

Smart Product: Product Requirements for the Development of a Responsive Mirror for Elderly Support

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ABSTRACT

A responsive smart product can connect with a network, to sense and gain awareness as well as to react to input signals and align with them. This paper describes the product requirements gathering process to assist the development of a responsive bathroom mirror connected with emergency centres for elderly support. The rapidly increasing ageing population has led to increased number of elderly people living alone. In this sense it is essential to pursue strategies that can guarantee ageing in place safely, independently, and with confidence, and improve the quality of life of those who wish to continue living in their own living environment. Driven by recent advances in technology, the development of smart products that can respond to human needs and wants, and to improve everyday tasks, became a tangible reality. When smart products are developed for senior citizens daily support, responding to what their expectations are and whether they are satisfied with them, and what opportunities and worries they associate with their age, overcoming technological barriers from the user's point of view, it will have a huge impact on the communities: older people, their families, and the healthcare system. To address these issues, this paper provides a systematic identification of product requirements, technological and from user's point of view, for the future development of a responsive mirror. Towards a holistic development approach, first, existing studies on smart products, research on related technological trends and development were reviewed, supplemented with case studies of existing smart products for healthcare. The first list of requirements was developed from this research. Additionally, studies and public statistics were analysed to confirm the relation between domestic environment and high levels of injuries, as well as places and situations of the accidents that have high impact on health and well-being. Smart products typically have a strong sense of technology. Being a mirror a product that is used in a daily basis, it is mandatory to gather simultaneously the user's preferences and technological requirements. Based on a systematic approach, a Kano Model was developed; requirements were synthesized and organized within a comprehensive user requirement framework delineating three levels of needs: basic, performance and delight. Research from the field of smart products demonstrated that there are several technological trends that can be applied to mirrors, that there are smart mirrors for applications in automobile and fashion industries. Nevertheless, examples of these products in healthcare remain limited. Additionally, recent technological developments enable the development of a responsive smart mirror that not only serve as an interface for displaying information but can predict the presence of the user.

Keywords: Smart products, Smart mirror, Ageing in place, Holistic design, Product requirements

INTRODUCTION

Information technology is revolutionizing products. Products once composed solely of mechanical and electrical parts have become complex systems combining hardware, sensors, data storage, microprocessors, software, and connectivity in myriad ways. These smart products offer exponentially expanding opportunities for new functionality, far greater reliability, and capabilities that cut across and transcend traditional product boundaries (Porter and Heppelmann, 2014). One of its potential applications is to support ageing in place, allowing older adults to maintain their independence and enjoy a higher quality of life, while their loved ones have peace of mind knowing that their safety is being monitored.

Smart mirrors are a cutting-edge technology and are gaining traction as a smart device that can integrate a range of functions designed to help the elderly in their daily lives. With this research we aimed at contributing for smart living environments for the elderly, through the identification of the requirements for the future development of a smart mirror for elderly support. To that end, we will start the research by the surrounding concepts definition. Next, towards a holist development approach, existing studies on smart products, research on related technological trends will be performed supplemented with case studies of existing smart products for healthcare. Based on a systematic identification of product requirements for the design and development of a smart responsive mirror, either from technological and from user's point of view, a list of product requirements will be elaborated as well as a Kano model.

SMART PRODUCTS AND AGEING IN PLACE

'Ageing in place' refers to the ability of older adults to live in their own homes, in their familiar communities safely, independently, and comfortably, regardless of age, income, or ability level, rather than moving to institutions such as nursing homes (Moreland et al., 2020; National Center for Equitable Care for Elders, 2019; Wiles et al., 2012). Ageing in place was seen by Wiles et al. (Wiles et al., 2012) as an advantage in terms of a sense of attachment or connection, practical benefits of security and familiarity, and as being related to people's sense of identity through independence and autonomy. It has benefits for older adults, including improved health and well-being, reduced social isolation, and lower healthcare costs (United Nations, 2013). It also has benefits for families and caregivers, who can have greater peace of mind knowing that their loved ones are being well-cared for in their own homes (Mahoney, 2003). Overall, ageing in place is a preferred option for many older adults, and with the right support and resources, it can provide a high quality of life and a sense of independence and dignity.

