40% were found to be for sale without the energy label or with an incorrect implementation [43] and the commission estimate that overall non-compliance is 20%. It is estimated that 10% of the energy savings of the directive are lost due to poor enforcement [44].

Measurement of energy efficiency differs by the appliance. For example, it may be expressed as the energy consumed per typical task (e.g. washing 4kg of cotton at 40°C) or its annual energy consumption. To illustrate, for refrigerators an energy efficiency index is calculated by dividing the fridge’s annual energy consumption by a standard value. This standard value takes into account a range of factors including the type of fridge/freezer (e.g. chest freezer, upright fridge etc), volume, and added features such as a chill compartment. The result is multiplied by 100 to get a percentage, and the rating is assigned based on this value (see below). The relative ranges for the label categories depend upon the type of appliance and the set boundaries change over time. For example, the boundary between the A+ and A classes was 44 up to 1 July 2014 and 42 afterwards.

Refrigerating appliances, as EEI									
A+++	A++	A+	A	B	C	D	E	F	G
<22	<33	<42/44	<55	<75	<95	<110	<125	<150	>150

Figure 5. Label categorisation for refrigerators

2.1 EFFECTIVENESS

The energy label directive and the broader eco-design directive work together to drive greater energy efficiency in the market through a “push” and “pull” effect. The eco-design directive sets out mandatory requirements for energy efficiency and thus “pushes” industry towards more efficient products by banning the least efficient products from the market. The energy label both “pushes” and “pulls” customers towards purchasing more efficient products by ranking them on energy efficiency. Additional voluntary schemes (such as the European ecolabel) further pull customers to the most energy efficient products on the market. The combined impact of this push and pull effect of both mandatory directives and voluntary labels has improved the energy efficiency of a range of products [45]. It is estimated that the results of these labels and standards will contribute to an energy saving of around 175 Mtoe (million tonnes of oils equivalent) by 2020 which is roughly the annual energy consumption of Italy [43]. However, despite its introduction in 1995, the label has demonstrated somewhat limited efficacy over time. This is largely due to poor design and implementation of updated versions of the label in consumer settings, which will be discussed below.

Early research demonstrated that consumers are willing to pay more for energy efficient products as rated by labelling schemes [46, 47] and around half of citizens from ten European countries opt for Energy Labels as a key source of information to support purchasing decision making [48].

Whilst consumers may be more willing to pay for more efficient devices, this does not always translate into better purchasing choices. The presence of the label does lead people to pay more attention to energy-related information [49] and consumers spend longer looking at labelled products compared to unlabelled ones [50], however this does not necessarily lead to more energy efficient product choices [49]. This mismatch between consumers’ intentions to purchase energy efficient products and their actual behaviour is known as the *intention-behaviour gap* [51]. This gap accounts for the fact that consumers may be motivated to purchase energy efficient products but in reality, purchase inefficient ones. This mismatch has contributed to a rise in energy consumption contrary to what was predicted following the introduction of the energy efficiency directives [52].

The intention-behaviour gap has risen in part due to consumers employing heuristics (mental shortcuts) during decision making. When people make decisions, they do not always engage in a rational decision making process in which they take account of all available information. Instead, they rely on heuristics to help make decisions [53] which helps avoids the cognitive demand of processing lots of information. The *affect heuristic* is one mental shortcut we use when making decisions, in which concepts, pictures, attributes and other types of information that are connected to an emotional affect influence our decision making [54]. For example, we have stronger affect for concepts to which we are regularly exposed (such as A-E grades) than towards ambiguous concepts such as technical information to which we are rarely exposed (such as wattage) and these exposed concepts are better at influencing our decision making [54]. The design of the energy label works with what is known about heuristics and human biases in decision making. The use of letters and colour cues on the energy label makes the information salient to a consumer. It is more noticeable and accessible, directing their attention towards energy information [49].

An unintended consequence of the affect heuristic, however, is that people struggle to interpret the additional information that is presented alongside the energy efficiency rating (see Figure 4). This accompanying information is important for consumers to compare the energy consumption of devices. For example, without attending to this information, consumers will not understand how the electricity consumption of laptops and desktop computers differ [55]. This has led to biased search behaviour, as consumers focus on efficiency and not consumption, which is problematic as efficiency is relative to the size of the product and cannot be used to compare products of different sizes [49]. Consequently, consumers may incorrectly interpret information provided on labels and focus too much on energy efficiency and purchase products that are energy efficient but still consume a large amount of energy [49]. This has been referred to as an *energy efficiency fallacy* as people assume that a high energy efficiency rating implies low energy consumption. This is a particularly problematic issue for energy-intensive devices such as freezers [56].

