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Impact-Centered Design: *Introducing an Integrated Framework of the Psychological and Behavioral Effects of Design*

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This paper introduces a framework for impact-centered design that maps the direct and indirect psychological, social, and behavioral effects resulting from human-product interactions, as well as the strategic pathways that designers utilize to achieve these effects. The framework was created through a series of expert workshops in which 186 design cases were analyzed. The framework includes three basic levels. At the base, user-product interaction evokes three types of direct product experience: aesthetic experience, experience of meaning, and emotional experience. The second level describes more indirect and long-term types of impact: on behaviors, attitudes, (general) experiences, and users' and stakeholders' knowledge. The third and final level represents the general quality of life and society. This paper details the characteristics of and theoretical models underlying the various impact areas, provides illustrative student design cases, and describes how the impact areas relate to each other and how design can influence them. Design research can help increase the designer's influence by contributing theoretical models that explain the various relationships in the impact areas. We propose a three-part classification of these models to get an overview of the current state of knowledge of each impact area, and to discuss the different ways in which models can guide designers. In the discussion, we offer four action points to help set a concerted agenda for impact-centered design research.

Keywords – Design Theory, Impact-Centered Design, User-Centered Design, Positive Design, Social Design.

Relevance to Design Practice – The introduced framework helps designers to reflect on the potential impact of their designs and to formulate their design intents with clarity and precision.

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Introduction

User-centered design is characterized by designers' empathic concern for the users of products and services. To support individual and societal well-being, user-centered designers actively consider people's goals, feelings, abilities, and practices. Their overall aim is, effectively, to have a *positive impact on people*. Because there may be a variety of intentions behind a designer's aim to foster positive impact(s), user-centered design is infinitely diverse in its manifestations—from pencil sharpeners for people with reduced hand function to ticket machines people genuinely enjoy using. Rather than representing a design *genre*, user-centered design might therefore best be seen as representing a coherent set of design *intentions* (see Norman, 1988). In this paper we deconstruct these intentions and classify them by *impact level*, to support design theory development and user-centered design practice.

User-centered designers are showing increasing interest in the psychological and social impact of products beyond the confines of direct human-product interaction;[1] the repertoire of intentions behind new designs has expanded to include all kinds of derived and less immediate psychological effects. For example, besides being enjoyable to use, a water faucet can also be designed to motivate people to use less water (Sohn & Nam, 2015), and besides enabling people to select and view programs, a television can be designed to support family bonding (Hassenzahl et al., 2013). These kinds of intentions stem from the belief that design has a profound, albeit indirect impact on the way people live their lives, and hence designers should aim to create products that have the most beneficial effects on people and society as a whole. This growing awareness of design's potential impacts is fueled by global conferences and new practice movements such as persuasive technology, social design, value-sensitive design, what design can do, and design with intent; their originators seeking to further explicate designers' expanding remit and responsibility. The ongoing expansion in the repertoire of intentions is the stuff of lively debates about the designer's role in product creation, and designers' responsibilities in terms of practice and education.

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For user-centered design researchers, these developments imply a significant expansion in research scope. Understanding how products make people feel, think, and act requires new knowledge. For instance, insights from behavioral science have been used to consider how product features can nudge people towards healthier or more prosocial behavior (e.g., Lockton et al., 2010; Thaler & Sunstein, 2009; Thorpe & Gamman, 2011; Tromp et al., 2011). Structural theory from motivation psychology has been used to understand how products can fulfil fundamental human needs and life aspirations (e.g., Hassenzahl et al., 2013; Ozkaramanli & Desmet, 2012). And knowledge from positive psychology is actively used to explore how products can contribute to the subjective well-being of individuals (e.g., Desmet & Pohlmeyer, 2013; Keinonen et al., 2013). In this paper, we call this a shift from *user-centered* design to *impact-centered* design.

Beyond the new scientific horizons it has opened up, this growing research domain is generating some confusion. There are two related issues that may hinder advancement in the field: (1) conceptual ambiguity and (2) knowledge fragmentation. The first is the observation that identical terms are used to describe different psychological concepts or, conversely, different terms are used to describe the same phenomenon. For instance, when different people say that a social media platform should have a more positive impact on its users, one could mean that it should result in healthy online behavior, while another could mean that it should contribute to the subjective well-being of its users. This kind of semantic confusion makes it difficult to compare initiatives in design research, practice, and education. The second issue is the fragmentation of knowledge development. The psychological impact of design is fundamentally holistic: products evoke a seamless and mutually dependent stream of actions, thoughts, and feelings that never exist in isolation from one another. For research purposes, it is useful to conceptually separate these components and study how they interact to orchestrate the overall impact. For example, if the quiet motor sound of an electric car makes its owner feel relieved about being environmentally conscious, which in turn leads him to drive more often, it is helpful to have a framework that explains how elements like the aesthetics of interaction, emotions, attitude, and behavior combine to generate this experience. In the past decade, various models have been introduced that explain individual psychological components in detail, but the interrelationships among these components has been left underexplored.

In this article, we introduce a framework for product impact that maps the various psychological, social, and behavioral effects resulting from human-product interactions, as well as the strategic pathways that designers choose to achieve their intended effects.[2] The framework distinguishes between distinct psychological impact areas that together form the human dimension of product impact. In the first part of this paper we report on the development process, introduce the framework with an illustrative design example, and discuss each impact area in some detail. In the second part, we describe the way in which designers formulate their impact-driven design intent and how the framework could help to frame these intentions. In the third part, we share examples of theoretical models that explain the impact areas and their interrelations, which designers can use to increase the specificity or efficacy of their design intent. Next, we argue that as impact-centered design research matures, theories advance from describing human phenomena to explaining and, ultimately, predicting them. The framework is intended to contribute to this expanding research agenda by providing a clear overview of the direct and indirect psychological effects of human-product interaction. We propose a three-part categorization of theoretical models to classify the current state of knowledge of each impact area. In the discussion, we offer four action points to help set a concerted agenda for impact-centered design research.

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Paul Hekkert is Full Professor of form theory and head of the Design Aesthetics group at the school of Industrial Design Engineering, Delft. Paul conducts research on the ways products impact human experience, values, and behavior. With Matthijs van Dijk, he published *Vision in Design: A guidebook for innovators* (2011), a book that describes an approach to design and innovation that has been widely applied in both education and industry. More recently, Paul co-authored *Designing for Society: Products and Services for a Better World* (2019, with Nynke Tromp). Paul is Captain of Science of the Dutch Creative Industries sector and chairs the International Advisory Council of DRS.

The Impact-Centered Design Framework

The framework's contribution is that of a descriptive theory. Descriptive theories summarize the commonalities found in discrete observations—in this case, in the form of a classification of the human dimensions of product impact. While modest in its ambition, descriptive theory is needed when little is known about the phenomenon in question (Gregor, 2006). For that reason, our framework addresses two questions: "Which types of effects comprise the human dimension of product impact?" and "How can these types be grouped according to similarities and differences?" In addition, we indicate some relationships among these types. It is important to stress that these relationships are classificatory in the sense that they presume causality; they are what we found in the data.