Smart Products, Smart Mirror, Responsive Mirror

Rijsdijk and Hultink (Rijsdijk and Hultink, 2009) defined smartness as a combination of the dimensions autonomy, adaptability, reactivity, multifunctionality, ability to cooperate, humanlike interaction and personality, and the scope to which a product possesses one or more of these dimensions.

Authors also defined smart products as products that have smartness and intelligence, once they contain information technology (IT) in the form of, for example, microchips, software, and sensors that are able to collect, process, and produce information. Furthermore, a main requirement for smart products is the capability to adapt to situations, to users, and other products.

In this sense, smart products are cyber-physical products/systems (CPS) which additionally use and integrate internet-based services to perform a required functionality. CPS is a system featuring a tight combination and coordination between the system's computational and physical elements. Usually, the sensor and actuator networks are seen as the precursor of CPS. Basically, CPS focuses on intelligent interaction, interactive applications, and even distributed real-time control. Internet of Things (IoT), a concept where an object having the ability to transfer data over a network without the need for human interaction to human or human to computer, is known for its advantage that can help simplify people's everyday routine (Yusri et al., 2017). IoT has four major components including sensing, heterogeneous access, information processing, applications and services, and some additional components such as security and privacy. Machine-to-machine (M2M) refers to the interaction and communications between computers, embedded processors, smart sensors, actuators, and mobile devices without or with limited human intervention. Through interfacing with wireless sensor networks (WSNs), a wide range of information can be collected by sensors for M2M systems. Thus, in addition to M2M communications, machines also can make action through the collected information with the integration with WSNs. With the capabilities of decision-making and autonomous control, M2M systems can be upgraded to cyber-physical systems (CPS) (Chen et al., 2012).

Raff et al. (Raff et al., 2020) suggested that smart products may be conceptualized as a range of archetypes that build on each other, and are characterized by a particular configuration of defining criteria in four different archetypes, each one being defined by a particular criteria orchestration as follow (see Figure 1):

1. **Digital:** Smart products that have a digital component but are not necessarily connected to the internet (e.g., digital cameras, digital music players, and digital thermometers).
2. **Connected:** Smart products that are connected to the internet or to other devices (e.g., smart home devices, fitness trackers, and smart speakers).
3. **Responsive:** Smart products that can respond to user inputs and provide feedback (e.g., touch-screen devices, wearable devices, and virtual assistants).
4. **Intelligent:** Smart products that have the ability to learn, make decisions, and act autonomously (e.g., self-driving cars, predictive maintenance systems, and artificial intelligence systems).

Based on the reviewed concepts and on Raff et al. archetypes, we define a smart responsive mirror as a device that, by the integration of technology with a traditional mirror, can sense, gain awareness, and respond quickly and

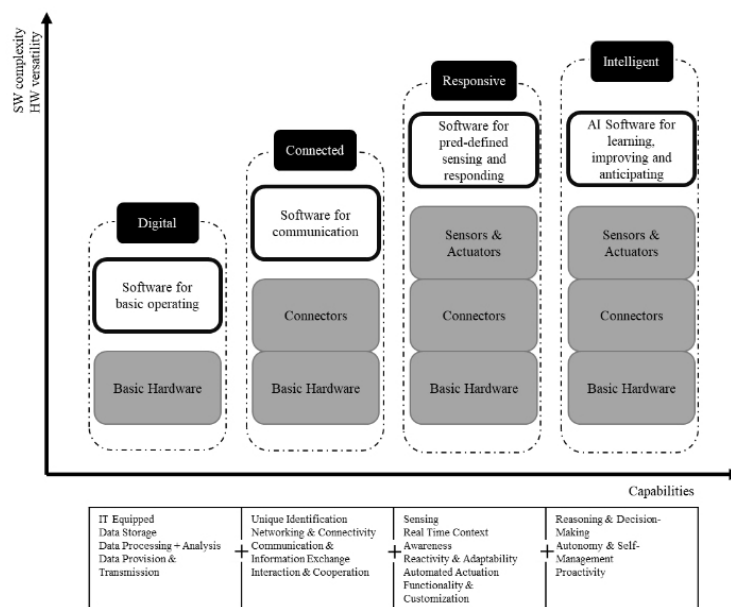


Figure 1: Framework of smart product archetypes (Adapted from (Raff et al., 2020)).

positively to customer requests, issues, and changes in the environment. By the integration of basic hardware with sensors, actuators, and connectors, it will be able to sense and identify a fall, and autonomously (IoT) send an alert to a predefined emergency centre.