Furthermore, the content of the accompanying information on energy labels is not always well understood. A multi-country survey on the washing machine energy label found that consumers understand the energy efficiency component label but less so, information around other characteristics, such as capacity and noise emissions of washing machines [57]. Other work has shown that pictograms on energy labels such as the drying efficiency on dishwashers are also not understood by consumers [44]. A further challenge is that the accompanying information is device-specific which requires consumers to have knowledge about the importance of this information for each type of device.

A further challenge for consumers is that the variability of products with A+++ to G is dependent on the product. For example, in 2010 all washing machines that were in label category A were prohibited and to drive further market shifts, all future washing machines needed to be in the A+ to A+++ range [58]. However, for televisions the label encompasses A+ to F and for coffee machines, they use the existing scheme of A to G [49]. These distinctions are largely invisible to the consumer and can confuse consumers across product types, especially in cases where appliances less than A+ are not available on the market [43], as is the case for washing machines [59]. Customers can therefore be misled into thinking that they are choosing the most energy efficient product on the market when they are not.

The introduction of A+ to A+++ has also undermined the efficacy of the label as consumers do not perceive the difference between A+ to A+++ as the same as A to G [60]. As such, they are less willing to pay for the higher classes of efficiency [61, 62]. Consumers perceive that A is already good and therefore will not make additional investments for what they consider as marginal improvements. Another issue is that the implementation of the new scheme has caused some confusing situations. For example, at one point there were up to three different versions of the energy label on the market for televisions [59].

Consumers want a less time consuming, clear and simplistic alternative [63] to the current implementation of the energy label. A lack of adequate consumer testing of the A+ scheme has led to the effectiveness of the energy label being undermined [60] and for biased behaviour to arise as consumers conflate energy efficiency and energy consumption [56]. Additionally, insufficient implementation (such as not being placed on products in shops) and weak support by NGOs and other stakeholders has inflated the energy efficiency gap [64]. Recognising the limitations of the current implementation of the label, the EU are to update the label to remove the A+ grading and to create a product database to enable market surveillance and to assess whether the efficiency calculations correspond to those declared by manufacturers [65].

3. Physical Security Schemes and Privacy Labels

In the context of crime and security in the consumer domain, there is much less research, but two examples are worth discussing. The first is the Home Office's car theft index. This was first published in 1992 in response to the fact that vehicle crime was soaring at that time, and the manufacturing industry seemed unwilling to improve the physical security of vehicles. This was despite substantial lobbying by the Home Office and consumer groups such as Which? The index was derived by simply ranking makes and models of vehicles according to the rate (number stolen divided by the number on the road) with which they were stolen in the UK, and acted as a market lever to encourage the manufacturing industry to increase levels of security or risk reputational damage [66].

A second example is the Secured by Design scheme[3], which is currently applied to building materials and products (e.g. doors, locks and windows) that are built to a specified standard that is resistant to attack, as well car parks and commercial premises. This is currently a binary accreditation scheme that is intended to encourage housing developers (and others) to design out crime at the planning and building stage of development. Research suggests crime is less likely in and around housing that is constructed to SBD standards [67]. As far as we are aware, the impact of the scheme on consumer choice is unknown, but industry membership of the scheme – an alternate metric of the influence of the scheme - is substantial, with over 400 companies building products to SBD standards.[4]

Whilst there is currently no certification label for cybersecurity of consumer goods that has been tested with consumers, a body of academic work has explored a privacy "nutrition" label on websites that summarises privacy policy content covering the way organisations collect, use and share a consumers personal information. Privacy policies are known to be an unusable mechanism as reading them is time consuming and challenging for consumers [68, 69]. As such, many users elect not to read them despite having concerns about their privacy – a phenomenon known as the "privacy paradox" [70]. The label sought to reduce the burden on consumers by visually presenting the information in a more digestible way and to ease the

---

[3] http://www.securedbydesign.com
[4] See http://www.securedbydesign.com/members/

comprehension of privacy policies. They found that the label enabled participants to find information more quickly and accurately than standard privacy policies [68]. These studies demonstrate that communicating privacy-related information through a label is a potentially more usable mechanism for consumers.