The framework was developed during two series of each four workshops with experts from different areas of impact-centered design, including various approaches to product experience, behavior, and well-being[3]. The authors parcipated in all workshops. Our data set consisted of 186 design cases that explicitly stated there was a desired effect on users and other people. The cases included 106 master's thesis projects of design students at Delft University (2015-2017), 27 designs that were presented at the Amsterdam Stedelijk Museum exhibition *Dream Out Loud—Designing for Tomorrow's Demands* (2016), and 53 designs that were presented at the Rotterdam Boijmans van Beuningen exhibition *Change the System* (2018). The cases were selected to represent designs of which (a) explicit first-hand descriptions of the designer's intentions were available, and (b) these descriptions included statements that refered to some psychological effect(s). We used a thematic analysis to untangle the wide range of psychological effects that can be pursued through impact-centered design. We adopted an interpretivist approach, which means that we examined the designers' intentions instead of the surface meaning of the case descriptions (see Schwandt, 1994, for a discussion on the interpretivist approach). The process followed the six phases of thematic analysis proposed by Braun and Clarke (2006). We started by familiarizing ourselves with the data by reviewing all collected design cases. Next, we generated initial codes to represent interesting specific psychological effects. Third, we collated codes into initial effect themes and categorized the design cases relevant for each potential theme. The analysis indicated that the descriptions of several cases mentioned *routes*, which means that one effect was used as a means to reach another (e.g., creating an experience in order to influence behavior). These routes were individually coded. Fourth, we reviewed the effect themes and routes, checking if they adequately represented the samples in the design collection. Fifth, we refined the themes and overview of design routes by revisiting the initial impact codes. The sixth and final step was to create the framework, to select vivid examples from the data set, and to visualize the identified design routes.

The end result is depicted in Figure 1. The arrows in the framework represents the most common pathways designers explored to reach their impact-centred claims. It includes three types of product experiences originally introduced by Desmet and Hekkert (2007)—product aesthetics, product meaning, and product emotion—and augments them with four indirect areas of human impact: behavior, attitude, (general) experience, and knowledge. When analyzing products in terms of their impact (intended or unintended), the logic of the framework flows from bottom to top: the properties of the product result in a certain product interaction, which in turn evokes a product experience and further human impact. The colored boxes in the center represent the successive effects that the product has on the user. The process starts with the user-product interaction (orange), moves through the different types of product experience (pink), and on to the more indirect and long-term types of human impact on users or other stakeholders (green), finishing with the quality of life and society (yellow). Analogously, when practicing impact-driven design one would essentially follow a reverse trajectory, starting at the top level and reasoning all the way down to a design with its various properties. Table 1 provides short descriptions of all components, illustrated with observed (and sometimes intended) effects from the design case *Tovertafel*. We have chosen this example because we are familiar with the intentions behind it, and because these intentions cover the entirety of our framework and therefore help to explain it.

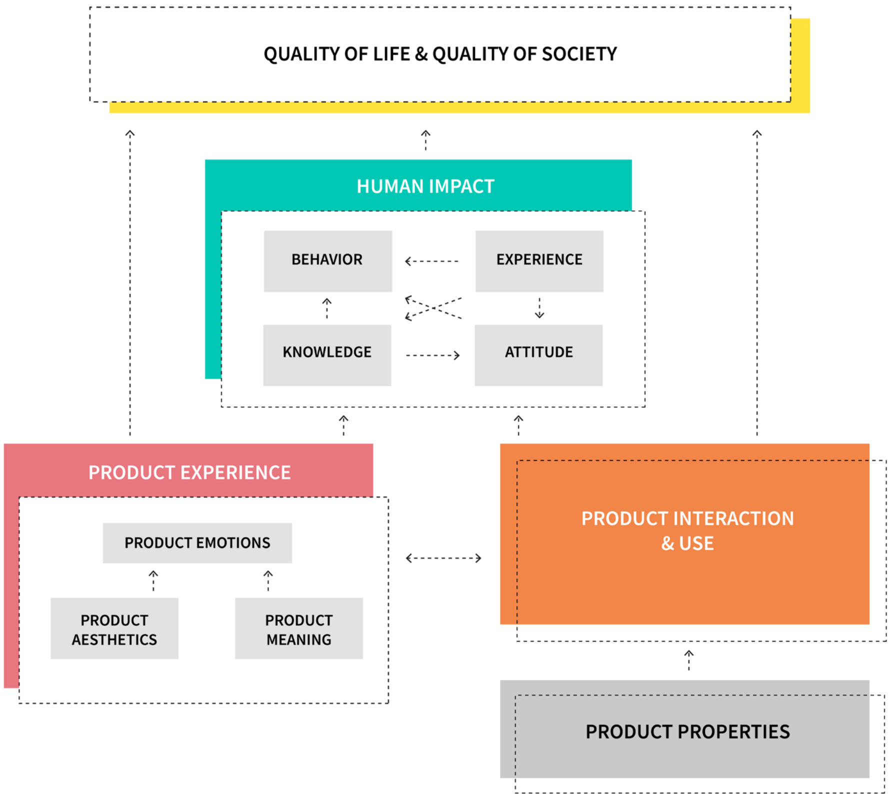


Figure 1. The impact-centered design framework.

About 90% of older people with dementia in care homes suffer from apathy. They withdraw into their own world, barely make outward contact with anyone or anything, and get little exercise, all of which is detrimental to their physical, emotional, and cognitive health. This problem is addressed by the Tovertafel (magic table): a white console mounted on the ceiling that projects colorful interactive animations onto a table. Infrared sensors register people's hand movements, enabling them to play with the images. A variety of games are available—tap on floating stars and let them make music, push a beach ball to another player, or stroke rotating flowers to make them grow. The Tovertafel asks people to make wide gestures with their arms, and also to be socially aware. Its impact is broad: care home residents have an activity that draws them outward, and their family members enjoy the pleasant atmosphere and attention to the residents that the specially-designed tool provides. The Tovertafel also supports and unburdens care workers, and management benefits when staff that can do their work well and feel good. Design by Hester Anderiesen Le Riche for Active Cues.

Figure 2. Tovertafel design case.

Table 1. Basic descriptions of the framework elements and a design case example.

Impact Dimension			Examples from the Tovertafel case
Overall Impact	Quality of Society	The overall impact on the composition and values of a society	The table contributes to a society in which people with dementia are included and can participate as much as possible.
	Quality of Life	The overall impact on the well-being of individuals and communities	The table ultimately enhances the quality of life of people with dementia, as well as that of their family members and carers.
Human Impact Thoughts, actions, and feelings (of users and/ or people in the context of use).	Behavior	Activities and deeds that are enabled and stimulated by using the product.	Users become more active. They move their arms extensively and interact with others while playing a game. The presence and use of the console prompts carers to introduce other creative well-being interventions.
	Knowledge	Insights gained and greater understanding facilitated by using the product.	The table raises carers' awareness about the detrimental consequences of apathy, and increases their understanding of how to reduce it.
	Experience	Feelings evoked by situations and events that are enabled or supported by the product.	Family members enjoy new ways of connecting to their loved ones. Bystanders experience curiosity. Carers feel proud about taking part in these exciting new experiences in their care homes.
	Attitude	Opinions (about people, objects, events, activities, and ideas) that are influenced by using the product.	The table has an impact on attitudes towards the user group. Whereas dementia sufferers are sometimes seen as *lost cases*, carers can more clearly see how apathy is strongly influenced by someone's situation and context.
Product Experience Pleasant and unpleasant feelings towards the product's appearance or behavior	Meaning	Meanings, expressions, and associations assigned to the product.	The table is perceived as magical, playful, and inviting, and the projections are sometimes perceived as naughty. The product console is seen as high-quality and *serious*—in a friendly way.
	Aesthetics	The extent to which the product gratifies (or offends) the human sensory systems.	The light projections are seen as beautiful (gratifying the visual sense); in terms of colors, shapes, and movements. The sounds are experienced as pleasing by some, and as displeasing by others.
	Emotions	Positive and negative emotions evoked by the product.	Users are surprised by the interactive nature of the light projections; they feel joy when playing the games and pride when they experience a sense of control over the animations.
Human-Product Interaction		All events that take place between the individual and the product, such as perceiving it, using it, and storing it.	The projected animations move autonomously (when there is no user response), but they also respond when users interact with them. Users can use a remote control to select games and adjust volume.
Product Properties		The product's size, shape, textures, materials, and colors, as well as its technical features, and interactive technology.	A white metal console houses a projector, several infrared sensors, a processor, and a speaker. Its casing displays the Tovertafel logo and images that refer to images used in some of the games. The product projects colored images, such as flowers, fish, or beach balls onto the table.