Domestic Environment and High Levels of Injuries: Studies and Public Statistics

In recent years, the relationship between the domestic environment and high levels of injuries has received increasing attention from researchers and health organizations. This paper section aims to analyse studies and public statistics to confirm the correlation between the two and to identify the places and situations in the domestic environment that have the greatest impact on health and well-being.

The pace of population ageing is much faster than in the past. Countries face major challenges to ensure that their health and social systems are ready to make the most of this demographic shift. According to the World Health Organization (World Health Organization, 2020) the proportion of the world's population over 60 years of age is projected to increase nearly double from 12% to 22% between 2015 and 2050; in 2020 the number of people aged 60 years and older outnumbered children younger than 5 years. With the dramatic increase of this population, the need for programs and initiatives that address their healthy ageing also increases. Ensuring that older adults have access to health care and the ability to “age in place” is a priority both from a quality of life perspective and a cost savings perspective (Litomericky, 1990; National Center for Equitable Care for Elders, 2019).

In order to analyse the relationship between the domestic environment and high levels of injuries a comprehensive search was conducted in World Health Organization (WHO) platform, namely the Global Health Estimates (GHE) that provides the latest available data on death and disability globally, by region and country, and by age, sex and cause. The WHO Mortality Database is the leading data source for comparative epidemiological studies of mortality by cause.

According to it, leading unintentional injury causes of death include road traffic collisions, drownings, and falls. Cause of falls are age-related loss of muscle mass (known as sarcopenia), problems with balance and gait, and blood pressure that drops too much when one gets up from lying down or sitting (called postural hypotension), being all risk factors for falling (National Center for Equitable Care for Elders, 2019). Stevens et al. (Stevens et al., 2014) study, on older adults at high risk for falls, found that most falls occurred at home and that women and people aged 85 and older were most likely to be injured. More, the study noticed that there was a greater likelihood of injury from falling forward, sideways, and backward and landing flat, compared to falling backward to sitting. And finally, for falls inside the home, there was a significantly greater likelihood of sustaining an injury in the bathroom compared to the living room.

Bathrooms tend to have naturally slippery surfaces and are often wet. Furthermore, there are sharp edges that pose additional hazards. Recent studies have shown that for people aged 65 and older, falls account for approximately 60% of all injury-related emergency department visits and over 50% of injury-related deaths annually. And up to 80% of falls in the home occur in the bathroom (Stevens et al., 2014; Tang et al., 2022).

The results of the studies and public statistics proves the correlation between the domestic environment and high levels of injuries and indicates:

- i. that falls are the most common cause of injury in the domestic environment, accounting for nearly half of all injuries;
- ii. that risk areas in the domestic environment include the bathroom, kitchen, and stairs;
- iii. the elderly and young children are the most vulnerable populations in the domestic environment, with falls being the leading cause of injury in both groups.

SMART MIRROR REQUIREMENTS

In this paper section we comment on technological trends that support smart products development; recent works related to smart products for health-care; and we briefly review the state-of-the-art in smart mirrors both in the research/prototype stage and commercial ones.

Technological Trends and Smart Products Analysis

Smart products are products which incorporate advanced technology, providing us with a range of efficient and creative solutions that make

our lives easier. Major technological trends, that can act as enablers to the development of a smart connected mirror, can be summarized as (Brynjolfsson and McAfee, 2014; Business Insider, 2021; Santarelli et al., 2022):

1. Artificial Intelligence (AI) and Machine Learning (ML): AI and ML algorithms can be used to make the mirror more intelligent, allowing it to predict user behaviour and preferences.
2. Internet of Things (IoT): IoT technology can be used to connect the mirror to other smart devices, allowing for seamless integration and a more personalized experience.
3. Human-Computer Interaction (HCI): HCI research can inform the development of more intuitive and user-friendly interfaces for the mirror.
4. Predictive Analytics (PA): PA can be used to anticipate the user's needs, providing relevant information and recommendations proactively.

