Office for Product Safety & Standards

Experiences of harms from smart products in the home

Research

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Executive Summary

Two studies (Study 1, N = 1464, Study 2, N = 497) were designed to gain a comprehensive understanding of the types of harms that people anticipate experiencing (Study 1), as well as having direct experiences of harms (Study 2), from using smart products in the home - consumer products with internet connectivity (CPIC) (e.g., voice assistants, smart TVs, smart doorbell, smart baby monitor, smart glasses). Along with this, another novel aspect of the studies is what types of actions respondents considered as most appropriate for individual types of harms (anticipated, directly experienced).

Study 1

Study 1 examined harms that might be expected to be associated with a variety of smart products some of which are common (e.g. smart watches) and others which have yet to dominate the market (e.g. smart toothbrush). The aim here was to explore the relationships between the following: (1) familiarity with the products, (2) the harms (physical harm, psychological harm, financial harm, property damage), (3) their likely occurrence under different states of the product (internet breach, malfunctioning, normal function), (4) which appropriate actions should be taken given a harm was experienced (remove product from the market, issue a large fine to the company, issue a public campaign, introduce a warning label).

Familiarity appeared to track in the direction that the more familiar with smart products respondents were then proportionally less expected any harm to occur within a year compared with those unfamiliar with smart products. Regardless of familiarity, or the causes of the harm, preference for particular risk management actions was strong. Overall, in the presence of a harm removing product from the markets (36%) and fines (30%) were more popular than warning labels (21%) and public campaigns (13%). This may also imply how the public view the effectiveness of different methods of risk management action.

Study 2

Study 2 extended the insights from Study 1 by exploring the rates of harms directly experienced from a single smart product that was owned (including those in Study 1, and three additional ones - societal harms, environmental harms, animal harms). Respondents indicated which of the harms had been experienced in association with a specific smart product they used. In addition to their harm experiences, users were also invited to select a harm they considered should be prioritised along with suggested actions a regulator could take in response. The risk management actions options presented to respondents were the same as Study 1 along with an additional option to gather more evidence.

The majority of respondents did not report direct harms (62%), of those that had reported harms (38%) the most common were psychological (19%) and financial (18%). There was no consistent correspondence between the harms a user experienced directly from the smart product and harms the same user proposed that the regulator should prioritise; this is also because the majority of users had not experienced a harm *per se*. The most common harms that respondents proposed that a regulator should take some action against were psychological (35%), financial (34%) and physical (13%). When presented

with the options for what actions the regulator ought to take, the most common was to collect more data (43%) followed by removing the product from the market (21%).

Conclusions

Experience with smart products impacts how often and what types of harms are associated with smart products, with more experience anticipated and actual rates of harm were lower. Regardless of familiarity, cause of harm, and rates of occurrence, the harms themselves were predictive of which risk management action was preferred.

Introduction

There are many examples of products that are currently in our homes that can be described as functioning smartly (e.g. personal voice assistants, smart TVs, Smart door locks) and autonomously (e.g. robotic vacuum cleaner). What constitutes smartness is a matter of debate (for review see Raff-Heinen et al., 2020), but in the main the products either carry out some actions autonomously (e.g. smart thermostat- automatically creates efficient heating schedules), can be voice activated to respond to commands (e.g. personal assistants that switch devices on or off), and can be monitored and operated remotely (e.g. smart pet feeder). Therefore, an alternative term for these products is consumer products with internet connectivity (CPIC) which generically refers to the fact that their operations typically require internet connectivity regardless of how smart they are (Osman, 2025a). In fact, because of the number of devices and appliances with smart functionalities, and because they are networked to our home Wi-Fi, in combination, these now constitute smart homes (e.g. Buil-Gil et al., 2021; Kumar et al., 2023).

Over the past 10 years there have been several reviews of findings regarding user experiences and perceptions of smart homes (e.g., Kumar et al., 2023; Li et al., 2021; Li et al., 2022; Percy-Campbell et al., 2024; Thakur et al., 2016; Wilson et al., 2015). Recently,empirical studies have investigated user's concerns (e.g., Briggs et al., 2025; He et al., 2019; Nicholson et al., 2025; Wenda et al., 2025; Whysel & LeVasseur, 2024), reasons for resistance to adoption (e.g., Klobas et al., 2019; Li et al., 2021; Mani & Chouk, 2017; Seymour et al., 2024), perceived benefits (e.g., Shank et al., 2021; Li et al., 2021; Wang et al., 2018; Wilson et al., 2017), perceptions of risk (e.g., Cohen et al., 2023; Hunte et al., 2024; Li et al., 2021; Wang et al., 2018; Wilson et al., 2017; Zhu et al., 2021), and tolerances of risks (e.g. Hunte et al., 2024; Jenkins & Osman, 2025).

General user concerns around smart products

Regarding general concerns, He et al (2019) examined 75 user's concerns based on the specific products they owned (e.g. smart cameras, smart lights, smart thermostats, smart kitchen appliances, smart door locks). Along with security and privacy concerns, users reported negative experiences especially around network failures that cause products to fail, but that were interpreted at times as malicious activity (e.g. hacking); that is, false positives caused enormous alarm to users especially as to what actions they could take. In a similar vein, Briggs et al. (2025) interviewed 23 respondents on their experiences with products including smart phones, laptops, smart watch, smart tv, voice assistants, smart security cameras and smart lights. Not all respondents owned these products, so the interviews were based around the products that they currently owned. Overall, the indication is that convenience, usefulness and ease of use were factors taken into account against concerns about being overly reliant on the products, financial costs of the products and the services attached to them, and trust. Trust related specifically to security issues around data protection, as well as privacy concerns. Nicholson et al., (2025) qualitative study complement the findings, based on examining 15 older adults' experiences with smart homes, using a simulated smart home environment. Again, the concerns centred around changing habits through increased reliance on the products, security and privacy, poor network coverage or battery that would mean product failures, along with possible property damage (e.g. the product catching fire).

Quantitative approaches, such as Whysel and LeVasseur (2024) survey work examined overall safety concerns by asking 882 respondents in the US "How Safe Are Internet-

Connected Products?" (with options ranging from very unsafe, unsafe, neutral, safe, very safe) in reference to "smart homes", "smart tvs" and "smart appliances". Smart homes *per se* are not products but rather a collection of them, where the majority (39.7%) were neutral. Also, smart TVs are a type of product whereas smart electrical appliances are a category of product that could refer to ovens, dishwasher, washing machines, washer dryers, vacuum cleaner, irons, or refrigerators. This category of products includes product that have different functions and different hazard profiles that in turn have different safety issues (e.g., SABS Standards Division 2009). Regarding the former, the majority responses were neutral (36.4%) and safe (36.4%), and for smart appliances the most (44.4%) gave the neutral response with respect to safety.

Perceived risks and risk tolerance of smart products

Often, studies that have focused on the attributed benefits to a smart home or specific smart products as a way to determine which factors influence adoption, contrast these with perceived risks. However, there are studies that have specifically focused on examining risk perceptions (e.g., Cohen et al., 2023; Hunte et al., 2024; Zhu et al., 2021), and risk tolerances of smart products (e.g. Hunte et al., 2024; Jenkins & Osman, 2025). Again, what we see is a wide range of smart products that are used to gauge public risk perceptions and their tolerances of risks. For instance, Cohen et al (2023) focused specifically on public perceptions of risks of a smart oven. They experimentally varied the smartness of the oven and compared risk perceptions against a conventional non-smart oven. They also manipulated the comprehensiveness of the information of the functionality of the smart oven, and how the product was marketed as additional factors that could influence perceptions of risk. Similarly, Hunte et al (2024) examined risk perceptions for a smart microwave oven and a smart vacuum cleaner compared to their non-smart equivalents. Both Cohen et al (2023) and Hunte et al (2024) reported that smart ovens were perceived as more risky than their non-smart equivalents, and this pattern extended to the smart vacuum cleaner compared to the non-smart version.

Zhu et al (2021) used a nationally representative sample (n = 1850) to examine risk perceptions for a range of smart products (smart oven, smart ladder, smart pet feeder, smart diapers, smart mug, smart jacket) and their non-smart equivalents. Consistent with previous findings (Cohen et al., 2023; Hunte et al., 2024) risk perceptions were higher for smart version of the smart oven compared to the non-smart equivalent, but also for smart diapers, and smart jacket compared to their non-smart versions. For the smart ladder and smart pet feeder risks were lower compared to the non-smart equivalents, and for smart mug and non-smart version there was no different risk perceptions. Zhu et al (2021) also examined the impact on perceptions of risk based on the way in which products were marketed. Both Zhu et al (2021) and Cohen et al (2023) reported similar findings, indicating that risk perceptions could be differentiated by how the product was marketed. That is, if the product was marketed as safe rather than to increase efficiency (i.e. time saving) impacted risk perceptions, particularly when the products were described as being defective leading to negative outcomes (e.g. burning food in the case of a smart oven or failing to provide sufficient food to the pet). Zhu et al (2021) and Cohen et al (2023) found higher attributions of risk were made when the products were labelled as safe than efficient for the reason that higher standards were attributed to products labelled as safe than efficient, and so when those products failed, then risk perceptions increased. In fact Zhu et al (2021) also collected measures of who was responsible for product failures (product user, manufacturer, retailer, regulator). Overall, when the smart product was perceived to be increasing the risk relative to its non-smart counterpart, respondents were more likely to blame third parties when the product failed. However, when the product

appeared to be aimed towards safety (thus decreasing the risk compared to the non-smart counterpart), respondents were more likely to blame themselves for the product failing and less likely to blame the other parties. The explanation for this was that given the product was marketed as safe, thus increasing the expectancy that the product should be of a higher standard, user's causal model attributed any product failure and ensuing harms as a result of their misuse of the product rather than a defect in the product itself.

Work examining perceived benefits of smart products include measures of perceived risks as a way to gauge overall benefits relative to risks (e.g. Li et al., 2021; Wang et al., 2018; Wilson et al., 2017). The studies have typically reported patterns of responses based on the overall benefits attributed to smart homes rather than individual products. The concept of integrating risk and benefits into a single metric has been used to develop a metric of risk tolerance (e.g. Jenkins et al., 2024) where the level of risk (e.g. harms caused, uncontrollability, unfamiliarity) people are prepared to accept is determined relative to several benefits (e.g., utility, cost). The underlying rationale is that people intuitively perform trade-offs of risks and benefits to make decisions according to what level of risk is tolerated – namely the extent to which the benefits outweigh the risks, or vice versa, what is intolerable – namely the extent to which the risks overwhelmingly outweigh the benefits.

Two recent studies developed metrics to explicitly calculate public risk tolerance of smart products (Hunte et al., 2024; Jenkins & Osman, 2025). Hunte et al. (2024) reported that the public were less tolerant of the risk of smart versions of home appliances (i.e. microwave oven, vacuum cleaner) compared to non-smart versions, and in turn indicated overall lower utility of compared to their non-smart counterparts. Jenkins and Osman (2025) examined public perceptions of risk, risk tolerances and causes of harms for 10 smart products (smart pet feeder, smart speaker, teddy camera, connected children's toy, smart doorbell, smart toothbrush, Bluetooth tracker, smart door lock, smart robot sweeper, smart watch). They also collected qualitative data in the form of descriptions respondents provided about their concern about the products. Their risk map was able to locate the 10 products on two dimensions concern (e.g., worried about potential risks, controllability, concern around data handling) and benefits (e.g., familiarity, frequency of usage, personal benefits). Products that were perceived as most beneficial were smart door lock, smart speaker, smart doorbell and smart Bluetooth tracker. However, at the same time, they were also perceived as the most concerning along with the smart teddy bear. Along with examining individual risk tolerances of each product, they also showed that risk tolerance increased as overall perceived importance of the smart products to one's life and trust in/pursuit of new technology increased.