4. Implications for cybersecurity of consumer Internet of Things

4.1 Why do we need a labelling scheme for consumer IoT?

Firstly, in the absence of a regulatory approach, a market failure will arise that limits consumer choice due to *'information asymmetries'* in transactions between manufacturers, retailers and consumers. This will occur because consumers and retailers as economic agents do not have information about the benefits afforded by more secure consumer IoT devices. Specifically, if manufacturers do not provide correct and accessible information (for example, on a label) to inform consumers and retailers about the level of security their devices offer, and if it is costly to buy products or assess (in terms of cognitive effort or time taken) their security then consumers may not purchase more secure devices and retailers may not stock them. These information asymmetries need to be addressed before they contribute to further market failures and IoT security breaches.

At present, consumers cannot distinguish between devices that offer good and bad security when making purchasing decisions. In fact, currently they have to research the security of the product themselves before deciding [71], which involves evaluating technical information including its encryption standards, length of support, whether it ships with a default password etc. One approach to encourage consumer behaviour would be to employ an awareness and behaviour change intervention intended to motivate consumers to routinely assess the security of IoT devices they are considering purchasing. However, if implemented alone, such an intervention would almost certainly fail for at least three reasons. First, manufacturers do not systematically communicate information about the security features devices possess that would need to be evaluated to assess their level of security. Second, the average consumer will not (and the burden should not fall to them to) have the expertise that would be required to assess this information if it were communicated. And, third, research indicates that consumers act in ways to avoid cognitively demanding tasks [53]. As such, the behaviour does not meet the criteria for behaviour change interventions as it is not easy to do and is unlikely to be implemented by consumers [72]. A label that consumers can attend to and that would meaningfully inform their decision making is a more achievable interventions that could impact upon consumer choice. This is akin to the issues of privacy policies and as discussed earlier, a labelling scheme offers a more usable alternative and has been shown to be effective in aiding consumer decision making around privacy.

Finally, a labelling scheme would also likely act as a lever to encourage companies to compete on security as a form of market differentiation. It would also hold them to account to some extent by encouraging attention to be explicitly paid to the security of devices and for this to be done against clear criteria and best practice. In turn, this would potentially allow market surveillance authorities to assess compliance to IoT security in a more consistent and accessible manner.

4.2 Recommendations

The current market self-regulatory approach to IoT security is unlikely to be sufficient to drive changes in IoT security and may contribute further to *'information asymmetries"* in consumer IoT. In the absence of regulation, a labelling scheme may be the best and most useful route to addressing these asymmetries.

Any labelling scheme is going to be more effective in influencing consumer decision-making than the current state of play. However, the choice of the most appropriate format of the labelling scheme needs to be evidence based and derived from research on consumer behaviour and subsequent consumer testing. Based on the literature regarding the food and energy label and other behavioural science research, we make the following observations to help inform the choice and format of a consumer IoT labelling scheme:

- **Graded scheme**: A coloured graded scheme would allow consumers to compare the security of different devices. The use of colours and letters is a noticeable and accessible format and makes the information salient to consumers, directs their attention towards important information and is easy to interpret [49]. This format has demonstrated efficacy in the energy and food labels and is more effective than binary or informational labels [26]. However, the implementation of a graded scheme would likely need to be mandatory to be effective, as is the case for the energy label. Companies may be unwilling to display a label that indicates that a product has poor security if the scheme were voluntary.
- **Binary "seal of approval"**: Consumers prefer simple labels [36], [63] but they are less effective in guiding attention and informing consumer choice [37]. They can reduce cognitive burden but can also lead to dichotomous thinking [12]. For example, consumers may consider a device without a label to be "insecure". This situation is likely to arise if the label scheme is not mandatory. Furthermore, logos are more vulnerable to "halo effects" [39], which in this context, may mean that consumers are lead into a false sense of security when buying a device with a seal of approval or assume that it requires no intervention from them to keep it secure.
- **Information-only label**: Descriptive labels that communicate important information to consumers (such as the support period offered with a device) may provide proximate indicators of a device's security posture. The amount of information needs to be kept relatively simple and not too excessive as consumers have limited cognitive resources to expend during purchasing. Pictograms may be more successful than written information as they are more accessible to different demographics [73]. However, research on the energy label has demonstrated that the accompanying information is often misunderstood [57] and consumers often give more weight to certain types of information than others (e.g. energy efficiency over consumption) and this can lead to biased search behaviour [49]. An information label may be an adequate way to communicate the most important information to consumers

but must undergo significant user testing to avoid the same implementation challenges faced with the energy label. Furthermore, this type of label may be most suitable for voluntary uptake.