Smart mirrors have the potential to revolutionize the automotive and fashion industries by providing new and innovative ways to interact with technology (Badwaik et al., 2022; Bianco et al., 2021; Raff et al., 2020). In the automotive industry, smart mirrors can display important driving information, improving the driving experience and enhancing safety. In the fashion industry, smart mirrors can change the way customers shop by allowing them to virtually try on clothing and accessories, improving the shopping experience and reducing waste. These are just a few examples of the many potential applications of smart mirrors and the impact they can have on different industries.

First known smart mirror was built by Michael Teeuw back in 2014 using a Raspberry Pi2 (Teeuw, 2014). In the same year that Teeuw mirror was released, Toshiba presented their own concept at CES (Bianco et al., 2021), claiming that it could respond to needs in each living space, like kitchen and living room, once it come with a built-in camera, letting users interact with the mirror via gestures. Badwaik et al. (Badwaik et al., 2022) proposed the development of a smart mirror to monitor and display heart rate, oxygen level, and body temperature. For health monitoring, the physiological data is collected by the biomedical sensors in the mirror and communicated to medical personnel so they can learn more about the patient's health.

Healthcare Smart Products

Traditional fall detection systems offer several advantages over other forms of emergency response systems, they are typically compact and portable, making them ideal for use by the elderly and young children. Additionally, they provide an immediate response in the event of a fall, which can be crucial in the event of an injury. However, traditional fall detection systems also can be intrusive and uncomfortable to wear, and some users may find them unappealing or inconvenient to use. Additionally, being not real-time context aware, they may not be effective in detecting all types of falls, particularly those that occur in the shower or bath. In this section we will

list examples of responsive smart products in healthcare (Business Insider, 2021):

1. **Fitbit:** a wearable device that tracks physical activity, sleep patterns, and heart rate. It can be used to monitor health and wellness, and can also connect with other healthcare devices, such as glucose monitors, to provide a more comprehensive view of the user's health.
2. **Apple Watch:** a smartwatch that has a range of features to support health and wellness, including heart rate monitoring, fall detection, and an ECG app. It can also be used to track physical activity, sleep patterns, and provide reminders to take medication.
3. **Echo Dot with Alexa:** a smart speaker that can be used to access health information and manage healthcare tasks, such as setting reminders to take medication or ordering groceries. Alexa can also provide information on symptoms and conditions, and can connect with other healthcare devices, such as smart scales, to provide a more comprehensive view of the user's health.
4. **Beddi Smart Alarm Clock:** a bedside device that tracks sleep patterns and provides personalized recommendations for sleep improvement. It can also be used to control other devices in the room, such as lights and smart plugs, and can provide weather and traffic updates in the morning.
5. **Withings Body Cardio Scale:** a smart scale that tracks body weight and body composition, including body fat percentage, muscle mass, and bone mass. It can also track heart rate and sync with other healthcare devices and apps to provide a comprehensive view of the user's health.
6. **Smart Pill Dispenser:** a device that dispenses medication at the appropriate times and can alert the user when it is time to take their medication. It can also alert caregivers or family members if the user misses a dose and can provide information on medication usage and adherence.
7. **Walabot HOME:** a smart home device that uses advanced imaging technology to detect and monitor movements, changes, and potential hazards within the home environment. Its ability to detect falls and other hazards, as well as its integration with other smart home devices, make it a valuable tool for families and caregivers. However, it has some limitations. Its advanced imaging technology may not work well in homes with thick walls or other obstructions, limiting its ability to detect movements and changes within the home environment. Additionally, the device requires a power source and may not be suitable for use in areas without reliable electricity.

Based on bibliographical analysis, and smart products benchmarking, a list of key product requirements, technological requirements, and user needs, was elaborated to serve as input for next stage, the Kano model development (see Table 1).

Table 1. Smart mirror product requirements.