Evidence gaps in the extant literature on smart products

Across the wealth of work on smart products that have been reviewed from the perspective of public concerns, barriers to adoption and their benefits and risk, there are several consistent patterns to be found. The level of trust, familiarity and prior experience with smart products that constitute a smart home increase adoption, and in turn, inform increases in perceived benefits over the perceived risks. The range of risks that have been studied include financial risk, privacy risk, security risk, performance risk and risks in controlling the product in view of potential hazards that might present. When compared with their non-smart equivalents, typically smart products fare less well, and are typically judged to be more risky, and tolerances of the risk are lower.

If one were to ask, which of the range of smart products on the market are viewed as or experienced as most harmful, or for that matter want to understand what types of harms are typically experienced, there would be considerable difficulty in doing so. There are

three main reasons for this. The first is the enormous variability in what products are included in the studies to measure attitudes, perceptions and direct experiences while using them. The second is that often analyses of dependent measures (e.g. risk perceptions, perceived benefits, attitudes towards adoption) provide a holistic assessment of smart homes, rather than of the individual products themselves. Third, while there are qualitative studies that ask users to record their experiences of using an individual smart product, or respond in structured interviews about their general experiences, to date there is no study that has focused specifically on examining the times of harms anticipated to occur from usage of smart products, or reporting on the harms that have been directly experienced from using smart products.

Understanding user experiences of harms from using smart products is not only important to address empirically to best understand the safety issues that these new types of technologies present, but also from a practical perspective. Empirical work investigating the frequency of different types of harms users experience has relevant applications for policy and regulation because it provides useful insights that can inform the assessment of risk. Therefore, one of the primary motivations of the present empirical work is to address this evidence gap through two studies that explore the type and frequency of harms from smart products.

In general studies of public risk perceptions do not ask respondents to also consider what kind of management decisions should be taken in view of the risks attributed to products, technologies and services. In view of conducting research that would have applied benefit to policy and regulation, the second motivation is to also address this evidence gap. The two studies were designed in to enable users of smart products to also indicate their preferences for actions that could be taken by an authority in response to harms resulting from smart products. To date, no other study has examined this.

To inform the first motivation behind the present empirical investigation, a range of harms were considered. As with other consumer products that users have in their homes, the range of harms that are considered in scope of risk assessments (e.g., EU, 2023; OPSS, 2022) typically include physical harm, but also financial harm, and property damage. In the advent of new product safety legislation in the UK (Product Regulation and Metrology Act, 2025) and in Europe the recently updated General Product safety Regulation (EU, 2023) several new harms are considered: Environmental harm, mental (otherwise referred to as psychological) harm, societal harm, and animal harm. One issue of concern with mental or psychological harm is the loose way in which it is construed (Osman, 2025a, 2025b). Understanding what impact a smart product can pose to an individual that results in adverse psychological outcomes has been highlighted as problematic (Heath, 2025; Jenkins & Ayton, 2025; Zeelenberg & Kogler, 2025). Moreover, as many of these researchers have commented, establishing a baseline from which to determine an increase in adverse psychological experiences is in and of itself difficult (Heath, 2025), and independent of other harms that would inevitably also be associated with adverse psychological experience (Osman, 2025a). Many of these issues also apply to other harms which have been included in legislation but have yet to include formal and operationalised definitions (e.g. environmental harm, societal harm, animal harm). Given this limitation, the present empirical investigation provided details of each harm to respondents in the two studies to ensure some consistency in how the way in which they can be interpreted.

To inform the second motivation of the present empirical investigation the types of interventions that could be taken in response to harm experienced fall broadly into two types, hard interventions (e.g., recalling a product from the market, fining the businesses) and soft interventions (e.g., adding a warning label on the product, putting out a public

campaign) (Gold et al., 2023; Meder et al., 2018; Osman et al., 2018; Osman et al., 2020). The difference between hard and soft interventions refers to whether they are legally binding, highly restrictive and involve underlying changes in payoff structures (i.e. hard interventions) or by styling information or options without change to the underlying payoff structure they encourage effective positive behavioural change. Both types of interventions were presented in Study 1 and Study 2. In addition, in policy and regulation, an additional action that can be taken is to conduct further evidence gathering. This is particularly the case in circumstances where novel products and services are on the market, and so to understand the hazard profiles as well as associated harms that can present, evidence collection in the form of rapid reviews, data synthesis, modelling, and testing is often sought (e.g., Mayo & Hollander, 1994; Wolfe et al., 2019).

Objectives of the present empirical investigation

1. To understand the frequency and type of harms that people expect/experience from consumer products with internet connection in the home (i.e. smart products)
2. To understand the relationship between familiarity with consumer products with internet connection in the home (i.e. smart products) and experiences of occurrence of different harms
3. To understand the preferences for addressing the harms from consumer products with internet connection in the home (i.e. smart products)
4. To examine the correspondence between personal experiences of harms and prioritisation of particular harms with respect to practical interventions for addressing them.

Study 1

Methodology

The study was an online survey that was nationally representative of a UK sample (n = 1464). The survey was hosted via Qualtrics an online platform used to conduct experiments online, and participant recruitment was carried out using Prolific, a crowd sourcing platform commonly used for panel studies. Ethics approval was granted for conducting the study, which was carried out between July and August 2025.

Along with basic demographic details (e.g., gender, age, parental status), the study involved three sets of questions. The first set asked respondents to indicate from a list of 35 smart products which they owned, which they are likely to buy within the next 12 months, and which they are unlikely to buy/need.

In the second set of questions there were 15 smart products that respondents were required to answer questions on (Smart speaker; Smart Watch; Smart Doorbell; Smart Toothbrush; Smart Bluetooth Tracker; Smart Smoke Detector; Smart Vacuum Cleaner; Smart Cooker; Smart Baby Monitor; Smart Door Lock; Smart Pet feeder; Smart Toy Robot; Smart Glasses; Smart Teddy Camera; Smart Drill). The questions asked respondents their level of familiarity with the smart product, and then they gave a forced choice response according to whether or not they expected a harm (financial, physical, property damage, psychological) to occur in association with that product for each of three different states of the product (internet breach, malfunction, normal function).

The four harms were defined as follows:

Physical harm

This is where there is some injury to you, or to other people in the household

Financial harm

This is where the problem leads to costs in dealing with the problem that the product caused

Property Damage

This is where the contents of your home or the physical structure of the building itself was damaged in some way

Psychological harm

This is where you experienced a negative impact on your wellbeing for longer than a few days, or other people in the household experienced a negative impact on their wellbeing for longer than a few days

In the third set of questions, respondents were required to select which they considered to be the most appropriate intervention a regulator ought to take (i.e. risk management action - remove product from the market , fine the company, issue a public campaign, introduce a warning label) in response to each of the four harms under each of the possible states of the product.

Key findings

In the first set of questions a sub-sample of respondents were asked which of 35 products they owned, were likely to buy, did not wish to buy/need. The first analysis was to ascertain which of the 15 products used in the main study were indeed commonly owned. The smart products most commonly owned by respondents (n = 1063) were smart speakers (50%), smart watches (45%) and smart doorbells (28%). We also see that overall ratings of familiarity of smart products broadly tracked rates of ownership or interest in buying the same smart products. Specifically, the highest ratings of familiarity (1 not at all familiar to 7 extremely familiar) were for smart speakers (M = 5.5, SD = 1.7) then smart watches (M = 5.5, SD = 1.7) and smart doorbells (M = 5.1, SD = 1.8).

When judging the occurrence (or not) of a harm over a 12-month period of owning a smart product, the highest proportion indicating the occurrence of harm was for property damage as a result of the smart drill malfunctioning (60%), physical harm resulting from using a smart drill (either when the product malfunctioned (57%) or functioned normally (47%)), and property damage as a result of a smart vacuum cleaner malfunctioning (58%) or functioned normally (50%). Also, the products for which respondents were most aligned in their preferred risk management action were smart doorbells (remove product from the market), smart speakers (remove product from the market) and smart vacuum cleaners (public campaign).

Detailed analysis revealed that when looking at the overall proportion of judged occurrence of harms occurring at least once over a 12-month period of usage (across all of the states of product – internet breach, malfunction, normal functioning), the proportions are approximately the same: financial harm (22%), physical harm (21%), property damage (22%), and psychological harm (22%). When considering familiarity with the product, there is a broad correspondence between level of familiarity with a smart product and judging a harm to occur when using it over 12 months. That is, the lower the level of familiarity, proportionally more judge a harm to occur, and this is consistent regardless of the state of the product (internet was breached, malfunctioning, normal functioning) when a harm could occur.

On the whole, the level of familiarity with a smart product did not influence the preference for risk management action for different types of harms experienced. Overall, across the board, remove product from the markets (36%) and fines (30%) were more popular than warning labels (21%) and public campaigns (13%). When looking at the correspondence between type of harm and risk management action, fines were most popular for financial harm and removing product from the markets most popular for physical harm and property damage. For psychological harm the most popular action was to add a warning label on the product.

On the whole, judged occurrence of a harm did not impact the preference for risk management action when the harm was associated with the product malfunctioning or functioning normally. The preference was to fine the business when a financial harm had occurred, remove product from the market, when a physical harm and property damage had occurred and add a warning label on the product when psychological harm had been experienced. It was only when the internet had been breached and there was a security issue that judged occurrence of harms impacted the preferred risk management action. Under these conditions if a financial harm had been judged as likely to occur then more preferred a fine (52%) to those that didn't judge the harm as likely occurring in a 12-month

period (47%). For physical harm, more respondents who judged them to not have occurred in a 12-month period preferred a remove product from the market (51%) to those that indicate the harm would occur in a 12-month period (47%). Here we see differential contributions of estimates of likelihood of a harm occurring when the internet had been breached causing a security issue.

Overall, regardless of the state of the product (breached via the internet, malfunctioning, functioning normally) it was consistently the case that, relative to all other risk management action options, when financial harm was experienced the preferred option was to fine the business; though this was at a higher rate when there was a security breach (48%) than malfunction (46%) or normal functioning (38%). For physical harm, the most consistently popular risk management action was remove product from the market the product for each state of the product; though this was at a higher rate when there was a malfunction (62%) than a security breach (50%) or normal functioning (54%). Also, for psychological harm, it was consistently the case that, relative to all other risk management action options, when experienced the preferred option was to add a warning label to the product; though this was at a higher rate when the product was functioning normally (36%), than when there was a security breach (29%) or a malfunction (32%). For property damage, the most popular risk management action when there was a malfunction was to remove product from the market the product (45%) and to remove product from the market it when it functioned normally (41%), but if there was an internet breach, then the preferred option was to fine the business (37%).

Insights

With respect to objectives one and two, Study 1 reveals that the proportion judging particular harms to occur is approximately the same, where 22% of respondents judged each of the four harms to occur at least once over the usage of the product in a 12-month period. Familiarity with the product decreased judgements of occurrence of harms relative to those unfamiliar, which suggests that respondents likely calibrate their judgements based on some knowledge of the product. Also, given the types of products included in the study, it is clear that some smart products are consistently viewed as proportionally more harmful than others (e.g., smart drill, smart vacuum cleaner, smart door lock, smart doorbell). With respect to objective three, the findings from Study 1 indicate that familiarity and judged occurrence of harms along with the state of the product (internet breach occurring, product malfunction, product functioning normally) have less of an influence on preferred risk management action than the type of harm itself. In fact there is remarkable consistency where particular harms are most commonly associated with particular preferred interventions. For financial harm the preference is to fine the business, for physical harm and property damage the preference is to remove product from the market the product, and for psychological harm the preference is to add a warning label to the product.