Primary flow of events

The Framework in Detail

Product Properties

The product properties category includes the components and composition of the product, including its size, shape, textures, materials, and colors (physical or virtual), as well as its technical features and technology. For services, this layer describes factual properties and features like access hours, services and service procedures, number of access points, available options, and costs of different service elements. Product properties are key, because these are the only elements in the chain of events that designers have direct and decisive control over.

Product Interaction and Use

Interactions are all the non-affective or pre-affective activities and events that take place between the product and the user. This includes perceiving and using the product: examining, starting, and ending usage; interacting with an interface; and updating and repairing the product[4]. More broadly, it also includes thinking about the product, usage anticipation, and even seeing it being used by someone else (e.g., Schifferstein & Hekkert, 2008).

Product Experience

Product experience refers to all possible affective experiences involved in human-product interaction. The product experience components in Figure 1 follow the integrated framework of product experiences (Desmet & Hekkert, 2007), which asserts that product experience consists of three dynamics: the experience of aesthetics, the experience of meaning and emotion, and the sculpting of experience that results from the interplay between the user's psychological make-up and the properties of the product. The framework disentangles these three experiential components and explains how they interact to shape a user's holistic product experience. A thorough treatment is provided by Desmet and Hekkert; below we provide a brief summary.

Product Meaning

People constantly assign meaning to products to make sense of their purpose and value. Some of these meanings refer to function, such as *this is a desk lamp*, or *this cup is made for hot beverages*, and so do not necessarily involve affect. Other meanings are more associative and normative, such as *this clock looks industrial*, or *this armchair is clunky*. This latter type of meanings is an integral part of product experience. Visual product appearance typically comes to mind first as a trigger of meaning, but meanings also arise from the sounds a product makes (*this car sounds powerful*), its tactile properties (*this phone feels sturdy*), or the product behavior (*this ticket machine is being rude*). Contextual factors like culture, other people, the user's personality, and the user's mental state influence the process of meaning attribution (see e.g., Karana & Hekkert, 2010). Some ascribed meanings are likely to be more ubiquitous—e.g., the attribution of the word *natural* to products made of wood and stone and *artificial* to plastic products—while others are highly culturally-dependent, like the appraisal of metal kitchen worktops as either factory-like (Turkey) or prestigious (Sweden) (see Ljungberg & Edwards, 2003). Since Desmet and Hekkert's (2007) original framework was introduced, it has become much clearer how this process of meaning attribution actually works (see e.g., Hekkert & Cila, 2015; Orth et al., 2018; Van Rompay & Ludden, 2015;).

Product Aesthetics

Product aesthetics concerns the extent to which the product gratifies (or offends) the human sensory systems, including our brain. Aesthetic experience differs from the two other types of product experience in that it appears to be unidimensional. While meaning and emotion can be categorized into several distinct experiences, aesthetic pleasure seems best modelled on a single dimension, from *not at all aesthetically pleasing* to *very aesthetically pleasing* (Blijlevens et al., 2017). We consider it as a distinct experiential component because unlike emotions, aesthetic experience is *disinterested*—it does not depend on the individual's product-related usage goals or motives. Just like assignments of meaning, aesthetic judgments can fulfill or harm user goals and needs. In the framework, this is represented by the arrows that go from product meaning and product aesthetics to product emotions (see below). Several principles form the foundation of the aesthetic gratification process, all of which adhere to the overarching principle of *creating order out of chaos* (see Hekkert, 2006, for an overview). For example, although people appreciate variety in a design, this variety must be accompanied by unifying rules (e.g., symmetry, similarity) in order to be aesthetically pleasing—a principle better known as unity-in-variety (Post et al., 2016). Similarly, we can only appreciate novelty when the product is also simultaneously perceived as familiar or typical, a principle coined MAYA, or Most Advanced, Yet Acceptable, by well-known industrial designer Raymond Loewy (Hekkert et al., 2003). Over the years, several of these aesthetic principles have been identified and empirically tested in isolation. Berghmann and Hekkert (2017) have also tested their joint operation and interrelatedness.

Product Emotions

Humans have a broad emotional repertoire that consists of pleasant emotions such as love, joy, pride, and relief, and unpleasant emotions such as anger, fear, boredom, and shame. *Product emotions* are emotions experienced in response to (using) a product. Like all emotions, product emotions are subjective because they do not only depend on product features, but also on the individual's personal needs, goals, values, and abilities (see Smith & Lazarus, 1990). Someone can enjoy a mobile phone because it allows to connect to loved ones in any location, long for a new car that allows them to get to their office faster, and become disappointed if their office chair thwarts their need for physical comfort. Aesthetic experiences and experiences of meaning can lead to emotions (see the arrows within the product experience box in Figure 1). For example, someone can be disappointed when a product's sound is not as nice as was expected (aesthetics) or admire a building for its modern facade (meaning). Because of their subjective nature, product emotions can differ between people, and even within the same person depending on the situation. One person may respond with irritation to their mobile phone's ringtone (while at work and needing to focus), and respond with enthusiasm to the same ringtone (while at home and in need of some diversion). In recent years, design researchers have investigated concepts related to emotional granularity (i.e., the ability to differentiate between emotions) in product design (see Yoon et al., 2016), and introduced typologies of positive emotions (Desmet, 2012), emotional conflicts (Colin & Droulers, 2017; Ozkaramanli et al., 2018), and the use of negative emotions to enrich user experience (Fokkinga & Desmet, 2013; Leddington, 2017; Zhang et al., 2016).

Human Impact

The psychological and behavioral impact of products and services extends far beyond what happens during the user-product interaction. For example, the availability of affordable cars has changed how people work, live, and engage in social relationships. Designers have long been aware of this wider psychosocial impact, and some have actively attuned their design activities to producing more desirable social effects. Motivated by elaborate political visions, early 20th-century Modernist designers like Walter Gropius and Le Corbusier aimed to create products and buildings that offered a better way of life that would in turn produce enlightened, pro-social behavior in users and inhabitants (Dorrestijn & Verbeek, 2013). Compared to these grand movements, contemporary efforts are relatively more modest, specific, and pragmatic, and arguably less ideologically motivated. For example, designers today look for novel ways to encourage people to develop new skills, or make their lives healthier, more sustainable, or more socially engaged.

We propose four primary categories of extended human impact: behavior, experience, attitude, and knowledge. Together, these effects lead to (positive or negative) impacts on another overarching layer of humanity: general quality of life and the quality of a society. We have found that these four categories can be meaningfully distinguished, and that together, they account for the bulk of impact-centered design intentions. Furthermore, as we will briefly summarize in the next sections, these categories are all thoroughly described in literature of the human sciences (e.g., psychology, sociology, neuroscience, behavioral science), making it easy to find a connection with existing models and empirical research. We use the term *impact-centered design* to denote design projects and processes that explicitly aim for these types of less immediate and often longer-term effects.

In order to attain these effects, designers need to find an effective pathway that starts from the product properties (the only element over which they have direct influence) to the intended impact area. Depending on this pathway, the design decisions will also affect other product expererience or impact areas.

Behavior

In an attempt to dissuade cyclists from skipping traffic signals, the city of Amsterdam installed traffic lights for cyclists that display the remaining waiting time before the light turns green (described by Tromp et al., 2011). The reasoning behind the design was that unclear waiting times lead to restlessness which causes cyclists to look for ways to get across the street more quickly. The visual countdown alleviates this anxiety and cyclists more easily act in accordance with the regulations. Evidently, people's behavior in such a context is influenced by a multitude of factors and the way they are intricately interwoven in a socio-technical ecosystem. Nevertheless, this is a typical example of design for behavior change: The design of specific interventions, such as products and services, with the intention to influence people's actions, activities, and habits.