A major challenge in the Internet of Things is scalability. It is estimated that there will be approx. 20 billion internet connected things by 2020 [74] and consumers, on average, will own 15 connected products up from 10 in 2017 [75]. This is challenging for any scheme that requires certification and significant pen-testing as it is costly and may not scale in a world of 20 billion connected things. A form of self-certification approach may be most scalable, and would be similar to that adopted by the food and energy labels, in which companies self-certify and provide evidence to a governing body such as the Office for Product Safety and Standards.

The consumer IoT area is rapidly evolving and so is the number of IoT labelling proposals. There is a clear interest for a labelling scheme but variability and co-existence of multiple types of labels in the market will confuse and frustrate consumers as is the case for the many food label implementations. DCMS are best placed to co-ordinate activity in this space and to identify the most suitable labelling format that is co-designed with industry, academia and consumers.

A labelling scheme for consumer IoT has the potential to aid consumer decision making and to also incentivise manufacturers to ship products that are Secure by Design. This report has outlined the strengths and weaknesses of different labelling designs on consumer behaviour based on evidence from other sectors. Further consumer testing, informed by these findings, is required to explore the potential utility of different labelling formats on consumer behaviour in the context of IoT security to identify the most optimal labelling format.

References

1. British Standards Institution. BSI launches Kitemark for Internet of Things devices. 2018. https://www.bsigroup.com/en-GB/about-bsi/media-centre/press-releases/2018/may/bsi-launches-kitemark-for-internet-of-things-devices/.

2. IoTMark. Making good design actionnable. 2018. https://iotmark.wordpress.com/.

3. Microsoft. Cybersecurity policy for the Internet of Things. 2017.

4. Infineon et al. Common position on cybersecurity (Infineon - NXP - STMicroelectronics - ENISA). 2016.

5. The Guardian. Smart fridges and TVs should carry security rating, police chief says. 2017. https://www.theguardian.com/technology/2017/jul/24/smart-tvs-fridges-should-carry-security-rating-police-chief-says.

6. Jamieson A. IoT Security - It's in the Stars! 2016. https://www.slideshare.net/AndrewRJamieson/iot-security-its-in-the-stars-169-v201605241355.

7. Food and Drink Federation. GDA Label. 2018. http://www.foodlabel.org.uk/label/gda_values.aspx.

8. Bupa. Food labelling. 2018. https://www.bupa.co.uk/health-information/nutrition-diet/food-labelling.

9. The Choices Programme. The Choices Programme. 2018. https://www.choicesprogramme.org/.

10. Draper AK, Adamson AJ, Clegg S, Malam S, Rigg M, Duncan S. Front-of-pack nutrition labelling: Are multiple formats a problem for consumers? Eur J Public Health. 2013;23:517–21. doi:10.1093/eurpub/ckr144.

11. European Commission [EC]. Commission Regulation (EU) No 1169/2011 on the provision of food information to consumers. Official Journal of the European Unio; 2011.

12. Kleef E Van, Dagevos H. The Growing Role of Front-of-Pack Nutrition Profile Labeling: A Consumer Perspective on Key Issues and Controversies. Crit Rev Food Sci Nutr. 2015;55:291–303.

13. Grunert KG, Wills JM. A review of European research on consumer response to nutrition information on food labels. J Public Health (Bangkok). 2007;15:385–99. doi:10.1007/s10389-007-0101-9.

14. Storcksdieck Genannt Bonsmann S, Celemín LF, Larrãaga A, Egger S, Wills JM, Hodgkins C, et al. Penetration of nutrition information on food labels across the EU-27 plus Turkey. Eur J Clin Nutr. 2010;64:1379–85. doi:10.1038/ejcn.2010.179.

15. Malam S, Clegg S, Kirwan S, McGinigal S. Comprehension and use of UK nutrition signpost labelling schemes. Food Standards Agency. 2009; May:1–150. doi:10.1007/s10389-007-0101-9.

16. FSA. Guide to Creating a Front of Pack (FoP) Nutrition Label for Pre-packed

Products Sold through Retail Outlets. Food Stand Agency. 2013; June:27. www.dh.gsi.gov.uk.