Study 2

Methodology

The study was run online and was nationally representative of a UK sample (n = 497). The survey was hosted via Qualtrics using the same set up as Study 1, and participant recruitment was carried out using Prolific, using the same sampling approach as Study 1. Ethics approval was granted for conducting the study, which was carried out in March 2026.

Along with basic demographic details (e.g., gender, age, parental status), the study involved two sets of questions. The first set asked respondents to indicate from a list of 35 smart products which they owned, which they are likely to buy within the next 12 months, and which they are unlikely to buy/need.

In the second set of questions asked respondents to base their responses on a specific product that they had an issue with in the last 12 months. For their chosen product they had to describe the smart product along with the issue itself that had raised problems, and then from a list of possible harms (financial, physical, property damage, psychological, environmental, societal, animal[1]) they were to select which, if any, they had experienced. The definitions of the harms used in Study 1 were the same for Study 2. Below is the presentation of the details of the additional harms as defined to respondents:

Animal harm

This is where there was some injury to pets in the home

Environmental harm

This is where harm was caused to the quality of your water supply, air pollution, harm to your garden or other areas around the location you are resident it

Psychological harm

This is where you experienced a negative impact on your wellbeing for longer than a few days, or other people in the household experienced a negative impact on their wellbeing for longer than a few days

Societal Harm

This is wide spread failures that individually or in combination would undermine the stable functioning of society (incl. digital technologies that pose major disruption to national infrastructure - such as hospitals, power grid, transport)

They were then asked to select a harm they considered an authority (e.g. a government department, regulator) should consider taking risk management action for (remove product from the market, fine, public campaign, warning label, collect more evidence around incidents) along with the corresponding risk management action they thought was the most appropriate.

The rationale for this setup was to build on the insights from Study 1. The findings from Study 1 indicated that there are differences in responses, at least when it comes to judging the occurrence of a harm, and so the aim of Study 2 was to focus exclusively on understanding rates of harm based on direct experiences of owning a particular smart

[1] The expanded list of harms was in informed by new legislation (Product Regulation and Metrology Act 2025) that outlines a range of possible harms that need to be mitigated.

product. Moreover, it was worth exploring if, like Study 1, the preferred risk management action was based on the type of harm the user had direct experience with, which seemed to primarily drive choices over and above other factors (e.g. cause of the problem, familiarity, occurrence of the harm).

Key findings

Study 2 also include responses to the question of ownership of the same 35 smart products presented to respondents in Study 1. Therefore it was possible to track the rates of ownership over the two periods in which the studies had been conducted (Study 1 July/August 2025, Study 2 March 2026). While no substantive changes were expected over ~6 months between studies, it is nonetheless interesting to observe ownership rates, intending to own, and no intention/no need to buy. Overall the pattern of responses for the three different options was broadly the same between Study 1 and Study 2. Also consistent with Study 1, for Study 2 the smart products most commonly owned were the same (Smart TV, Smart Speaker, Smart Doorbell).

When analysing the specific smart products that respondents volunteered to answer questions on in Study 2, there was a considerable range (a total of 43 products). For Study 2 the most popular smart products respondents based responses on for the remainder of the study were smart TVs (29%), smart speakers (21%), Smart doorbells (11%) which are aligned with overall rates of sample ownership for Study 1 and 2. For the remainder of the products the sample volunteered to base their responses, of the remaining 40 products, rates of ownership were in many cases less than 5% of the sample.

The next set of analyses examined the rates of harms according to the most common products (smart TVs, Smart speakers, smart doorbells, smart watches), length of ownership of the product (6 months, one year, more than two years) and frequency of use (daily, weekly, a few times in a year). Three main patterns emerged. First, overall, while respondents reported issues of concern around the product and problems they had with it, the vast majority of respondents had not experienced a specific harm (62%). Second, when harms had been experienced, the most common were financial harm (13%) and psychological harm (19%). Third, these did not change substantially when looking at specific harms related to individual products (namely that most had not experienced them, but when they did financial and psychological harms were the most common). The same applies to length of ownership and to frequency of use where again most had not experienced a harm directly, but for those that had, financial and psychological harms were most frequently referred to of all the harms they could choose from.

The third set of analyses examined the harms and preferred action to be taken by the regulator given a specific harm respondents considered the regulator should prioritise addressing. An initial analysis explored the pattern of response with respect to the harms that respondents reported they had experienced and whether this matched with the harms they proposed should be the priority for a regulatory to consider addressing. Given that the majority of respondents had not experienced a specific harm (62%, n = 325)), the analyses considered which harms this group favoured for the attention of a regulator. Here we see that the majority selected financial harms (32%) and psychological harms (33%); even though they had not experienced them this matched the common harms that had been experienced most often by respondents. The next pattern explored was the match between the harms respondents reported they had experienced with those that they proposed a regulatory should focus attention to, for which we see that the correspondence between the two was 72% of the remaining sample (n = 202). The closest matches were

found for animal harms (100%, n = 3[2]) societal harms (100%, n = 1) and financial harms (82%, n= 68). There were less matches for psychological harm (70%, n = 98), physical harm (62%, n= 13) and property damage (62%, n = 13) with the fewest for environmental harms (29%, n = 7).

Looking at the most commonly selected risk management actions overall, collecting more evidence to understand the harm was most frequently selected (43%), followed by remove product from the market the smart product (21%). There were fewer selections for fines (10%), public campaigns (13%) and warning labels (13%). The breakdown of preferred risk management action relative to all other harms was collecting more evidence to understand the harm for psychological harm (55%). Remove product from the market the product was strongly preferred for physical harm (49%) and fining the business was most frequently selected for property damage (17%). When it came to public campaigns, this option was selected most for environmental harms (19%), and for warning labels this was most frequently selected for property damage (24%).

Finally, in order to compare across Study 1 and 2 it was necessary to exclude the option regarding collecting more evidence, since it was not presented as an option in Study 1. After taking this into account, we see that for Study 2 remove product from the market products was the next most popular selected risk management action, and for physical remove product from the market the product was the most popular, which complements the finding of Study 1. Also, for Study 2 when it came to psychological harms the next most preferred option (outside of collecting more evidence) was to add a warning label which also aligns with the pattern of responses in Study 1.

However there were some differences, again excluding the data collection option, in Study 2 for financial harms, the next most preferred choice was to remove product from the market the product (whereas in Study 1 it was to fine the business). For property damage in Study 2 the preferred option was to add a warning label (whereas for Study 1 it was to remove product from the market the product).

Insights

Given that Study 2 was based on experiences that respondents reported based on actual smart products they owned and had adverse experiences with, this presents a more accurate picture of the rates of harms that are prevalent with respect to smart products. This addresses objectives one and two, given that we can be confident that respondents were responding based on their familiarity with the smart product given they owned it. The majority of respondents did not report experiencing a harm from the product even though they had described concerns about it. Of those that did report a harm having been experienced, the two most frequently occurring harms were psychological harm and financial harm. In Study 1 proportionally more anticipated a harm occurring at least once in 12 months for smart Door Locks, Smart Glasses, and Smart Drill, Smart Oven. In Study 2, while acknowledging that the products that respondents volunteered to base their experiences on were not controlled, smart TVs, smart speakers and smart doorbells were the most associated with a directly experienced harm. Here we see that smart doorbells appear in both Study 1 and Study 2 as a smart product that is anticipated to generate harm (Study 1), and that for which harm has commonly been experienced (Study 2).

Regarding objectives 3 and 4, of the five options presented to respondents, the most commonly selected overall, regardless of harm was for the regulator to collect more evidence to understand the nature of the harm. This was added as an option for Study 2

[2] The frequencies of respondents here refer to those that had reported a harm in the initial part of Study 2.

which was not included in Study 1. When comparing the frequency of selections of the same actions that could be taken by the regulator, then the next most commonly selected action for Study 2 was remove product from the market the product, which aligns also with Study 1. In addition, in Study 2 the harms selected for the regulator to address broadly coincided with the harms that respondents had commonly reported they experienced (i.e. financial harm, psychological harm). To draw comparisons between Study 1 and Study 2 to consider general patterns in the correspondence between harms and preferred action to be taken by the regulator, we see some consistency. For Study 1 and 2 (excluding the responses to options for collecting more evidence – and focusing on the remaining four comparable actions) when physical harm had been experienced then the most frequent action proposed was for the product to be removed from the market. Also, for both Study 1 and 2, when psychological harm had been experienced, the action most commonly selected for this was to add a warning label on the product. What is clear from Study 2 is that when considering responses to the additional action included, for psychological harm, the actual most frequently selected choice of all, was to collect more evidence around the harm, and in fact this received the most responses when considering all other harms.

Conclusions

The present studies were able to provide an understanding of the types of harms that the public anticipate would be experienced as a result of using smart products in the home, and the rates of harms that are directly experienced. In the former case (Study 1) the rates anticipated to be experienced within a year of use are approximately the same (20%) across the four harms presented (Financial, Physical, Property damage, Psychological). When looking at the rates based on a smart product a user had experienced issues with (Study 2), then the majority did not report a harm (62%) though they did volunteer details about user problems in the free text box. When they did experience a harm from which respondents could choose from several options (Financial, Physical, Property damage, Psychological, Environmental, Societal, Animal), then the rates are approximately in line with those anticipated (in Study 1), which were commonly for financial harm (18%) and psychological harm (19%). For anticipated and actual adverse experiences from smart products, the product that was identified as one of the most harmful in both studies was smart doorbells.

When presented with the option of risk management action an authority (e.g. regulator) could take with respect to harms that had been reported as experienced by the user, then of five options (remove product from the market, fine, public campaign, warning label, collect more evidence about the harm), the most commonly selected option overall was for the regulator to collect more evidence; this was the case regardless of the harm. One reason for this is that as an emerging market, users of smart products recognise that more needs to be done to better understand harms that could occur, and the causes. Across studies, of the many potential factors, outside of the harms themselves, there was little to indicate the pattern of selections for risk management action that a regulator could take. That is, regardless of the familiarity with the product, the underlying causes of the harm, the likelihood of the harm occurring, the pattern of selections were most evident when examining the harms themselves.

While severity of harm was not manipulated in the study, it may still be the case that users nominally differentiate harms by those that they consider most impactful to them from those lower down the ordering. It is also clear that some measures carry more significance than others because they have legal and financial implications (hard interventions) whereas others are designed to increase awareness through the provision of more

information (soft interventions). Across both studies there was strong convergence for remove product from the market products that caused physical harm, and adding warning labels to products when psychological harm had been experienced. This may indirectly indicate a degree of proportionality with respect to the severity of the harm and the punitive measures that could be taken. That is, physical harm was consistently frequently associated with hard interventions and psychological harm was consistently frequently associated with soft interventions.