Products are in a unique position to influence behavior, because we use them to perform the bulk of our actions. Digital platforms shape many of our interactions with loved ones, furniture shapes our way of living, and public spaces shape our way of interacting with strangers. These effects are often subtle and go unnoticed—who is aware of the effects of retail design (e.g., shelf height, product placement) while they are shopping? By finding and exposing these relationships, designers will be in a position to change user behaviors in ways that benefit people or society at large. On the other side of the spectrum, a design might enlist the user as a deliberate and active participant in their own behavioral change. People try to quit smoking, exercise more, or comply with a course of medical treatment, and use (digital) products and services to help them. In this variant of behavior change, user motivation is key.

Of all four human impact components, behavioral consequences represent the kind of impact that has received the most research attention in the past two decades by far (see Michie et al., 2014, for overviews; Niedderer et al., 2018), with an emphasis on the domains of health (e.g., Fogg, 2003; Ludden, 2018) and sustainability (e.g., Kuijer, 2018; Lilley, 2009; Wever et al., 2008). Although it has been demonstrated that behavior can be effectively modified through behavior change interventions, these changes are often temporary and people easily fall back in their old habits. Various theoretical models have been proposed that explain how changes in behavior could be maintained (Kwasnicka et al., 2016).

Knowledge

Products and services can help to impart knowledge or awareness to users in several ways. They can make people aware of simple facts, like on-board entertainment systems that provide information about the present location of the airplane or destination city. They can also pass on larger amounts of information about the user themself (i.e., quantified self) alongside feedback about their behavior, such as a digital thermostat that gives people insight into their energy consumption or a wearable activity tracker counting our steps in addition to measuring our heart rate. Products can also help users obtain tacit knowledge in the form of skills or know-how, like an app that teaches people to sing in tune. *Serious gaming* is a well-known product category in the field of Human-Computer Interaction that explicitly intends to improve the knowledge and skills of its users (Michael & Chen, 2005). Researchers have studied serious games that help users learn math (Mayo, 2009), monitor their heart disease (Wattanasoontorn et al., 2014), and understand cultural differences (Zielke et al., 2009), among many other things.

Experience

Human experience is clearly already present at the product experience level of the framework. But products also evoke many experiences *indirectly*—these experiences are mediated by the product, but not directed towards the product *as such*. These experiences consist of affective situations and events that are *enabled* by the product. For instance, a phone enables people to connect to distant friends, a picnic blanket enables a comfortable afternoon in the park, and an online airline check-in service gives people a more relaxed airport experience. The experiences in these situations are elicited by pleasant activities and in connection to other people—not by the products themselves. At the same time, products do facilitate and influence these emotions. Although the occurrence and nature of these indirect experiences largely depend on people's actions and dispositions, designers can make a deliberate effort to positively impact them. An example is the *Drift Table* (Gaver et al., 2004), a coffee table with a small hole through which users can see a satellite view of the British countryside. Users can control the direction in which the view floats by rearranging objects on the table. Rather than having an obvious functional value, the floating view facilitates an interesting social experience. In fact, much of what we nowadays would classify as experience design refers to these kinds of indirect experiential consequences of products and technology (e.g., Hassenzahl, 2010). Some scholars and practitioners have shifted the focus of their interest from understanding how design can *directly evoke* particular experiences to understanding how design can provide a *context* for particular experiences. Examples are initiatives that study how design can enable people to regulate their mood (Desmet, 2015), and explorations of the effects of various interior qualities on people's overall experiences, such as in hospitals (Dijkstra et al., 2008), classrooms (Woolner, 2010), living rooms (Yildirim et al., 2011), and offices (Küller et al., 2006).

Attitude

Attitudes are the opinions and affective beliefs we hold towards an object, person or phenomenon (Eagly & Chaiken, 1993). The sum of a person's attitudes determines how they regard the world and what decisions they are likely to make. Attitude formation and change is traditionally the domain of public relations, education, and advertising (Petty & Wegener, 1998). For example, in many countries, cigarette packs provide messages seeking to affect people's beliefs about the consequences of smoking (and thereby dissuade them from continuing), and various campaigns and billboards aim to change our opinions about the appropriateness of alcohol or smartphone use in traffic. Products and services also affect attitudes, often in ways that are less explicit but not less effective—in some instances, they are even more effective. A design genre that is often associated with attitude change is *critical design*. Through provocation, satire, and storytelling, critical design compels its users to reflect critically on social themes (Malpass, 2015). For instance, the *Life Counter* by lppei Matsumoto is a digital clock that asks you to set the number of years you still expect to live, and starts counting back. There are several different faces of the clock that will display your remaining time in years, days, hours, or seconds (Dunne & Raby, 2001).

Non-critical, mainstream design can also change attitudes. The Tovertafel (Figure 2), for instance, had a considerable impact on care workers' attitudes. Over the years, many had developed the belief that dementia patients simply tend to become apathetic. They believed apathy should be accepted as part of the progressive illness. They were genuinely surprised when they witnessed how some of the patients they saw as *lost causes* snapped out of their apathetic state through movement, social interaction, and laughter. Personally witnessing the effects produced by the console had a profound and lasting impact on their beliefs about people with dementia.

Quality of Life and Quality of Society

The final, overarching impact areas are Quality of life and Quality of society. These comprise everything that makes humans and society flourish. These are the impact areas that all impact-centered design ultimately aims to enhance one way or another—either deliberately or subconsciously. At the same time, this is impact at its most indirect, and as such is furthest away from the designer's influence. All designs for human impact implicitly or explicitly argue for, promote, or otherwise seek to contribute to a particular quality of life or preferred society. The countdown at the traffic light tells us that we prefer a city without chaos and accidents; an electric car embodies our desire for cleaner air and our awareness of how we contribute to climate change. The field of design is increasingly aware of its potential to nourish long-term well-being or human flourishing (see Desmet , Pohlmeyer, & Forlizzi, 2013), and direct its efforts towards the values held by society at large (e.g., see Niedderer et al., 2016; Tromp & Hekkert, 2019). As we have seen, some designs seek to achieve that goal indirectly, via products, services, and technologies. However, some designs are created or invented to *directly* target quality of life and society (the right-most arrow in Figure 1), rather than indirectly producing that effect. For instance, *The Ocean Cleanup* not-for-profit organization develops technologies to rid the world's oceans of plastic. Similarly, Studio Roosegaarde's *Smog Free Project* introduced a series of urban innovations intended to reduce pollution. The *Smog Free Tower*, for example, provides a local clean air solution for public spaces. Even though their initial intent is to target ocean and air quality improvement directly, these designs exert a noteworthy human impact by stimulating public debate and increasing the general awareness for relevant underlying societal issues (such as use of plastic).

Design Intent

Products that have a psychological impact on users are by no means new or exceptional. *All* products have effects at the Human impact level. However, these effects may not always be deliberate or intentional, and some may even be undesirable. Since the introduction of smartphones, the number of people who are late for appointments has increased notably: it is very easy to text or call to say that you will be late. In recent years, many additional unforeseen (unwanted) effects of smartphone usage have been documented (for an overview, see De Koning, 2019). For example, having a smartphone reduces the number of social smiles with 30% (Kushlev et al., 2019), and there is a direct relationship between smartphone overuse and sleep disturbances (Thomée et al., 2007). The purpose of the framework is to serve as a canvas that helps to make these effects explicit, to stimulate designers to reflect on the potential impact of their designs, and to identify potential inadvertent consequences. To give an impression, Figure 3 provides an overview of four [redacted] design student graduation projects, one for each of the four human impact components.[5] These are examples of the cases that served as input for the second series of workshops in developing the framework. In the case descriptions, the primary psychological domain of impact is underlined.