17. Hodgkins CE. Communicating healthier food choice – Food composition data , front-of-pack nutrition labelling and health claims. (Doctoral dissertation, University of Surrey (United Kingdom)).; 2016.

18. Szanyi JM. Brain food: Bringing psychological insights to bear on modern nutrition labeling efforts. Food and Drug Law Journal. 2010;65. http://heinonline.org/hol-cgi-bin/get_pdf.cgi?handle=hein.journals/foodlj65&section=9. Accessed 24 May 2018.

19. Schor D, Maniscalco S, Tuttle MM, Alligood S, Kapsak WR. Nutrition facts you can't miss: The evolution of front-of-pack labeling: Providing consumers with tools to help select foods and beverages to encourage more healthful diets. Nutr Today. 2010;45:22–32. doi:10.1097/NT.0b013e3181cb4561.

20. Vyth EL, Steenhuis IHM, Vlot JA, Wulp A, Hogenes MG, Looije DH, et al. Actual use of a front-of-pack nutrition logo in the supermarket: Consumers motives in food choice. Public Health Nutr. 2010;13:1882–9. doi:10.1017/S1368980010000637.

21. Vyth EL, Steenhuis IH, Roodenburg AJ, Brug J, Seidell JC. Front-of-pack nutrition label stimulates healthier product development: A quantitative analysis. Int J Behav Nutr Phys Act. 2010;7:65. doi:10.1186/1479-5868-7-65.

22. Crites Jr. SL, Aikman SN. Impact of nutrition knowledge on food evaluations. Eur J Clin Nutr. 2005;59:1191–200. https://www.nature.com/articles/1602231. Accessed 23 May 2018.

23. Drichoutis AC, Lazaridis P, Nayga RM. Nutrition knowledge and consumer use of nutritional food labels. Eur Rev Agric Econ. 2005;32:93–118. doi:10.1093/erae/jbi003.

24. Miller LMS, Cassady DL. Making healthy food choices using nutrition facts panels. The roles of knowledge, motivation, dietary modifications goals, and age. Appetite. 2012;59:129–39. doi:10.1016/j.appet.2012.04.009.

25. Nayga RM. Nutrition knowledge, gender, and food label use. J Consum Aff. 2000;34:97–112. doi:10.1111/j.1745-6606.2000.tb00086.x.

26. Cecchini M, Warin L. Impact of food labelling systems on food choices and eating behaviours: a systematic review and meta-analysis of randomized studies. Obes Rev. 2016;17:201–10. doi:10.1111/obr.12364.

27. Kardes FR. Spontaneous Inference Processes in Advertising: The Effects of Conclusion Omission and Involvement on Persuasion. J Consum Res. 1988;15:225. doi:10.1086/209159.

28. Lobstein T, Landon J, Lincoln P. Misconceptions and misinformation: the problems with Guideline Daily Amounts (GDAs). In: In A Review of GDAs and Their Use for Signalling Nutritional Information on Food and Drink Labels. London: National Heart Forum.; 2007.

29. Grunert KG, Fernández Celemín L, Storcksdieck genannt Bonsmann S, Wills

JM. Motivation and attention are the major bottlenecks in nutrition labelling. Food Sci Technol. 2012;26:19–21. http://www.forskningsdatabasen.dk/en/catalog/2389221042. Accessed 23 May 2018.

30. Magnusson RS. Obesity prevention and personal responsibility: the case of front-of-pack food labelling in Australia. BMC Public Health. 2010;10:662. doi:10.1186/1471-2458-10-662.

31. Louie JC-Y, Flood V, Rangan A, Hector DJ, Gill T. A comparison of two nutrition signposting systems for use in Australia. N S W Public Health Bull. 2008;19:121–6. doi:NB07118 [pii].

32. Kelly B, Hughes C, Chapman K, Louie JCY, Dixon H, Crawford J, et al. Consumer testing of the acceptability and effectiveness of front-of-pack food labelling systems for the Australian grocery market. Health Promot Int. 2009;24:120–9. doi:10.1093/heapro/dap012.

33. Balcombe K, Fraser I, Falco SD. Traffic lights and food choice: A choice experiment examining the relationship between nutritional food labels and price. Food Policy. 2010;35:211–20. doi:10.1016/j.foodpol.2009.12.005.

34. Jones G, Richardson M. An objective examination of consumer perception of nutrition information based on healthiness ratings and eye movements. Public Health Nutr. 2007;10:238–44. doi:10.1017/S1368980007258513.