Future Considerations

One point worth highlighting with respect to new harms that are currently being considered in legislation, as noted in the introduction, the way in which they are articulated is vague (e.g., Farrand, 2024; Osman, 2025a, 2025b). As a result, in the two studies efforts were taken to define the different harms in ways that could be meaningfully interpreted by the respondents. For instance, psychological harm was defined as follows "this is where you experienced a negative impact on your wellbeing for longer than a few days, or other people in the household experienced a negative impact on their wellbeing for longer than a few days"; this was informed by Heath (2025) definition of psychological harm "*sustained drop in stable functioning negatively impacting well-being"* (Heath, 2025, p155). The type of negative impact is left open for interpretation, and the length of the experienced impact lasting longer than a few days also leaves considerable room for interpretation. Given this, it may not be a surprise that the anticipated and reported rates of psychological harm are approximately 1 in 5 users. As Heath (2025) outlines in her definition, the impact psychologically needs to be a sustained drop relative to a baseline. Therefore, the findings from the empirical investigation presented here needs to be treated with caution, since more needs to be done to follow up what respondents experience as types of sustained drop in stable functioning, and the length of time from which they recover from this.

In fact, Study 1 and 2 suggest that the preferred risk management response to psychological harms is labelling products, which is a soft intervention. While in Study 2 the overwhelming preference as a risk management response to the majority of harms was to gather more evidence, for psychological harms it was the most common choice (55%). One speculation is that respondents appreciate that this is an atypical harm in relation to those typically associated with consumer products they use in their home, which is why they consider that more needs to be done to understand it. In fact, this could be said of environmental harm, animal harm and societal harm, which was explored in Study 2. Not only are the frequency of these harms very low (environmental harm, animal harm) or not experienced at all (societal harm), but there is also a lack of overall unity in the way they are construed in the academic literature. Take societal harms as another illustration. For respondents in the present empirical investigation of harms, it might be the case that societal harm itself is too abstract to warrant being selected. Alternatively it might be that societal harm is too broad to be considered a harm that a single individual user of a smart product would experience the impact of themselves directly. When it comes to harms from artificial intelligence that is built into new products users can enjoy the benefits of in their home, societal harm is often referred to as occurring "… when one or more interests of society are wrongfully thwarted" (Smuha, 2021, p5). Or, as discussed by Andrea (2026) "Societal harm constitutes the most complex and diffuse category of AI-related risk. Unlike physical or psychological damage, it affects collective structures, institutions, and social processes rather than individual users." (2026, p 37) Regardless of how it is defined, there is agreement that it cannot be reducible to an individual's experience of harm (Kutz, 2000) and may in fact be the reason why so few respondents in the study selected it.

Practical Insights

Finally, what insights could be drawn from the findings that could be instructive to those that have to design policies and regulations to protect users from harm from consumer products?

One thing that is clear from the findings is that there are differences in responses depending on users familiarity with smart products. While there are nice overlaps between Study 1 and Study 2, even with Study 1, expectations of the presence of harms were lower when users were familiar with smart products than when they weren't. If future survey work is conducted to accurately gauge prevalence of different types of harms, then this needs to take account ownership and usage of the products. Perhaps another aspect to highlight is that when respondents in Study 2 that had the opportunity to report on adverse experiences they had from a smart product they owned, the majority reported that they had not experienced a harm. This is at least reassuring that in the majority of cases the products are not causing harm, though clearly do present issues 98% of participants described an issue they had with the smart product they volunteered to answers questions on. Clearly more needs to be done to understand the profile of issues that are typical as well as atypical. Previous work has reported on how temperamental and unreliable smart products are (Osman & Jenkins, 2026), which also presents valuable insights for policy and regulation. Even if smart products don't pose harm that often, or the harms that are experienced aren't severe, there are nonetheless issues that require businesses be responsible for ensuring that the products perform as advertised, and that customer services address user problems well and in a timely manner.

Unlike previous empirical work, the present study explicitly considered different types of products and the different states in which the product operated under (e.g. normally, malfunctioning, security breach). While it is hard to draw firm conclusions it is the case that there was consistency across both studies when it came to which risk management actions were typically associated with harms. To the extent that a public policy maker or regulator takes into consideration public tolerances of harms, indirectly the findings presently suggest which are more and less tolerable based on the measures most commonly associated with them. That is, physical harm, property damage, and financial harms are less tolerable given that respondents typically preferring hard interventions (removing the product from market, issuing a fine to the business) when these harms are experienced, likely as a way to deter similar experiences repeating. This is not the case for psychological harm where the preferred risk management response was to add a warning label on the product (Study 1), or to collect more evidence to better understand the harm and the causes of it (Study 2). Many of the other new harms under consideration in response to new legislation (e.g., animal harm, environmental harm, societal harm) do not appear to be experienced frequently as indicated in Study 2. In part this may be because they are likely to be rare, as well as the fact that more needs to be done to make clear what the defining aspects of the harms are. Even if the public is unlikely to experience them, the details of the harms need to be accessible and tangible to users, businesses as well as policy and regulation itself.

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Supplementary materials

Detailed methods and analysis of findings of study 1 and 2

This section presents a comprehensive account of the methodology of Study 1 and Study 2 along with a detailed presentation of the findings, first presented as descriptive statistics, and where appropriate the inferential statistics used.

Study 1

The study was designed in mind of addressing the following objectives:

1. To understand the frequency and type of harms that people expect/experience from consumer products with internet connection in the home (i.e. smart products)
2. To understand the relationship between familiarity with consumer products with internet connection in the home (i.e. smart products) and experiences of occurrence of different harms
3. To understand the preferences for addressing the harms from consumer products with internet connection in the home (i.e. smart products)

To achieve this, the study was set up so that respondents would respond to a set of smart products which would likely vary according to their level of familiarity with them, from which they would appraise them according to occurrence of different harms, and preferred interventions to address different harms.

The survey study required respondents to respond to a series of questions around 15 smart products (Smart speaker; Smart Watch; Smart Doorbell; Smart Toothbrush; Smart Bluetooth Tracker; Smart Smoke Detector; Smart Vacuum Cleaner; Smart Cooker; Smart Baby Monitor; Smart Door Lock; Smart Pet feeder; Smart Toy Robot; Smart Glasses; Smart Teddy Camera; Smart Drill). Respondents were randomly allocated to respond to 5 out of the 15 smart products, the rationale for this being that in order to ensure high quality responses, and to not exhaust respondents, 5 smart products would be a reasonable number, and which they could respond to within a 10-minute online study.

The questions were divided into three sets (see Table 1). Set 1: questions asking which of 35 different smart products respondents currently owned, intended to buy, or had no wish to buy. Set 2: a question on familiarity with the smart product. This meant that for each smart product that respondents were invited to consider, they reported on their level of familiarity on a Likert scale ranging from 1 (not at all familiar) to 7 (extremely familiar). Along with this respondents were asked to give a categorical judgment about the likelihood that a harm (financial, physical, psychological, property damage) would occur or not within a 12-month period. That is, for each harm the question was posed with respect to three types of states of the smart product, there was an internet breach that led to unauthorised access, the product malfunctioned, and the product was performing normally. This meant that for each of the four harms, respondents responded either Yes (the harm would occur at least once in a 12-month period) or No, for each of the three possible described states of the smart product. Set 3: Respondents were then asked to consider for each harm for each possible state of the smart product which of four risk management actions they

judged to be most appropriate (remove product from the market the product, fine the business, issue a public campaign, add a warning label on the product).

In this way, the set up was controlled so that for every smart product that respondents were presented with, they would indicate their level of familiarity with it, their judgment as to the likely occurrence (or not) of the harm given each of three states of the product, and the corresponding risk management action, as judged by them to be the most appropriate. The aim here was to assess whether familiarity with the product impacted judgments of prevalence of four types of harm, and the severity of the risk management action. In addition, it was also possible to examine whether there is any correspondence between the prevalence of the harm and risk management action.

Prior to the main study respondents were required to provide their consent to taking part and to indicate their understanding of the requirements of the study, as per the ethics that were granted by Judge Business School ethics board, University of Cambridge (CJBS- 25-34). All respondents were then asked to provide their unique Prolific ID (the platform on which recruitment for respondents was conducted), their gender (male, female, if not specified please state, prefer not to say), their age (18-24, 25-34, 35 -44, 45-54, 55-64, 65+, prefer not to say), and if they were parent/guardian (yes – aged between 0-10, yes – aged between 11-18, both, no, prefer not to say).

All respondents took part in the study online using Qualtrics, and after completing the study they were reimbursed for their time. The study took approximately 10 minutes to complete, and respondents were reimbursed £2.00 for their time.

The study was nationally representative of UK users of smart products, based on age, gender, ethnicity, and where the first language was English, and that all respondents taking part reside in the UK. In total 1500 respondents were recruited, and 1464 respondents completed the study in full and so their findings are reported on in the analyses.

Of those, 1464 respondents 47.8% were male, 51.8% female, 0.3% identified as other, and 0.1% preferred not to say. The age break down was as follows, 18-24 (8.3%), 25-34 (16.9%), 35 -44 (17.5%), 45-54 (18.4%), 55-64 (26.5%), 65+ (12.1%), prefer not to say (0.2%). Regarding parent/guardian status, 70.8% indicated no, 12.5% indicated yes – aged between 0-10, 11% indicated yes – aged between 11-18, and 5.1% indicated both.

Table 1. Questions included in the main part of the survey for both smart and non-smart products.

Question	Forced choice Options	Open ended question instructions
Product Ownership. Indicate for each of the products listed below (total of 35 different smart products) whether you own one, are thinking about owning one... (e.g. - Ownership of a smart products - Smart Door Bell)	Yes I own one, Likely buy in 12 months time, Unlikely to buy/need to buy one	

Product Familiarity. How familiar are you with the above product?	*1 = Not at all familiar to 7 Extremely familiar*	
Occurrence of Harm. You may already own this product, if not, imagine owning and using this smart product for at least a year. (e.g. For each of the descriptions of harms that was caused by the smart aspect of the product select the option you think is most accurate: - An internet security breach that leads to financial harm)	Zero times, Once	
Risk management action. You may already own this product, if not, imagine owning and using this smart product for at least a year. (e.g. Now imagine that you have experienced each of descriptions of a harm that was caused by the smart aspect of the product, for each experience indicate which action you think is most appropriate. - An internet security breach that leads to financial harm)	The product is removed from the market (remove product from the market), The business will be required to pay a large fine (fine), There is a public campaign to inform people of how to protect themselves (public campaign), The law requires a new warning label to indicate the harm it can cause (warning label)	
Product review. Imagine you had the opportunity to write a review for a smart product that describes a negative experience based specifically on the smart aspect of the product. You can base the review on a negative experience of a smart product you own, or on an experience of someone close to you (i.e. a friend, colleague, family member).		Write the short review (2-3 sentences) in the box below. If you do not wish to write a review, simply type "NA" in the text box below.

Study 1 results

This section is divided into three overarching sections, the first explored patterns of responses in association with specific smart products, the second section explored relationships between familiarity and occurrence and risk management action, and the

third explored occurrence and risk management action. For the purposes of the present study only the quantitative data is analysed, though all data that was collected is publicly available (https://osf.io/sekdz/files/osfstorage).

Section 1: Patterns of responses associated with specific product (Study 1)

Level of Familiarity with the 15 different smart products

The first thing to clarify is that the likelihood that a respondent owned a smart product and then answered questions on it in the main survey was rare. Of those respondents that took part in Set 1 questions of ownership (N = 1063) (see Table 2), in theory there would be a total of 15945 responses of ownership if all 1063 respondents owned all 15 smart products that were included in the main study. In fact 4766 responses of ownership were indicated (29.9%). Of those 4766, only 134 matched with smart products that were presented to them that they owned. This is a very small sub-set so this cannot be a basis on which any analyses can be performed.