A. Mindful Bites (Behavior)

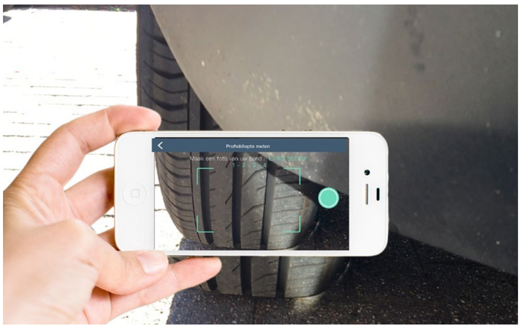
Mindful Bites is a product line designed to positively influence feeding behavior of cat owners. The products teach owners to reward their cats with smaller quantities of snacks. Cat obesity caused by overfeeding is an increasing problem. The tendency to overfeed typically comes from the owner's affection for their cat, but too much food is ultimately unhealthy. Mindful Bites provides an alternative way to feed affectionately, in which love goes hand in hand with positive health.

Design by Alev Sonmez (2017).

B. H5N8 Collection (Attitude)

In 2014, the Netherlands experienced a widespread outbreak of H5N8—aka the bird flu. Over 150,000 chickens were culled, resulting in 300 tons of waste material. The H5N8 Collection converted some of this tainted material into products, revealing its aesthetic and utilitarian potential. The collection is both alluring and provocative, stimulating a debate about the commoditization of animals, and challenging people's general attitudes towards the raw materials that feed our consumption culture.

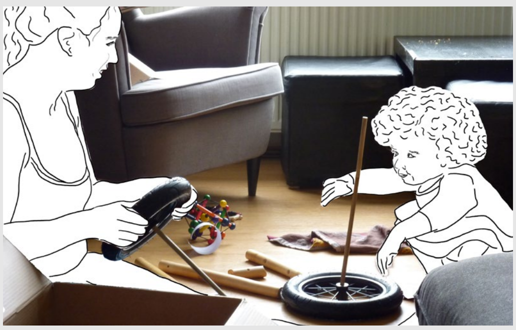
Design by Emilie van Spronsen (2015).



C. Carlo (Knowledge)

In the Netherlands, 60% of all cars have at least one under-inflated tire, and 43% have worn tires, which can lead to dangerous situations. One of the main reasons for this is that people are generally unaware of their tire conditions. Carlo translates the complex and inaccessible tire condition data into easy-to interpret information. With the help of sensors embedded within the tire, the application creates visualizations depicting tire pressure in real time. In addition, it enables the phone to conduct a simple tread depth check, and explains the benefits of good tire conditions.

Design by Kristel Breukers (2016).



D. KaboogaBike building kit (Experience)

With the KaboogaBike building kit, parents and children build a bike together. The purpose is to facilitate parent-child bonding. Five building adventures stimulate playful exploration. In every adventure, new components are discovered and a part of the bike is built. Hidden parts trigger curiosity, and discovering them gives a feeling of shared ownership. The building adventures fit the child's capabilities and interests and shifts the parent's focus from the end-goal to the enjoyment of creating shared memories.

Package design by Wanda Bloemers (2016).

Figure 3. Four examples of Impact-centered design.

Relationships between Components

The framework separates out each type of human impact to clarify the different types of positive impact designers can have on people's lives. In reality, however, designers will rarely be able to isolate and focus on a single impact phenomenon. This means there may be more than one strategic route to the desired human impact, and hence more than one pathway through the framework. There are at least three reasons for this.

1. Psychological Effects do not Exist in Isolation

The components of human impact broken down above are in fact intimately intertwined: they co-depend and coincide. Attitudes, beliefs, and motivations are affected by knowledge and feedback, and vice versa. Knowledge and attitudes influence behavior, new behavior leads to a different experience, and moods will also factor into the behavior equation. In principle, because each of the four components can affect every other component (and subsequent components), there are many pathways designers might take through the framework. In Figure 1 we have used arrows to emphasize the common strategic pathways that we found in the design examples. For example, Carlo (Figure 3c) takes the pathway from knowledge (informing car owners about the condition of their car's tires) to behavior (encouraging owners to take better care of their tires). The aforementioned Life counter takes the pathway from experience (the eerie feeling of seeing your life seconds ticking away) to attitude (a new perspective on mortality). And the traffic light countdown takes the pathway from experience (alleviates cyclists' impatience at crossroads) to behavior (making them more inclined to follow the traffic rules). In a later section of this paper, we briefly touch upon each of the six common pathways and give examples of theoretical models that support them.

2. Designers can only Influence Human Impact Indirectly

Designers exert their influence by manipulating product properties, which means intervening at the base of the framework. Fortunately, there is more than one route to the top. For instance, the human impact area can be reached in two ways: through product experience, which might be called the *conscious route*; or directly from a product interaction, the *unconscious route*. Consider the H5N8 collection (Figure 3b): by combining aesthetic appeal with controversial meaning, it elicits mixed emotions (at the product experience level). These emotions may lead people to reflect on their attitude towards their consumption behavior. We call this the conscious route because the user's attitude change is caused by *how they experience* the product—which is by definition a conscious process. The other option is the unconscious route, when the user may not be aware that the impact is caused by the product. For example, guests at an all-you-can-eat buffet could receive small plates to discourage overserving themselves without them consciously experiencing this effect (Kallbekken & Selen, 2013). This unconscious or implicit route is very interesting from a designerly point of view—and perhaps even more effective because much of human behavior is automatic (Marteau et al., 2012)—but also debatable from an ethical standpoint. To what extent are designers entitled to nudge people into displaying the *right* attitude or behavior? (For a discussion on the ethical issues related to design for impact, see Tromp & Hekkert, 2019). A recent study showed that perceived effectiveness was the strongest predictor of acceptability for nudging interventions to reduce obesity (Petrescu et al., 2016).

3. Unintended Effects in All Directions

Although we conceptualize the main flow of intended causality from the bottom of the framework to the top (starting at Product Features and finishing at Quality of Life and Quality of Society), unintended effects also cascade horizontally and even in the opposite direction. For example, having enjoyed the shared experience of building KaboogaBike (Figure 3d; experience), a toddler might be more careful when playing with it (product use) to avoid scratches. In this manner, the relationships between elements on different levels result in loops of evolving experiences and behaviors. To illustrate, Verbeek (2005) describes how the introduction of the microwave had a primarily positive effect on families, as it fostered flexibility in cooking and dining practices. However, this flexibility can indirectly have an unwanted side-effect on family structure, because the need for family members to share mealtimes is greatly diminished.

Using Theoretical Models in Impact-Centered Design

Designers who aim for specific changes in user behavior, attitude, and so forth will likely make use of their life experience and intuition to find effective approaches. For example, the designers of the bike countdown traffic lights may have considered which factors lead them to skip a red light themselves. However, as user contexts become more complex or are further removed from designers' everyday experience, personal intuition becomes increasingly ambivalent and unreliable, and designers need to turn to theory to support their efforts. This is where the wide variety of available theoretical models comes to the fore.

In the following two sections, we briefly discuss a number of notable models and theories from social sciences that could support impact-centered design and research. The first section discusses models for the five impact areas, while the second section provides models for the six impact relations (the arrows between the impact areas, see Figure 1). This brief selection is meant to give an idea of the types and diversity of theories that we think could support impact-centered design—not as a comprehensive overview of theories.