35. Leek S, Szmigin I, Baker E. Consumer confusion and front of pack (FoP) nutritional labels. J Cust Behav. 2015;14:49–61. doi:http://dx.doi.org/10.1362/147539215X14267608004087.

36. Feunekes GIJ, Gortemaker IA, Willems AA, Lion R, van den Kommer M. Front-of-pack nutrition labelling: Testing effectiveness of different nutrition labelling formats front-of-pack in four European countries. Appetite. 2008;50:57–70. doi:10.1016/j.appet.2007.05.009.

37. Koenigstorfer J, Wąsowicz-Kiryło G, Styśko-Kunkowska M, Groeppel-Klein A. Behavioural effects of directive cues on front-of-package nutrition information: The combination matters! Public Health Nutr. 2014;17:2115–21.

38. Butler KML. Making smart choices: health claims, regulation, and food packaging. Master's Thesis, University of Pittsburgh. (Unpublished); 2010. http://d-scholarship.pitt.edu/7067. Accessed 24 May 2018.

39. Andrews JC, Burton S, Kees J. Is Simpler Always Better? Consumer Evaluations of Front-of-Package Nutrition Symbols. J Public Policy Mark. 2011;30:175–90. doi:10.1509/jppm.30.2.175.

40. Grunert KG, Wills JM, Ferna L. Nutrition knowledge , and use and understanding of nutrition information on food labels among consumers in the UK §. Appetite. 2010;55:177–89. doi:10.1016/j.appet.2010.05.045.

41. Koenigstorfer J, Baumgartner H. The Effect of Fitness Branding on Restrained Eaters' Food Consumption and Postconsumption Physical Activity. J Mark Res. 2016;53:124–38. doi:10.1509/jmr.12.0429.

42. Department for Business Energy and Idustrial Strategy. Regulations: energy information - Guidance for suppliers and dealers. 2018. https://www.gov.uk/guidance/the-energy-labelling-of-products#how-do-i-comply.

43. European Commission. Review of Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication of labelling and standard product information of the consumption. 2015.

44. ECOFYS. Evaluation of the Energy Labelling Directive and specific aspects of the Ecodesign Directive. 2012. http://www.pnas.org/content/107/37/16054.short.

45. European Commission. Energy Efficiency. 2018. doi:https://ec.europa.eu/energy/en/topics/energy-efficiency.

46. Sammer K, Wüstenhagen R. The influence of eco-labelling on consumer behaviour - Results of a discrete choice analysis for washing machines. Bus Strateg Environ. 2006;15:185–99.

47. Ward DO, Clark CD, Jensen KL, Yen ST, Russell CS. Factors influencing willingness-to-pay for the ENERGY STAR®label. Energy Policy. 2011;39:1450–8. doi:10.1016/j.enpol.2010.12.017.

48. Presutto M, Stamminger R, Scaldoni R, Mebane W, Esposito R. Preparatory study of eco-design requirements of EuPs Lot 14: Domestic wash- ing machines and Dishwashers Task 1–2. 2007. http://www.ecowet-domestic.org/index.php?option=com_docman&task= cat_view&gid=18&Itemid=40.

49. Waechter S, Sütterlin B, Siegrist M. Desired and undesired effects of energy labels - An eye-tracking study. PLoS One. 2015;10:1–26.

50. Shen J, Saijo T. Does an energy efficiency label alter consumers' purchasing decisions? A latent class approach based on a stated choice experiment in Shanghai. J Environ Manage. 2009;90:3561–73. doi:10.1016/j.jenvman.2009.06.010.

51. Sheeran P, Webb TL. The Intention–Behavior Gap. Soc Personal Psychol Compass. 2016;10:503–18.

52. Gillingham K, Palmer K. Bridging the energy efficiency gap: Insights for policy from economic theory and empirical analysis. 2013. doi:10.1093/reep/ret021.

53. Kahneman D, Egan P. Thinking fast and slow. New York: Farrar, Straus and Giroux.; 2011.

54. Slovic P, Finucane M. The affect heuristic. Eur J Oper Res. 2007;177. http://www.sciencedirect.com/science/article/pii/S0377221705003577. Accessed 18 Jan 2016.

55. Attari SZ, DeKay ML, Davidson CI, Bruine de Bruin W. Public perceptions of energy consumption and savings. Proc Natl Acad Sci. 2010;107:16054–9. doi:10.1073/pnas.1001509107.