It is possible to draw some reasonable inferences though. In Table 2 we can see that estimates of familiarity loosely track the likelihood of a particular smart product being owned. That is, the greater the proportion of people owning a particular smart product, the higher the rating of familiarity with the product, irrespective of whether the individual providing their rating owns it or not. What this is implies is that there is likely to be a better understanding of the product, either because people are aware through media, or through other people they interact with that own those products.

Table 2. Mean, Standard Deviation and Variance of judgments of familiarity of each of the 15 smart products against current status of ownership of the 15 smart products

Smart Products	Currently Own	Likely buy	Unlikely buy	N	Mean rating familiarity	Std. Deviation	Variance
Smart Speaker	50.0	10.1	39.9	498	5.5	1.7	2.7
Smart Watch	45.1	12.6	42.3	494	5.5	1.7	2.8
Smart Doorbell	27.8	22.7	49.6	490	5.1	1.8	3.1
Smart Toothbrush	11.5	11.8	76.8	479	3.8	2.1	4.2
Smart Bluetooth Tracker	10.4	8.7	80.8	491	4.2	1.9	3.5
Smart Smoke Detector	9.5	15.4	75.1	490	3.4	2.1	4.3
Smart Vacuum Cleaner	7.9	12.7	79.4	482	4.2	1.8	3.3

Smart Cooker	5.2	8.0	86.8	496	3.1	1.8	3.1
Smart Baby Monitor	4.1	3.1	92.8	484	3.6	2.0	3.9
Smart Door Lock	3.3	12.2	84.5	481	3.4	1.9	3.6
Smart Pet feeder	2.8	8.0	89.2	494	3.3	1.9	3.8
Smart Toy Robot	2.2	3.0	94.8	487	2.7	1.7	2.9
Smart Glasses	2.2	8.5	89.4	483	3.5	1.8	3.3
Smart Teddy Camera	1.4	3.2	95.4	482	3.1	1.8	3.2
Smart Drill	1.2	3.7	95.1	486	2.3	1.7	2.8

Judgments of prevalence of harms associated with the 15 different smart products

There are several patterns indicated in the overall summary of judgments of prevalence for the various harms across the 15 different smart products (see Table 3). There was a high proportion of respondents indicating a harm occurring at least once in a 12-month period against specific types of smart products rather than a spread across all products. The highest rates overall appear against the Smart Door Lock smart product. Second, the highest rates (and second highest rates) congregate around four products: Smart Door Lock, Smart Glasses, and Smart Drill, Smart Oven. This suggests that respondents associated the occurrence of harms with particular products. In addition, the highest rates (e.g. range between 60% of respondents to 50% of respondent) were associated with the smart drill (for physical harm and property damage) and for the smart vacuum cleaner (for property damage).

While averages and standard deviations are a gross indicator of patterns given that the collapse across responses (e.g. either by rates across products, or across harms), nonetheless, it is worth noting that the highest mean proportion of respondents judging the occurrence of harms for a given product was for the Smart Door Lock, followed next by the Smart Drill, and then the Smart Cooker. When it came to harms, collapsed across all 15 products, the highest mean proportion of respondents judging the occurrence of the harm was for property damage as a result of the smart product malfunctioning, followed by physical harm of the product malfunctioning.

Table 3. Percentage of respondents indicating the occurrence of each of four types of harms (Financial, Physical, Property damage, Psychological) by the current state of the product (internet breach, malfunction, normal functioning) for each of the 15 smart products

Smart Products	Fin Breach	Fin Mal	Fin Norm	Phy Breach	Phy Mal	Phy Norm	Prop Breach	Prop Mal	Prop Norm	Psych Breach	Psych Mal	Psych Norm	Average & St dev
Smart Speaker	37	29	26	11	13	7	13	15	12	27	14	16	18, 9
Smart Watch	23	17	14	10	17	11	5	8	5	23	22	20	15,7
Smart Doorbell	26	21	16	13	12	9	25	27	19	26	17	17	19,6
Smart Toothbrush	14	13	9	15	38	32	10	16	10	13	19	15	17,9
Smart Bluetooth Tracker	26	17	17	15	11	9	14	11	10	27	17	17	16,6
Smart Smoke Detector	18	22	13	18	35	15	23	41	23	20	25	15	22,8
Smart Vacuum Cleaner	16	23	14	17	34	24	23	58	50	12	13	11	25,15
Smart Cooker	17	26	20	25	46	33	27	48	37	20	22	13	28,11
Smart Baby Monitor	22	18	15	21	24	17	15	17	11	34	30	25	21,7
Smart Door Lock	39	42	25	28	26	15	44	48	27	38	37	21	33,10

Smart Pet feeder	15	15	11	13	27	15	11	18	11	11	14	8	14,5
Smart Toy Robot	25	21	17	14	29	24	13	22	14	28	25	21	21,6
Smart Glasses	40	30	29	21	28	22	13	12	9	36	33	33	26,10
Smart Teddy Camera	35	23	23	22	19	16	21	20	14	35	29	27	24,7
Smart Drill	13	20	13	21	57	47	24	60	49	10	24	14	29,18
Average & St dev	24,9	22,7	17,6	18,5	28,13	20,11	19,10	28,18	20,14	24,9	23,7	18,6	24,9

Judgments of risk management action for each of the four harms associated with each of the 15 different smart products

There are several patterns worth highlighting as indicated in Table 4 with respect to preferred risk management action for each of the four types of harms. Three smart products were associated with the highest and second highest proportions of respondents selecting a risk management action relative to the other smart products: Smart Doorbell, Smart speaker, and Smart vacuum cleaner. For the smart vacuum cleaner the most frequent risk management action against harms (physical damage, physical harm, psychological harm) was either a public campaign or a warning label. For the Smart speaker the most frequent risk management action against harms (financial harm, physical harm, property damage) was to remove product from the market the product. For the smart doorbell the most frequent risk management action against harms (financial harm, physical harm, psychological harm) was removal of the product from the market of the product.

While averages and standard deviations are gross indicator of patterns here because they collapse across product or risk management action, it is worth noting the following. There is little to differentiate smart products according to averaged proportions of respondents selecting risk management actions, this is because by default, respondents were required to select a risk management action for each of the harms, which is why the average proportions are ~25%, and the standard deviations are approximately the same.

The more interesting pattern is with respect to the overall preferred risk management actions against particular harms, collapsed across smart products. For physical harms the highest mean proportion of respondents selected fining the business was ~55%, for property damage the highest mean proportion of respondents selected fining the business was ~40% and for financial harm the highest mean proportion of respondents selected remove product from the market the product was ~37%, and for psychological harm the highest mean proportion of respondents selected adding a warning label to the product was ~32%.

Table 4. Mean[3] Percentage of respondents indicating their recommendations for risk management action by harm (Financial, Physical, Property damage, Psychological) for each of the 15 smart products

Smart Products	Fin Fine	Fin Remove product from the market	Fin Camp	Fin Label	Phy Fine	Phy Remove product from the market	Phy Camp	Phy Label	Prop Fine	Prop Remove product from the market	Prop Camp	Prop Label	Psych Fine	Psych Remove product from the market	Psych Camp	Psych Label	Average & STdev
Smart Speaker	21	44	10	20	52	22	8	15	39	32	10	19	18	21	24	35	24,13
Smart Watch	25	37	8	16	58	19	7	15	43	28	8	17	23	24	24	33	24,14
Smart Doorbell	25	43	13	19	51	22	9	18	35	31	13	20	23	22	24	34	25,11
Smart Toothbrush	24	42	10	19	55	21	8	15	42	31	10	18	24	23	24	31	25,13
Smart Bluetooth Tracker	25	41	7	18	55	21	6	15	38	31	7	18	21	23	22	33	24,13
Smart Smoke Detector	26	22	8	19	57	16	7	14	48	21	8	15	27	30	24	31	23,14
Smart Vacuum Cleaner	21	38	11	21	46	20	10	20	29	28	11	29	17	24	26	35	24,10
Smart Cooker	23	30	8	18	56	19	6	16	45	25	8	15	21	27	22	34	23,13
Smart Baby Monitor	29	32	8	17	65	18	7	11	46	26	8	18	27	26	20	32	24,15

[3] mean over all three types of states of a product associated with each of the four harms

Smart Door Lock	30	39	8	14	54	20	8	13	42	30	8	15	24	23	22	31	24,13
Smart Pet feeder	21	44	10	19	56	22	7	15	39	32	10	20	24	21	24	31	25,13
Smart Toy Robot	28	44	7	14	62	21	6	13	45	32	7	17	28	22	20	31	25,16
Smart Glasses	22	34	11	17	55	19	8	14	36	27	11	18	22	25	23	33	23,12
Smart Teddy Camera	26	44	8	16	59	22	7	14	42	32	8	19	24	21	23	32	25,14
Smart Drill	21	26	12	19	51	18	10	16	34	23	12	22	21	28	26	31	23,10
Average & Stdev	24,3	37,7	9,2	18,2	55,5	20,2	8,1	15,2	40,5	29,4	9,2	19,3	23,3	24,3	23,2	32,2	

Section 2: Familiarity and occurrence of harms and risk management action (Study 1)

Establishing criteria on which to classify responses according to levels of familiarity

In order to explore the relationships between familiarity with the smart product and other dependent variables, the option taken here was to split the sample according to three levels of familiarity of the product. This meant converting responses on the scale from 1 (not at all familiar) to 7 (extremely familiar), and re-code the scores so that 1 and 2 are classified as Not familiar, 3,4 and 5 are classified as Moderately familiar, and 6 and 7 are classified as Extremely Familiar. To check whether this was feasible chi-squared analysis was performed using ratings whether or not a harm would occur at least once in a 12-month period (collapsed across all four harms) and compare the rates for those giving a familiarity rating for the product 1 against those that gave the familiarity rating of the product a 2. This same logic was applied to all three new categories of familiarity. There were no substantive differences when a chi-squared analysis was applied, and the effect sizes were very low ($eta^2 = 0.001$) to low ($eta^2 = 0.01$) for each comparison performed. This provided a reasonable basis for combining scores of familiarity in order to classify them into three categories: Extremely familiar, Moderately familiar, Not familiar.

Relationship between familiarity with the smart product and judged occurrence of different types of harms

A detailed analysis was performed here to examine the extent to which familiarity with the smart product differentiates judgments as to the occurrence of each of the four types of harm. Based on the superficial pattern of results reported in Table 5, there are two things that are implied. First is that as unfamiliarity increases, broadly the proportion of respondents indicating the occurrence of harm increases. Second, the judgements of the occurrence of harm differs between harms and by familiarity, it appears that the proportion of respondents judging the occurrence of financial harms is broadly the same for all level of familiarity with smart products, but familiarity differentiates much more starkly for physical harm and property damage.

Table 5. Summary of total of respondents judging a harm will be present at least once in a 12-month period collapsed across the causes of the harm

	Financial Harm	Physical Harm	Property Damage	Psychological Harm
Not familiar (n = 2543)	1621 (64%)	1900 (75%)	1919 (75%)	1750 (69%)
Moderately Familiar (n = 2893)	1918 (66%)	1776 (61%)	1802 (62%)	1954 (68%)
Extremely Familiar (n = 1881)	1198 (63%)	1038 (55%)	970 (52%)	1087 (58%)

The chi-squared analysis compared the three different levels of familiarity against the frequency of judging the occurrence of each of the four harms at least once over a 12-month period of using the smart product. The analysis revealed that there does appear to be substantive difference in the judgment of occurrence of harm by level of familiarity, χ^2 (6) = 69.51, p = 0.00005, Eta^2 = 0.003). The effects sizes indicated that difference in response patterns is driven largely by familiarity (Eta = 0.057) than harm (Eta = 0.025).