Notable Examples of Theoretical Models for Each Impact Area

Behavior

The Theory of Planned Behavior has probably been one of the most influential theories that explains people's (non-automatic) behavior (Ajzen, 1991; Munro et al., 2007). It states that there are three main sources underlying our behavior: the attitude toward the behavior, subjective norm, and perceived behavioral control. The latter predictor, the perceived ease (or difficulty) with which the individual can perform the behavior, is very close to the famous notion of self-efficacy (Bandura, 1997). Social norms, through messages of other people's behavior or indications of what behavior is appropriate, have been shown to exert a powerful influence on people's behavior (e.g., Aarts & Dijksterhuis, 2003; Cialdini et al., 1991; Dwyer et al., 2015). Inspired by the the Broken Windows Theory, Keizer, Lindenberg, and Steg (2008) demonstrated in field experiments that when people observe others violating a social norm or legitimate rule, they are also more inclined to violate norms or rules. Lastly, Social Practice Theory adds the habitual predictors of behavior. It emphasizes that behaviors are shaped and routinized in socio-technical systems that involve both human and non-human actors (Reckwitz, 2002; Shove et al., 2012).

Knowledge

There is a plethora of knowledge acquisition theories (i.e., learning theories). Some theories attempt to cover the entire phenomenon, while others focus on specific elements of learning (e.g., the role of feedback), specific contexts (e.g., the classroom), or specific types of knowledge (e.g., languages). For example, Cognitive Load Theory (Sweller, 2011) focuses on the amount and type of information that a person can process, and suggests strategies to optimize comprehension and retention. Bloom's (1956) taxonomy distinguishes six categories of cognitive skills that each play an important role in knowledge acquisition and application. The taxonomy of Bloom et al. (2011) builds on Bloom's taxonomy and classifies knowledge into four categories: factual, conceptual, procedural, and metacognitive knowledge. Each knowledge type requires a different learning strategy.

Experience

Human experience is a holistic concept that harbours different phenomena (for overviews, see Dewey, 1939; Forlizzi & Battarbee, 2004; Hassenzahl, 2010). One is emotions, which are moment-by moment affective responses to events and people (e.g., feeling pride or anger). Another is mood, which is a person's general feeling state (e.g., being in a cheerful or grumpy mood). A third is the overall experience of engaging in an activity (e.g., the enjoyable experience of visiting a museum). A general theory of experience is core affect theory (Russell, 2003), which describes the variance in human experience with the two dimensions, valence (i.e., pleasant versus unpleasant) and arousal (low versus high activation). Other theories focus on specific types of experience. An example is the biopsychological mood theory of Thayer (1989), which sees mood experience as the outcome of two biological systems, one producing energy and the other producing tension. A second example is the functional emotion theory of Ortony, Clore, and Collins (1988) that proposes three broad classes of emotion, each related to a distinct aspect of the world: events (being pleased versus displeased), people (approving versus disapproving), and objects (liking versus disliking).

Attitude

The explicit-implicit theory divides attitudes into two categories: attitudes that people consciously hold (explicit attitudes) and attitudes that people are not aware of but which influence their choices and behavior just as much (implicit attitudes; e.g., Rydell & McConnell, 2006). The mere-exposure effect is the phenomenon by which people develop a more positive attitude of an object or person just by being more exposed to it (longer and/or more frequently; Zajonc, 1968). Cognitive dissonance theory (e.g., Cooper, 2011) describes how people strive to regain harmony when they hold two inconsistent attitudes, or an attitude that is inconsistent with one's behavior.

Quality of Life and Quality of Society

An individual's quality of life is represented by the broad concept of wellbeing. Wellbeing theories can be categorized into two main (interrelated) traditions: objective well-being (OWB) and subjective well-being (SWB). OWB is the degree to which external requirements for having a high quality of life are met. Theory in this tradition typically proposes lists of (universal) requirements, such as the eleven categories by Doyal and Gough (1991; e.g., adequate nutrition and water and adequate protective housing). SWB represents the degree to which life is *good* in the perception of the person who is leading it. SWB theory proposes two main sources of wellbeing, often labelled as Hedonism and Eudaimonism. In the hedonic perspective, well-being is achieved by the pursuit of pleasure, enjoyment, and comfort (Huta & Ryan, 2010) or the fulfillment of psychological needs (Deci & Ryan, 1985; Sheldon et al., 2001). In the Eudaimonic perspective, well-being is achieved by the pursuit of self-fulfillment or self-actualization, often conceptualized as the realization of one's fullest potential (Heylighen, 1992) or as the use and development of one's character strengths and virtues (Peterson et al., 2005).

When it comes to the quality of a society, or what constitutes a *good society*, there is evidently a plethora of theories and positions, varying from utopian visions, to political ideologies and shared value systems, such as the the sustainable development goals of the United Nations. An influential driver for design can be found in the field of sustainability and the changing set of economic values related to a circular, shared or purpose economy (see e.g., Bocken et al., 2015; Hurst, 2014; Mazzucato, 2018).

Notable Examples of Theoretical Models for Common Relations between Impact Areas

The Influence of Attitude on Behavior

The first determinant of the Theory of Planned Behavior (see section on Behavior) indicates that much of our behavior is mediated by our attitudes. If people have a positive attitude towards a particular behavior, such as recycling or increasing their fitness, they are more likely to engage in this behavior. Influencing people's attitudes can thus be an effective strategy for behavior change objectives. Influencing people's attitude can be done directly (see section on Attitude) or via one of its antecedents that each also have their direct behavioral impact. One antecedent of attitude is personal norms. These reflect internalized standards of proper behavior and therefore function as a moral obligation to engage in a particular behavior (Kallgren et al., 2000). Another antecedent is self-identity, the label individuals use to describe themselves (Cook et al., 2002). People prefer to act in line with their self-identity. For example, the stronger a peron's environmental self-identity, the more likely that person will engage in pro-environmental behaviour like recycling (Van der Werff et al., 2013).

The Influence of Experience on Knowledge

As a Chinese proverb goes, "Knowledge obtained by papers feels shallow; one must practice to understand." Without the contribution of a practice-based experience, knowledge is fragile and dull. Our sensory-motor experiences shape our understanding of the world (Johnson, 2007). Through our repeated bodily experiences, we gain a conceptual understanding of concepts such as *high* (superior) or *low* (inferior), *warm* (close, intimate) and *cold* (distant, unaffectionate), and so on. These are the metaphors we *live by* and they are so common in everyday language and communication that we easily overlook their experiential roots (Lakoff & Johnson, 1980; Pinker, 2007).

The Influence of Experience on Attitude

The theory of attitude emotionality explains how a person's attitudes towards objects, people, and ideas are influenced by their emotional experiences (Rocklage & Fazio, 2015). When people have conflicting evaluations about an object, with some evaluations being emotional (*hot*) and others cognitive (*cold*), the emotional evaluations win out. In design processes, these theories can be useful to develop a proposition about selecting which emotions to design for when aiming to stimulate certain user attitudes.

The Influence of Experience on Behavior

The Broaden and Build Theory explains the influence of experience on behavior (Fredrickson, 1998, 2001). This theory proposes that emotions come with a tendency to act and think in a particular way, and that positive emotions have a general *broadening effect* on our momentary thought-action repertoire. For example, people who experience joy have the urge to play or approach tasks in a more spontaneous and creative way. The Broaden and Build Theory aligns with general motivation-grounded emotion theory, which proposes that each (positive or negative) emotion represents a unique action tendency (e.g., Frijda, 2007; Lowe, 2011).

The Influence of Knowledge on Attitude

Theories of information integration deal with the question of how people use new information to update or maintain their attitude towards an object, and how they weigh it against pre-existing information (e.g., Davidson, 1995). An interesting mechanism in this domain is the decelerating set-size effect, which refers to the finding that new pieces of information with the same value as the attitude will add to the attitude (make it more extreme), but in a decelarating fashion: each additional piece of information will have less impact than the one preceding it (e.g., Anderson & Birnbaum, 1976).