Key product requirements:	User Requirements:	Technological Requirements
Usability: The mirror should be easy to use and intuitive, especially for elderly users who may have difficulty with technology	User-friendly interface: The interface should be easy to navigate and understand, with clear instructions and visual aids	
Display: The mirror should have a clear and large display that is easily readable from a distance	Multifunctional: The mirror should have multiple features, including, but not limited to, showing time, weather, news, and personal reminders	High-resolution: The display should be of high quality, with a clear and sharp image
Sensors: The mirror should be equipped with various sensors (e.g., motion, touch, voice) to allow for easy interaction with the device	Automatically monitors for falls	Emergency contact automatically called in case of fall
Voice Recognition: The mirror should have advanced voice recognition capabilities to allow elderly users to easily make requests and interact with the device	Voice-controlled: The mirror should be equipped with a voice-controlled system that allows users to control and access features with voice commands	Smart connectivity: The mirror should have Wi-Fi connectivity and integration with other smart devices
Safety: The mirror should be designed with safety in mind and should have features such as automatic shut-off in case of an emergency	Secure and private: The mirror should ensure the privacy and security of the user's personal information, such as biometrics and other sensitive data	Privacy: The mirror should be designed with privacy in mind and should have secure storage and protection of personal data
Connectivity: The mirror should have connectivity capabilities (e.g., Wi-Fi, Bluetooth) to allow for seamless integration with other devices and easy access to information and services		Power supply: The mirror should have a reliable power source, such as a rechargeable battery or a wired power source
Customization: The mirror should be customizable to meet the individual needs of each user, including the ability to adjust font size, volume, and lighting	Customizable appearance: The mirror should be able to adapt to the user's preferred style and design	Operating system: The mirror should have a reliable operating system that is optimized for the specific hardware and user requirements
Durability: The mirror should be durable, and able to withstand regular use and potential impacts or falls		Durable construction: The mirror should be made of high-quality materials that are durable and long-lasting

KANO MODEL

The Kano Model is a customer satisfaction framework that can be used to evaluate the expectations and preferences of users for a product (Sauerwein et al., 1996). In the context of a responsive mirror for elderly support, the

Kano Model can help understand the factors that drive customer satisfaction and identify areas for improvement. The Kano Model categorizes customer requirements into three categories of needs: must-haves, performance attributes, and delight. Must-haves are basic requirements that customers expect to be fulfilled, performance attributes are requirements that customers are satisfied with as they are fulfilled to a higher degree, these attributes directly impact the user's experience and satisfaction; and delight features are unexpected but desirable requirements that can greatly enhance the user's experience and drive customer satisfaction.

1. **Must-haves Attributes:** basic attributes would include factors such as accessibility, reliability, and safety. The responsive mirror must be easy for the elderly user to access, operate, and use, and must be reliable in performing its intended functions. Additionally, the mirror must be safe for the user to use, and automatically connected with an emergency centre.
2. **Performance Attributes:** performance attributes might include factors such as the size and resolution of the display, the responsiveness of the touch controls, and the accuracy of the feedback provided.
3. **Delight Features:** delight features for the responsive mirror could include advanced features such as voice recognition and control, integration with other devices and systems, and personalized recommendations and feedback.

Kano Model was a valuable tool for understanding the customer requirements and expectations for a responsive mirror for elderly support. By identifying the must-haves, performance attributes, and delight features, product designers can ensure that the responsive mirror meets the needs and preferences of the elderly population and drives customer satisfaction.

DISCUSSION

During the research we concluded that, although the use of smart mirrors in healthcare is limited, there is potential for their use. The ageing population is rapidly growing, and with it, the demand for technology that can help support and improve their quality of life. Equipped with cameras and sensors to track the user's movements and provide feedback, the responsive mirror can help reduce the falls injuries, as it provides an automatic connection with emergency centres. One of the biggest challenges with the responsive mirror is the cost, as it requires expensive components and specialized software. Additionally, there is a need for reliable and secure data storage and processing to ensure user privacy and security. There is also a need for user-centred design and user testing to ensure that the responsive mirror is accessible, usable, and appealing to the elderly population.

CONCLUSION

The findings of this analysis confirm the relationship between the domestic environment and high levels of injuries. A responsive mirror has the potential to be a valuable tool for reduce the falls injuries in elderly individuals, once it

integrates a fall detector into a traditional mirror, using motion sensors that automatically alerts a designated emergency contact.

Based on a systematic approach, a list of product requirements was developed, and a Kano Model was elaborated. Both will serve as a responsive smart mirror process development input. With further development and investment, the responsive mirror has the potential to be an important tool for supporting the elderly population ageing in place.

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