Next, the inferential tests performed using Chi-squared compared Extremely Familiar with Not Familiar categories of responses to determine differences in judged occurrence of harm for each type of contributor to the harm (i.e. internet security breach, Normal functioning of the product, product malfunction) (see Table 6). The rationale for focusing on only these two categories of familiarity is that they are the most extreme of each other, and there would be an expectation that familiarity differentiated responses to other dependent variables, it would be located when comparing extremes.

Table 6. Inferential statistics (Chi-squared) of total of respondents judging a harm will be present at least once in a 12-month period for each of the three different causes of harm, where comparisons were made between Extremely familiar with the smart product and not unfamiliar with the smart product.

	Financial Harm	**Physical Harm**	**Property Damage**	**Psychological Harm**
Internet security breach	χ^2 (1) = 1.06, Eta = 0.015	χ^2 (1) = 10.37, Eta = 0.048	χ^2 (1) = 10.94, Eta = 0.05	χ^2 (1) = 1.95, Eta = 0.021
Normal function of the product	χ^2 (1) = 0.51, Eta = 0.011	χ^2 (1) = 68.76, Eta = 0.125	χ^2 (1) = 55.1, Eta = 0.112	χ^2 (1) = 19.91, Eta = 0.067
Product malfunctioning	χ^2 (1) = 0.18, Eta = 0.006	χ^2 (1) = 45.17, Eta = 0.101	χ^2 (1) = 25.99, Eta = 0.077	χ^2 (1) = 9.26, Eta = 0.046

The findings suggest that more respondents in the Not Familiar category judge a harm will be experienced as a result of an internet security breach compared to those in the Extremely familiar category: Financial harm (NF = 600 vs EF = 469*[4]), Physical Harm (NF = 478 vs EF = 284), Property Damage (NF = 516 vs EF = 308), Psychological Harm (NF = 619 vs EF = 424*).

We see the same pattern when it comes to harms that result from the normal functioning of the product. More in the Not familiar category judge a harm will be experienced as a result of the normal function of the product compared to those in the Extremely familiar category: Financial harm (NF = 441 vs EF = 317*), Physical Harm (NF = 591 vs EF = 284), Property Damage (NF = 580 vs EF = 312), Psychological Harm (NF = 496 vs EF = 300).

This pattern is also consistent for harms resulting from the smart product malfunctioning. That is, more in the Not familiar category judge a harm will be experienced as a result of the product malfunctioning compared to those in the Extremely familiar category: Financial

[4] * = weak effect

harm (NF = 580 vs EF = 412*), Physical Harm (NF = 831 vs EF = 402), Property Damage (NF = 823 vs EF = 418), Psychological Harm (NF = 635 vs EF = 363).

In summary, the pattern of findings suggests that fewer Extremely familiar with a smart product judge the occurrence of harms within a 12-month period than those Not familiar with a smart product, and this pattern generally persists regardless of the state of the smart product (breached, malfunctioning, functioning normally).

Relationship between familiarity with the smart product and different types of harms by different causes and proposed action in response

The next question that is considered is the extent to which familiarity with the product impacted choice of risk management action. Here a chi-squared analysis was conducted examining the frequency of the most commonly selected risk management action for each of the harms, comparing the responses according to those that had indicated Extreme Familiarity with the smart product against those that had indicated No familiarity with the smart product.

Table 7. The percentage of respondents that had indicated either Extremely familiar (EF) or not familiar (NF) with the smart product for each harm according to each of the possible causes of harm, and the corresponding selection of risk management action, where the most popular selection is reported.

	Financial NF = 2543 EF = 1881	**Physical** NF = 2543 EF = 1881	**Property Damage** NF = 2543 EF = 1881	**Psychological Harm** NF = 2543 EF = 1881
Internet security breach	NF 48% Fine EF 48% Fine	NF 54% Remove product from the market EF 49% Remove product from the market	NF 37% Remove product from the market EF 37% Fine	NF 29% Label EF 29% Label
Normal function of the product	NF 38% Fine EF 39% Fine	NF 58% Remove product from the market EF 52% Remove product from the market	NF 45% Remove product from the market EF 39% Remove product from the market	NF 38% Label EF 36% Label
Product malfunctioning	NF 44% Fine EF 47% Fine	NF 66% Remove product from the market	NF 49% Remove product from the market	NF 33% Label EF 31% Label

		EF 61% Remove product from the market	EF 45% Remove product from the market	

Examining the pattern of response indicated in Table 7, there are considerable similarities with Table 6 which reported the proportion of respondents that judged at least one occurrence of harm within a 12-month period or did not expect the harm to occur, by the most common risk management action. The most commonly chosen risk management actions were fines and remove product from the market, with fines most commonly chosen regardless of cause of harm for financial harm, and remove product from the markets most commonly chosen regardless of cause for physical harm. Overall, the rates of selection of remove product from the market as a risk management action were higher overall compared with other risk management actions, and the least popular appears to be public campaigns which were not a common option for any type of harm. In addition, we see that there is a tendency toward common risk management actions to be selected at higher rates for those Not familiar with the smart products than Extremely familiar with the products, with a few exceptions.

For internet security breach and for malfunctioning, the chi-squared analysis revealed that there was no substantive difference by level of familiarity (Extremely familiar, Not familiar) and risk management action selected for each harm ($p > 0.8$) and very low effect sizes (internet security breach $Eta^2 = 0.0004$, malfunction $Eta^2 = 0.001$). However, there was a difference for harms caused by normal functioning of the product ($\chi^2(3) = 54.73$, $p = 0.000007$, $Eta^2 = 0.007$). Turning to Table x we can see why it is the case that the analysis revealed differences. For financial harm and for psychological harm the rates of selection of the most common risk management action are approximately the same, the key differences seem to be locate for physical harm and property damage. For property damage and for physical harm, more of those Not familiar with the products opted to remove product from the market the product compared with those Extremely familiar with the products.

In summary the pattern suggests level of familiarity with the product contributes less to the selection of risk management action than the cause of the harm, and the specific harm itself. Overall, fines and remove product from the markets were the most popular, where fines were most commonly associated with financial harm, and remove product from the markets were associated most commonly with physical harm and property damage, the most common risk management action for psychological harm was adding a warning label to the product.

Section 3: Occurrence of harms and risk management action (Study 1)

Relationship between judged occurrence of different types of harms by different causes and proposed action in response

The aim here is to examine what the most popular option is in terms of risk management action given a particular harm, of which there were four types of actions: Removal the smart product from the market (Remove product from the market), Issue a large fine to the business (Fine), put out a public campaign to inform users of the product of potential

issues (Campaign), or add a warning label on the packaging of the product (Label). In addition, given that there were descriptions of what might have caused the harm (i.e. internet security breach, normal functioning of the product, product malfunction), it was possible to examine the extent to which the possible cause of harm, for each harm, impacted the choice of risk management action. In order to explore this, for each possible cause of harm (breach, normal functioning, malfunctioning) the analysis examined if this impacted the choice of risk management action (Remove product from the market, Fine, Campaign, Label), for each harm (Financial, Physical, Property, Psychological).

To begin with, given that respondents were invited to judge whether or not a harm would likely occur within a 12-month period corresponding to a particular cause of that harm, it was worth exploring if this would influence choice of risk management action. Looking at the pattern of findings reported in Table 8 there are four striking patterns. First, for normal function and for malfunctioning products, there appeared to be considerable consistency in the most commonly selected risk management action. Second, fining a business and remove product from the market a product were more commonly selected risk management actions than adding a warning label; public campaigns did not feature as a common risk management action for any harm. Third, regardless of the cause of harm, for financial harm the most commonly selected risk management action was issuing a fine to the business, and for physical harm the most commonly selected risk management action was remove product from the market the product. Fourth, overall, of all possible risk management actions for any of the harms, when it came to physical harm, remove product from the market the product was generally selected more frequently than any other risk management action.

For each cause of harm, a chi-squared analysis was conducted examining the frequency of the most commonly selected risk management action for each of the harms, comparing the responses according to those that judged the harm would occur at least once in 12 months against those that judged the harm would not occur within a 12-month period. Given this, the next step was to consider the extent to which expecting a harm to occur at least once would lead to selections of more punitive corrective measures than not expecting a harm to occur.

Table 8. The percentage of respondents that had judged the occurrence of each harm according to each of the possible causes of harm, and the corresponding selection of risk management action, where the most popular selection is reported.

	Financial None = ~5500 Once = ~ 1700	**Physical** None = ~6000 Once = ~ 1250	**Property Damage** None = ~5800 Once = ~ 1300	**Psychological Harm** None = ~5500 Once = ~ 1700
Internet security breach	None 47% Fine Once 52% Fine	None 51% Remove product from the market Once 47% Remove	None 37% Fine Once 37% Fine	None 29% Label Once 29% Fine

		product from the market		
Normal function of the product	None 38% Fine Once 42% Fine	None 56% Remove product from the market Once 50% Remove product from the market	None 42% Remove product from the market Once 36% Remove product from the market	None 36% Label Once 39% Label
Product malfunctioning	None 46% Fine Once 48% Fine	None 63% Remove product from the market Once 60% Remove product from the market	None 46% Remove product from the market Once 42% Remove product from the market	None 32% Label Once 31% Label

For normal functioning and for malfunctioning, the chi-squared analysis revealed that there was no substantive difference in the frequency of the popular risk management action selected by each harm ($p > 0.1$) by judged occurrence of harms and very low effect sizes (normal function $Eta^2 = 0.001$, malfunction $Eta^2 = 0.0007$). However, there was a difference for harms associated with an internet security breach ($\chi^2 (3) = 13.53$, $p = 0.004$, $Eta^2 = 0.003$). Turning to Table 8 we can see why it is the case that the analysis revealed differences. First, with the exception of property damage, that the frequency of the risk management action that was the most popular for psychological harm differed by risk management action. Also, the most popular risk management action (i.e. Fine) was more frequently selected by those that estimated financial harm occurring once in 12-months, and the most common risk management action (i.e. Remove product from the market) was more frequently selected by those that did not expect physical harm to occur in a 12-month period.

In summary the pattern suggests that the extent to which a harm is expected to occur within a 12-month period or not expected contributes less to the selection of risk management action than the cause of the harm, and the specific harm itself. Overall, fines and remove product from the markets were the most popular, where fines were most commonly associated with financial harm, and remove product from the markets were associated most commonly with physical harm and property damage, the most common risk management action for psychological harm was adding a warning label to the product.

Risk management action in association with different states of the product and different harms

The aim here is to examine if respondents were sensitive to the state of the product (i.e. internet breach had occurred, the product malfunctioned, the product was functioning normally) when choosing which was the most appropriate risk management action for each of the four types of harms. The patterns as indicated in Table 9 suggest that in the

main, at least four three of the four harms, regardless of the state of the smart product, the most popular risk management action for financial harm was to issue a fine to the business, remove product from the market the product when physical harm had occurred, and add a warning label when psychological harm had been experienced. It is only for property damage there were differences. That is, when an internet breach had occurred the most popular choice was to fine the business, and when the product malfunctioned or functioned normally and property damage occurred the product should be remove from the market. The second pattern that is noteworthy is that relative to other types of risk management action, for those harms for which the popular risk management action was consistent regardless of the state of the product, there were differences. For example, for financial harms, more selected fining the business when an internet breach had occurred compared to a malfunction or normal functioning product. More selected remove product from the market the product when it malfunctioned anda physical harm had been experienced relative to the other possible states. Also, more selected adding a warning label when a psychological harm had been experienced through the normal functioning of the product, relative to the other possible states.