The Influence of Knowledge on Behavior

Most behavior models include one or more types of knowledge as a determinant. For example, the aforementioned Theory of Planned Behavior states that detailed knowledge about the consequences of the behavior will make the behavior more likely. The influence of knowledge on behavior via attitudes has also been studied. It has been found that if a person's attitude is based on more knowledge, they are more likely to act on that attitude (Kallgren & Wood, 1986).

Classification of Theoretical Models

In what ways can such models guide the impact-centered design process? And how do designers discern which type of model works best for their impact-centered design challenge? In this section, we move away from the specificities of the framework to propose a classification of the theoretical models that elucidate the psychological phenomena and the relationships between them. This classification consists of three main categories, each with its particular merits and limitations: (1) Identification & Description, (2) Explanation & Causation, and (3) Prediction & Prescription (Figure 4). This classification is a simplified version of others proposed by Gregor (2006). The purpose of the classification is to help designers and design researchers to categorize and evaluate theoretical models on their merit and applicability. We will describe each category in detail in the paragraphs to come, and provide examples from studies at the product experience level which were published since the framework by Desmet and Hekkert (2007).

Type 1: Identification & Description

The first step towards influencing a phenomenon is *understanding* it. Type 1 (T.1) models describe the nature and characteristics of the phenomenon in detail (T.1a). They deal with questions such as "What exactly is an aesthetic experience? How can meaning be described? What does an emotional experience consist of?" T.1 models can frame a phenomenon in a generalized, *top-down* manner, such as Locher, Overbeeke, and Wensveen's (2010) framework of the aesthetics of product interaction. T.1 models can also describe a phenomenon *bottom-up*, from the perspective of the user or person in question. For example, one study describing how people experience mixed emotions in relation to consumer products offered open-ended descriptions of the thoughts, feelings, and motivations that they co-occur with (Fokkinga & Desmet, 2012). Flach, Stappers, and Voorhorst (2017) proposed a construct matrix with three dimensions—specifying, affording, and satisfying—whose combinations determine people's abilities to navigate and appreciate product use.

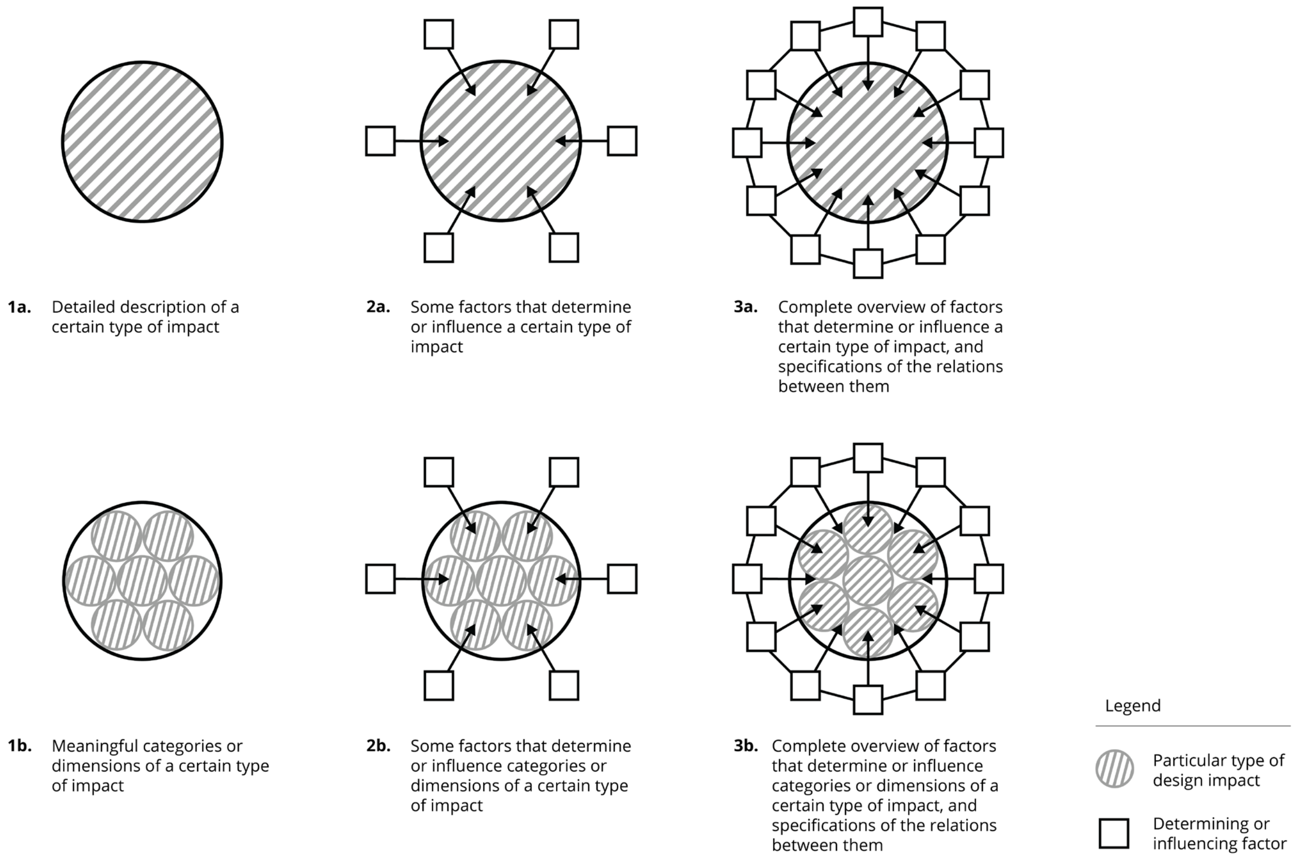


Figure 4. Three types (and six variants) **of theoretical design models.**

A variant of this type of model breaks a phenomenon down into meaningful categories or dimensions (T.1b), which often take the form of typologies. For instance, Desmet (2012) described and categorized 25 positive product emotions, and Fogg (2009) proposed his behavior grid, a two-dimensional model that classifies behavior change across the axes of temporal occurrence (one-time, periodical, and continuous) and nature (new, familiar, increase, decrease, stop), and whose intersections yield 15 behavior change goals. T.1b models show a granular and descriptive image of psychological effects, allowing designers to choose a specific direction for their desired user impact. Yoon et al. (2014) describe a case study in which students selected and designed for specific positive emotions. T.1 models can tell us much about a phenomenon, they do, however, not explain *how* these effects can be achieved.

Type 2: Explanation & Causation

T.2 models provide one or more causal relations between design decisions and psychological effects (T.2a). Similar to T.1 models, these models have variants in which the phenomenon is broken down into smaller pieces (T.2b)—they describe the determinants for the specified categories or dimensions of the effect. When developing T.2 models for product experience, researchers often draw from knowledge that researchers in psychology and other human sciences have acquired. For example, Van Rompay et al. (2012) borrowed embodiment theories from cognitive psychology to show how vertical visual cues, such as low camera angles, affect the perception of luxury in packaging and advertisements; using insights from semantics and personality attribution theory, Karana and Hekkert (2010) examined the product and user factors that should be considered to grasp the meaning attributed to materials; in HCI, empirical aesthetics was consulted to study a range of indicators of visual appeal (e.g., Moshagen & Thielsch, 2010); and emotion psychology was applied to predict how product interactions can evoke emotions like pride and disappointment (Demir et al., 2009).