56. Waechter S, Sütterlin B, Siegrist M. The misleading effect of energy efficiency information on perceived energy friendliness of electric goods. J Clean Prod.

2015;93:193–202. doi:10.1016/j.jclepro.2015.01.011.

57. Alborzi F, Schmitz A, Stamminger R. Consumers' comprehension of the EU Energy Label for washing machines. Tenside, Surfactants, Deterg. 2017;54:280–90.

58. Michel A, Attali S, Bush E. Energy efficiency of White Goods in Europe : monitoring the market with sales data. 2015; June:1–53. http://www.topten.eu/uploads/File/WhiteGoods_in_Europe_June15.pdf.

59. ANEC and BEUC. Simplifying the EU Energy Label Restoring the Successful and Well-understood Closed A to G Scheme. 2015. http://www.anec.eu/attachments/ANEC_BEUC%2520key%2520priorities%2520in%2520the%2520revision%2520of%2520the%2520EU%2520Energy%2520Label.pdf.

60. London Economics. Study on the impact of the energy label and potential changes to it – on consumer understanding and on purchase decisions. 2014. https://ec.europa.eu/info/sites/info/files/impact_of_energy_labels_on_consumer_behaviour_en.pdf. Accessed 7 Jan 2018.

61. Meibner M, Heinzle S, Decker R. Not worth the extra cost? Diluting the differentiation ability of highly rated products by altering the meaning of rating scale levels. J Consum Behav. 2008;12:223–31. doi:10.1002/cb.

62. Heinzle SL, Wüstenhagen R. Dynamic adjustment of eco-labeling schemes and consumer choice - the revision of the EU energy label as a missed opportunity? Bus Strateg Environ. 2012;21:60–70.

63. Langley E, Dickman A, Jenner M, Duke C, Suter J, Sinn M, et al. Research on EU Product Label Options. 2012.

64. Dendler L. Sustainability Meta Labelling: An effective measure to facilitate more sustainable consumption and production? J Clean Prod. 2014;63:74–83. doi:10.1016/j.jclepro.2013.04.037.

65. European Union. Commission publishes new energy efficient labelling regulations to empower consumers. 2017. https://ec.europa.eu/energy/en/news/commission-publishes-new-energy-efficient-labelling-regulations-empower-consumers.

66. Laycock G. The UK car theft index: An example of government leverage. In: Understanding and preventing car theft, vol. 17 of crime prevention studies. 2004. p. 25–44. http://discovery.ucl.ac.uk/11315/. Accessed 7 Jan 2018.

67. Armitage R, Monchuk L. Sustaining the crime reduction impact of designing out crime: Re-evaluating the Secured by Design scheme 10 years on. Secur J. 2011;24:320–43. doi:10.1057/sj.2010.6.

68. Kelley PG, Cesca L, Bresee J, Cranor LF. Standardizing privacy notices. Proc 28th Int Conf Hum factors Comput Syst - CHI '10. 2010;:1573. doi:10.1145/1753326.1753561.

69. McDonald AM, Reeder RW, Kelley PG, Cranor LF. A comparative study of online privacy policies and formats. Priv Enhancing Technol Lect Notes Comput Sci.

2009;5672:37–55.

70. Acquisti A, Brandimarte L, Loewenstein G. Privacy and human behavior in the age of information. Science (80-). 2015;347:509–15.

71. Blythe JM, Michie S, Watson J, Lefevre CE. Internet of Things in Healthcare: Identifying key malicious threats, end-user protective and problematic behaviours. In: Frontiers in Public Health. 2017. doi:10.3389/conf.FPUBH.2017.03.00021.

72. Michie S, Atkins L, West R. The Behaviour Change Wheel: A Guide to Designing Interventions. 2014.

73. Viswanathan M, Torelli CJ, Xia L, Gau R. Understanding the influence of literacy on consumer memory: The role of pictorial elements. J Consum Psychol. 2009;19:389–402. doi:10.1016/J.JCPS.2009.04.002.

74. Gartner. Gartner Says 6.4 Billion Connected “Things” Will Be in Use in 2016, Up 30 Percent From 2015. 2015. http://www.gartner.com/newsroom/id/3165317.

75. Wrap. Smart Devices & Secure Data Eradication: the Evidence. 2017. http://www.wrap.org.uk/sites/files/wrap/Data Eradication report Defra.pdf.