Chi-squared analyses were performed separately for each of the four types of harms, examining the different frequencies of selection of risk management actions under the three possible states of the smart product. All analyses showed substantive differences: financial harm (χ^2 (6) = 288.57, $p < 0.000001$, $Eta^2 = 0.007$); physical harm (χ^2 (6) = 522.85, $p < 0.000001$, $Eta^2 = 0.01$), property damage (χ^2 (6) = 400.28, $p < 0.000001$, $Eta^2 = 0.001$); psychological harm (χ^2 (6) = 293.27, $p < 0.000001$, $Eta^2 = 0.01$). The analysis confirms that there are clear differences between which risk management action is popular for each type of harm and generally support the pattern as indicated in Table 9.

Table 9 Summary of frequency of selected risk management actions for each possible state of the smart product by each of the four types of harms.

		Internet Breach	**Malfunction**	**Normal Functioning**
Financial Harm	Fine	3532	3382	2829
	Remove product from the market	1634	1970	1745
	Campaign	1024	777	1154
	Label	1127	1188	1589
Physical Harm	Fine	2005	1509	1258
	Remove product from the market	3677	4534	3979
	Campaign	669	377	648
	Label	966	897	1432
	Fine	2719	2346	1950

Property Damage	Remove product from the market	2557	3286	2972
	Campaign	804	460	765
	Label	1237	1225	1630
Psychological Harm	Fine	1960	1509	1223
	Remove product from the market	1591	1862	1578
	Campaign	1653	1594	1847
	Label	2113	2352	2669

Study 2

The survey study required respondents to report on their experiences for a smart product they owned, and a non-smart product they owned. This results in two sets of experiences that could be compared across respondents. What was not controlled was the products that respondents were required to report on, though the aim here was not to constrain this in order to assess whether there is typical product categories from which respondents spontaneously reported experiencing harms.

The design was simple in that the order in which respondents reported their experiences was randomised, that is they could either report on experiences based on smart products first then non-smart products, or vice versa. In addition, the options presented to respondents for the forced-choice questions were randomised, but the order of the questions was fixed for each participant. The order of the questions is presented in Table 10 along with the options that were available to them for the force-choice questions of which there were five and three open questions.

Prior to the main study respondents were required to provide their consent to taking part and to indicate their understanding of the requirements of the study, as per the ethics that was granted by Judge Business School ethics board, University of Cambridge (CJBS- 26-14). All respondents were then asked to provide their unique Prolific ID (the platform on which recruitment for respondents was use), their gender (male, female, if not specified please state, prefer not to say), their age (18-24, 25-34, 35 -44, 45-54, 55-64, 65+, prefer not to say), and if they were parent/guardian (yes – aged between 0-10, yes – aged between 11-18, both, no, prefer not to say).

All respondents took part in the study online using Qualtrics, and after completing the study they were reimbursed for their time. The study took approximately 20 minutes to complete, and respondents were reimbursed £4.00 for their time.

The study was nationally representative of UK users of smart products, based on age, gender, ethnicity, and where the first language was English, and that all respondents taking part reside in the UK. In total 506 respondents took part. Of those, 497 respondents completed the study in full so that their responses could be entered into analyses. Of the 497, 47.9% were male, 51.1% female, 0.6% identified as other, and 0.4% preferred not to say. The age break down was as follows, 18-24 (10.7%), 25-34 (17.1%), 35 -44 (16.3%), 45-54 (17.1%), 55-64 (27.8%), 65+ (10%), prefer not to say (0%). Regarding

parent/guardian status, 68.2% indicated no, 12.7% indicated yes – aged between 0-10, 12.1% indicated yes – aged between 11-18, and 6.6% indicated both.

While all 497 respondents were required to provide responses to a product they owned that was smart and again for a non-smart product, when examining the free text, it was clear from the details provided that the products that they were basing their responses on did not always correspond to the instructions. In many cases respondents reported on experiences related to smart products under the condition labelled “non-smart products”. Thus, after careful review, responses were classified according to the actual type of product that respondents were basing their responses on. In total 965 responses were used, where the split was based on 412 responses for non-smart products, and 553 responses for smart products.

Table 10. Questions included in the main part of the survey for both smart and non-smart products.

Question	Forced choice Options	Open ended question instructions
Product Ownership. Indicate for each of the products listed below whether you own one (total of 35 different smart products), are thinking about owning one... (e.g. - Ownership of a smart products - Smart Door Bell)	Yes I own one, Likely buy in 12 months time, Unlikely to buy/need to buy one	
Product type. Described the product on which you are basing your responses on		Provide a one to two word description in the text box provided
Ownership. Select from the options below the one that most closely corresponds to how long you have owned the product	A month; 6 months; A year; 2 to 5 years; More than 5 years	
Usage. Select from the options how often you use the product	Daily; 4-6 times a week; 2-3 times a week; Once a week; Once or twice a month; Annually (once or twice a year)	
Problem. Described the overall type of problem you had with the product		Provide a word or two description in the text box provided
Harm. Select any of the relevant options provide that were associated the problem that the product caused. You can select more than one option.	Physical Harm - this is where there was some injury to you, or to other people in the household; Psychological Harm - this is where you experienced a negative impact on your wellbeing for longer than a few days, or other people in the house hold experienced a negative impact on their wellbeing for longer than a few days; Property Damage - this is where the contents of your home or the physical structure of the building itself was damaged in some way ; Animal Harm - this is where there was some injury to pets in the	

	home; Societal Harm - wide spread failures that individually or in combination would undermine the stable functioning of society (incl. digital technologies that pose major disruption to national infrastructure - such as hospitals, power grid, transport); Environmental Harm - this is where harm was caused to the quality of your water supply, air pollution, harm to your garden or other areas around the location you are resident in; Financial harm - this is where the problem lead to costs in dealing with the problem that the product caused; No Harm	
Review. This is your opportunity to write a review like a product review you often see online. In this case write the review for a consumer product in the home that describes a negative experience. You can base the review on a negative experience of a consumer product you own, or on an experience of someone close to you that owned the product (i.e. a friend, colleague, family member).		Write the short review (2-3 sentences) in the text box provided
Responding to a harm from the product. This is your chance to indicate what you think is a priority harm that the government regulator of consumer products should focus on concerning the smart product you wrote your product review about.	Physical Harm - this is where there was some injury to you, or to other people in the household; Psychological Harm - this is where you experienced a negative impact on your wellbeing for longer than a few days, or other people in the house hold experienced a negative impact on their wellbeing for longer than a few days; Property Damage - this is where the contents of your home or the physical structure of the building itself was	

	damaged in some way ; Animal Harm - this is where there was some injury to pets in the home; Societal Harm - wide spread failures that individually or in combination would undermine the stable functioning of society (incl. digital technologies that pose major disruption to national infrastructure - such as hospitals, power grid, transport); Environmental Harm - this is where harm was caused to the quality of your water supply, air pollution, harm to your garden or other areas around the location you are resident it; Financial harm - this is where the problem lead to costs in dealing with the problem that the product caused.	
Action. This is your opportunity to suggest what you think the appropriate action should be if you could recommend an intervention in response to the negative experience described in your product review of the non-smart product. Select **only one** of the options provided.	Collect more evidence to better understand the nature of the harm associated with the smart product; The smart product should be removed from the market; The business that developed the smart product should be required to pay a fine; There should be a new warning label on the smart product; There should be a public campaign informing people of the issues concerning the smart product	

Study 2 Results

This section is divided into three overarching sections, the first explored patterns of responses in association with specific smart products and ownership across Study 1 and Study 2, the second section the prevalence of harms, and the third explored the relationship between harms and risk management action. For the purposes of the present study the only qualitative data that was analysed for the purposes of addressing objectives 1-4 was the description provided of the product which support all other quantitative data analysed. The remaining qualitative data that was collected is publicly available (https://osf.io/sekdz/files/osfstorage). Moreover, while the study considered harms in association with smart products and non-smart products, only responses to smart products are considered in the analyses, for the reason that patterns across Study 1 and Study 2 could be considered.

Section 1: Ownership of smart products (Study 1 & 2)

A cursory analysis was performed to determine the frequency of respondents that reported owning the 15 products that were the basis of Study 1 with those reporting owning them in Study 2. A chi-squared analysis revealed that there was no difference in rates of ownership between Study 1 and Study 2, (χ^2 (13) = 5.52, p = 0.96, Eta^2 = 0.001). The same analysis was conducted but this time for respondents indicating their likelihood of buying the smart product, again there was no substantive difference between Study 1 and Study 2, (χ^2 (13) = 8.27, p = 0.83, Eta^2 = 0.003). There was however a difference in rates of unlikely to buy/need the products between Study 1 and 2, though the effect was weak, (χ^2 (13) = 25.28, p = 0.02, Eta^2 = 0.001). The implication being that few respondents were unlikely to buy/need the products in Study 2 compared to Study 1 (see Table 11).

Because this was a forced choice question, respondents had to indicate whether they own, likely to buy, unlikely to buy the product, while there is no difference based on ownership and intentions to buy, there should also be no substantive difference between unlikely to buy. Given that the effect was weak, it is fair to say that the general findings suggest little to no main difference between Study 1 and Study 2, at least based on patterns of ownership and likelihood or not of buying the 15 products included in Study 1.

Table 11 Proportion of respondents in Study 1 (n = 1063) and Study 2 (n = 505) that indicated the status of ownership (own, likely to buy, unlikely to buy) of 35 different smart products. The first 15 products were included in Study 1.

Smart Products	Currently Own (Study 1)	Currently Own (Study 2)	Likely buy (Study 1)	Likely buy (Study 2)	Unlikely buy (Study 1)	Unlikely buy (Study 2)
Smart Speaker	50	63.4	10.1	10.5	39.9	26.1
Smart Watch	45.1	52.2	12.6	14.8	42.3	33
Smart Doorbell	27.8	37.4	22.7	21.5	49.6	41.1
Smart Toothbrush	11.5	15.8	11.8	14.6	76.8	69.6
Smart Bluetooth Tracker	10.4	13.6	8.7	11.9	80.8	74.5
Smart Smoke Detector	9.5	11.5	15.4	18.6	75.1	70
Smart Vacuum Cleaner	7.9	8.9	12.7	18	79.4	73.1
Smart Cooker	5.2	7.3	8	10.5	86.8	82.2
Smart Baby Monitor	4.1	4.2	3.1	4.5	92.8	91.3

Smart Door Lock	3.3	5.1	12.2	12.6	84.5	82.2
Smart Pet feeder	2.8	4.5	8	10.1	89.2	85.4
Smart Toy Robot	2.2	1.6	3	4	94.8	94.5
Smart Glasses	2.2	3	8.5	10.9	89.4	86.2
Smart Teddy Camera	1.4	0.6	3.2	3.4	95.4	96
Smart Drill	1.2	1	3.7	3.8	95.1	95.3
Smart TV	78	85	7.4	5.9	14.6	9.1
Smart Fitness Tracker	33.4	36	13.7	14.2	52.9	49.8
Smart Light Bulb	27.1	35.6	14.9	15.8	58	48.6
Smart Plug	24.5	29.4	13.6	15	61.9	55.5
Smart Thermostat	23.6	33	14.4	18.8	62	48.2
Smart Washing Machine	16.7	21.1	12.6	14.2	70.7	64.6
Smart Radio	12.5	12.1	6.5	10.3	81	77.7
Smart Motion Detector	11.4	14.4	9.7	12.5	78.9	73.1
Smart Air Purifier	6.8	7.9	9.8	12.8	83.4	79.2
Smart Fridge	6.2	10.3	11.7	15.6	82.1	74.1
Smart Kettle	5.1	5.9	12.2	14.8	82.7	79.2
Smart Unit Charger	4.8	8.3	8.6	8.7	86.6	83
Smart Electric Blanket	3.3	4.7	6.3	7.5	90.4	87.7
Smart Shower	2.7	1.4	8.2	6.9	89.1	91.7
Smart Mirror	2	2.8	4	5.9	94.1	91.3
Smart Measuring Tape	1.8	2	4.9	5.1	93.3	92.9
Smart Clothing	1.6	2.2	4.2	3	94.2	94.9
Smart Baby Rocker	1.1	1.4	2	3	96.9	95.7
Smart Power Saw	0.8	1.4	3.3	2.6	96	96
Smart Nappies	0.6	0	1.8	1.8	97.6	98.2

Smart Products volunteered by respondents

After carefully examining the descriptions of the products that respondents volunteered to answer questions around harms and risk management action, it was clear that 553[5] respondents described smart products that they wished to answer questions regarding harms and risk management action. Table 12 presents the frequency of smart products that respondents based their responses to questions around harms and risk management action. It is no surprise that the most common smart products on which respondents based their responses on correspond with the smart products most commonly owned (Smart TV, Smart Speaker, Smart Doorbell), though the range (a total of 43 products) indicates that

[5] The total sample in the study was 497, and each respondents was asked to complete all questions on harms and risk management action once for a smart product they had experienced an issue with, and again for a non-smart product they owned that they had experienced an issue with. Despite the instructions, some respondents chose to response to harms and risk management actions twice with reference to a smart product they owned. Because of this, there was no even distribution of respondents for smart products and non-smart products.

while not common, there is clearly a diverse range of smart products that generate issues of some concern.

Table 12 Frequency and percentage of smart products volunteered by respondents in Study 2 that they based their responses on. Rows highlighted in blue indicate products that were also in Study 1.

Smart Products	Frequency	%	Smart Products	Frequency	%
Smart TV	155	28.0	Smart Air Fryer	1	0.2
Smart Speaker	116	21.0	Smart Blanket	1	0.2
Smart Doorbell	59	10.7	Smart Cat Flap	1	0.2
Smart Watch	43	7.8	Smart Electric Vehicle Charger	1	0.2
Smart Thermostat	21	3.8	Smart Fire Alarm	1	0.2
Smart Light Bulb	18	3.3	Smart Hairdryer	1	0.2
Smart Plugs	14	2.5	Smart Health Monitor	1	0.2
Smart Washing Machine	14	2.5	Smart Keyboard	1	0.2
Smart Vacuum Cleaner	13	2.4	Smart Kitchen Appliance	1	0.2
Smart Fitness Tracker	11	2.0	Smart Motion Detector	1	0.2
Smart Fridge	9	1.6	Smart Oven	1	0.2
Smart Security Camera	9	1.6	Smart Pet Feeder	1	0.2
Smart Energy Meter	7	1.3	Smart Smoke Alarm	1	0.2
Smart Door Lock	6	1.1	Smart Toaster	1	0.2
Smart Phone	6	1.1	Smart Toothbrush	1	0.2
Smart baby monitor	5	0.9	Smart VR Headset	1	0.2
Smart Dishwasher	5	0.9	Smart Weighing Scales	1	0.2
Smart Kettle	4	0.7	Broadband router	1	0.2
Smart Lights	4	0.7	Laptop	1	0.2
Smart Headphones	3	0.5			
Smart Home Security System	3	0.5			
Smart Printer	3	0.5			
Smart Radio	3	0.5			
Smart Bathroom Scales	3	0.5			

Section 2: Types of harms and where they are found

Given the range of products volunteered by respondents, examining the relationship between specific harms and particular products would be difficult. The focus here was to look at the four most commonly volunteered products to see if there were any patterns in the harms that people reported they had experienced (see Table 13). The first thing to emphasise is that respondents were instructed to base their responses to questions regarding a smart product they had particular issues with, this did not necessarily entail that they had experienced any direct harm as a result of the issue they had. For this reason, we see that for all four types of products, while there was a product issue, for most, there was no harm experienced. Of all three products more harms were experienced (proportionally) for smart doorbells, of which the most frequent was psychological harm. For Smart Speakers and Smart Watches the most frequently reported harm was psychological harm, whereas for Smart TVs the most frequently reported harm was financial.

Table 13 Percentage of harms associated with the four most commonly volunteered smart products in Study 2.

Harm	**Smart TV** (n = 155)	**Smart Speakers** (n = 116)	**Smart Doorbell** (n = 59)	**Smart Watch** (n =43)
No Harm	66%	72%	44%	70%
Financial	17%	8%	17%	9%
Physical	0	0	3%	5%
Property	0	2%	3%	0
Psychological	16%	17%	29%	26%
Environmental	0	1%	0	0
Societal	0	0	2%	0
Animal	0	0	0	0

We can also consider length of time the product was owned and different proportions of harms experienced (see Table 14). In this case this is irrespective of the product type itself which could not be analysed given there were uneven numbers of respondents to the different types of products they volunteered to answer questions on. Again, the vast majority of respondents did not experience a harm. When harms had been experienced,

they were psychological and financial harm. The other pattern implied in Table 14 is that there seem to moderately more harms experienced in the first six months of owning the product and owning it for more than two years than when owned for a single year. Similarly, proportionally more seem to report no harms experienced in the first six months of owning the product and after more than two years of owning it than owning it for a single year.

Table 14 Percentage of harms by length of ownership[6] of the smart product in Study 2.

Harm	One to Six Months	One Year	More than 2 years
No Harm	52%	32%	66%
Financial	14%	8%	13%
Physical	5%	2%	1%
Property	8%	5%	1%
Psychological	20%	14%	17%
Environmental	2%	1%	1%
Societal	0	0	0
Animal	0	0	0

Even if products are owned and for a considerable length of time, this does not necessarily correspond to the frequency with which they are used. Therefore, it was also important to consider if particular harms occurred more often than others depending on the frequency of their usage (see Table 15). The main pattern that emerges is the vast majority do not experience harms regardless of the usage of the product, though proportionally more had not experienced harms using the product on a weekly basis than daily or infrequently (i.e. multiple times in the year). The second pattern, consistent with length of ownership, is that financial and psychological harms were experienced more than other harms regardless of how often the smart product was used.

Table 15 Percentage of harms by frequency of usage[7] of the smart product in Study 2.

Harm	Daily	Multiple times a week	Multiple times in a year
No Harm	58%	69%	56%

[6] There was a total of 5 options (one month, 6 months, one year, 2-5 years, more than 5 years) however, there were so few responses for some of these options that they were merged; one month and 6 months were merged and 2-5 years and more than 5 years were merged.

[7] There were 6 options (daily, 4-6 times a week, 2-3 times a week, once a week, once or twice a month, annually) however, there were so few responses for some of these options that they were merged; 4-6 times a week and 2-3 times a week were merged, and once a week, once or twice a month, annually were merged.

Financial	14%	13%	8%
Physical	2%	1%	6%
Property	2%	6%	0
Psychological	22%	8%	22%
Environmental	1%	3%	3%
Societal	0	0	3%
Animal	0	0	3%

Section 3: Harms and actions in response to them

The set-up of Study 2 involved first asking users of smart products to volunteer the problems they had experienced with them, along with the harms, if they had occurred, and in particular the type of harm. Users of the smart products had a range of options to choose from (i.e. no harm, financial harm, physical harm, property damage, psychological harm, societal harm, environmental harm, animal harm). Users were then presented with the same harms and asked to choose which they would want a regulator of products to prioritise, from which they would also choose which action they think should be taken in response.

The first thing to consider here is the profile of harms reported relative to the harms that users had indicated the regulator should prioritise (see Table 16).

Table 16. Proportion of respondents reporting harms as a result of smart products they own and use and harms that they consider the regulator should prioritise addressing

	(overall sample) % of reported harms	**(overall sample) % of prioritised harms**	**(those reporting no harms) % of prioritised harms**
No Harm	62	0[8]	-
Financial	13	34	32
Physical	2	13	16
Property	2	6	4
Psychological	19	35	33
Environmental	1	3	4

[8] Note that when asked to identify which harms a regulator should focus on addressing with a particular time of action, respondents were not given the option to select “no harm”.

Societal	0	8	10
Animal	1	1	1

It is worth highlighting that the majority of respondents indicated that while they had an issue with the smart product they had not experienced a harm as a result, therefore it is of interest to see which harms they considered worth prioritising even if they hadn't experienced them. The most common harms were in fact the same harms that had been most frequently directly experienced (financial harm, psychological harm) (see Table 16). In fact overall, the most commonly experienced harms were also the most prioritised by the whole sample. However, excluding those that had initially indicated they didn't experience a harm (n = 325), it is also worth exploring whether those that had reported a harm selected the same harm for the regulator to prioritise. In fact there was a match for 72% (n = 202) of the remaining sample, suggesting that the majority used their own experiences as a basis on which to judge which harm a regulator should prioritise addressing in relation to smart products.

The greatest correspondence was for animal harms (100%, n = 3[9]) societal harms (100%, n = 1) and financial harms (82%, n= 68) followed by psychological harm (70%, n = 98), physical harm (62%, n= 13) and property damage (62%, n = 13) and lastly environmental harms (29%, n = 7).

Risk management action and specific harms

The next aspect to consider is which actions overall were most popular, and which were commonly associated with specific types of harms. As indicated by the pattern of responses in Table 17, overall the most frequently selected option as a response to any harm was to collect more evidence to better understand the harm and its causes. If we look at the most commonly selected risk management actions relative to all harms, then collecting more evidence to understand the harm was most frequently selected for psychological harm. Remove product from the market the product was strongly preferred for physical harm and fining the business was most frequently selected for property damage. When it came to public campaigns, this was selected most for environmental harms, and for warning labels this was most frequently selected for property damage.

Table 17. Proportion of respondents selecting risk management actions overall and by each specific harm

	Collect more data	**Remove product from the market**	**Fine**	**Public Campaign**	**Warning label**
Overall % of selections (n = 527)	43	21	10	13	13
Financial (n = 181)	38	20	15	14	12

[9] The frequencies of respondents here refer to those that had reported a harm in the initial part of Study 2.

Physical (n = 68)	29	49	7	10	4
Property (n = 29)	24	17	17	17	24
Psychological (n = 182)	55	12	4	12	16
Environmental (n = 16)	44	13	6	19	19
Societal (n = 44)	41	20	14	16	9
Animal (n = 7)	43	43	0	0	14

Excluding this option to consider the extent to which the findings in Study 2 map on to Study 1, first we see that overall remove product from the market products was the next most popular selected risk management action, and for physical remove product from the market the product was the most popular, which complements the finding of Study 1. Also, for Study 2 when it came to psychological harms the next most preferred option was to add a warning label which also aligns with the pattern of responses in Study 1.

However there were some differences, again excluding the data collection option, in Study 2 for financial harms the next most preferred choice was to remove product from the market the product (whereas in Study 1 it was to fine the business). For property damage in Study 2 the preferred option was to add a warning label (whereas for Study 1 it was to remove product from the market the product).

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