T.2 models thus enrich our understanding of what goes on in the minds of users and give designers a more concrete grasp of how to achieve psychological effects. However, they cannot fully predict these effects because the described mechanism is typically only one of many that combine to produce the effect. For example, one model may state that immediate feedback helps people retain knowledge, but there are dozens of other determinants of knowledge retention. Furthermore, the mechanism may work in most, but not all cases. To illustrate, Pashler et al. (2005) found that immediate feedback works well when it is provided after a wrong answer, but may actually harm knowledge retention if it is given after a correct answer. In addition, the different concepts and terminology that each model brings have made it difficult to find conceptual common ground and develop a holistic understanding of the overall psychological impact of products. Thus, T.2 models describe a single causal factor, or a set of causal factors, with the understanding that there are still other, unknown factors, and that the relations between factors are also unclear. Therefore, for a given psychological effect, there might be hundreds (if not thousands) of T.2 models that describe a different influence or mechanism.

Type 3: Prediction & Prescription

T.3 models contain the majority of factors that determine a certain effect on people and specify the relationships between them (T.3a). These models enable designers to predict a psychological effect when the values of its parameters are known, and, by extension, to prescribe which values of parameters are necessary to achieve a given effect. T.3 models are probably only achievable when the intended effect and context are reasonably constrained (T.3b). For example, a T.3 model might describe all the factors that influence a visitor's clicking behavior on a specific webpage, or the narrative and audiovisual factors that influence the emotional experience of a movie viewer. The existence of a T.3 model for a certain effect does not imply that one can completely control and predict that effect. Numerous factors will nearly always remain outside the designer's control, such as the user's current state of mind, the personality of the user, other events occurring in the context, and so forth. However, a T.3 model would enable the designer to maximize the influence that he or she has through the product properties.

Model Category Occurrence in Impact-Centered Design Research

Over the years, we have seen an increasing number of research initiatives that explore the strategies designers can employ to influence people at the Human impact level. The majority of these initiatives focus on the behavioral consequences arising from the use of designs and technologies. At the T.1 level, an example is the behavior grid (Fogg, 2009) described earlier. At a more general level, the habit loop model sets forth that all automatic behaviors consist of a continuous cycle of cue, routine, and reward (Duhigg, 2012). More recently, we have also seen a range of studies trying to model the effect of design on our quality of life or more general states of well-being, such as Desmet and Pohlmeyer (2013) who identified three components in the intent to design for human flourishing.

At the T.2 level, we see research activities in most impact areas. When it comes to the experience component, Fokkinga and Desmet (2013) introduced ten types of rich emotional experiences, and how they can be evoked through product interaction. And Hassenzahl et al. (2013) described how needs can mediate between product features and overall experiences. Related to knowledge, Wouters et al. (2013) conducted a meta-analysis on the effects of *serious* games, and concluded that compared to conventional instructions, the genre is more effective for learning and retention (but not for motivation).

Behavior is the most-studied impact area at the T.2 level also. Various authors have proposed tools, methods, and strategies to instigate behavioral change (e.g., Lockton et al., 2010; Thaler & Sunstein, 2009; Tromp et al., 2011; see Niedderer et al., 2018, for an overview). Whereas some of these efforts aim at developing generic models that can be applied in most domains, others have focused on domain-specific strategies in fields such as health care, sustainable consumption, crime, or the social realm. Still other T.2 models looked into behavioral interventions in relation to the stages of change people are in (Ludden & Hekkert, 2014) or different user models (Lockton et al., 2012).

The T.3 level is a different story. To our knowledge, hardly any studies have tried to model the complex set of factors that would jointly predict people's attitude, behavior, and experience at the Human impact level. As argued, these effects are mostly indirect and relatively long term, and therefore much more vulnerable to a range of intervening variables than the more immediate effects at the product experience level. For the more general effects at the Human impact level that often occur in more open-ended contexts (e.g., people's behavior in a public space), a T.3 model is arguably more a theoretical endpoint of model development than a realistic possibility, because of the virtually endless number of variables that it would need to include. Nevertheless, there are a few models that aspire to the T.3 level. For instance, Peters et al. (2018) recently proposed an all-encompassing model for the effects of digital technology on our long-term well-being. It looks at all the spheres of experience a technology could be effective, from early adoption and task engagement all the way up to life satisfaction and societal well-being. Another example is the UMA model that, based on insights from evolutionary psychology and motivational psychology, aims to describe and predict how products evoke aesthetic pleasure at different levels of processing (Berghman & Hekkert, 2017).

Discussion

Discussion of the Framework

When developing this impact-centered design framework (Figure 1), we made it simple for the sake of readability and clarity. The boxes and arrows emphasize the intended designer's influence over the process, but do not explicitly show the influence of the user or the context of use. This does not mean that we do not acknowledge this influence. Evidently, the context of use and the psychological make-up of the user, including cultural background and personality traits, will nearly always have a marked effect on behavior, experience, and so on. Proper theoretical models should account for the variability in impact responses that may result from individual differences and contextual factors. These influences have, however, been omitted from the figure for the sake of simplicity, but can thus be understood as feeding into every box of the framework.

The framework was created through an analysis of a relatively large number of design cases, which originated from a limited number of sources. The reason for this selection was our criterion that each case should include information about the designer's intent, which was available for the three analyzed sets. Although we have no reason to believe that including additional sets would change the framework substantially, it may have biased our analysis in some way.

Setting a Research Agenda for Impact-Centered Design

In the introduction, we identified two types of obscurity that hinder the advancement of impact-centered design research: conceptual ambiguity and knowledge fragmentation. We developed the framework of this paper with the intention of clarifying some of this obscurity. We hope that it will enable designers to formulate their intent and design researchers to formulate their research ambitions with clarity and focus. Most importantly, we hope the framework contributes to a concerted research agenda for the field. Similar to how product experience frameworks in the 2000s helped to advance and coordinate research on product aesthetics, meaning, and emotions (e.g., Desmet & Hekkert, 2007; Hassenzahl & Tractinsky, 2006), we hope that the current framework helps to align research efforts in impact-centered design.

We proposed three categories to typify design research models that aim to contribute knowledge about human impact areas. We believe that impact-centered design research should ultimately strive to develop T.3 models for each impact area (although completely attaining that objective is probably impossible). This would allow designers to more accurately predict the effects of their designs, and do so in comprehensive detail. In this section, we propose four action points that we think will help to realize this research aim. They are based on observations about the field that the framework helped us to make. We invite other researchers to contribute their own points to the agenda.

1. Conduct more Research on the Impact Areas and Their Mutual Relations

In order to create T.1, T.2, and T.3 models, we need much more research on each impact area. Behavior change has received the most attention within design research and HCI. The other impact areas of experience, attitude, knowledge, and quality of life & society are still relatively underexplored in this domain. Multiplied with the wide variety of possible technical and non-technical interventions—biofeedback, digital coaching, social support, nudging, rewards, gamification, mindfulness, surprise, fun, and so on—there is an enormous amount of knowledge to be gained and applied.

Secondly, we need to better understand the different pathways that lead to a desired impact. For example, behavior change can sometimes be achieved directly through product interaction, in other cases indirectly through a change in attitude, experience, or knowledge, or a combination of these. We included six pathways on the human impact level which we found to be common in impact-centered design cases. The questions remain: What other pathways may exist? Which pathways are most effective? How much does this depend on the specific context and domain?

Thirdly, more research is needed to understand how design interventions can achieve long-term impact. Some interventions may temporarily change behavior, experience, or attitudes, but taper off once the novelty has worn off. Recent reviews of studies on the effect of feedback on one's behavior, for instance through Fitbits, showed evidence for its immediate beneficial effect in disrupting habitual behavior, but these effects often do not last over the long run (Hermsen et al., 2016; Noah et al., 2018). We need to invest in more longitudinal studies to examine these kinds of long-term effects.

2. Use the Findings Generated by Modern Human Sciences

The upper levels of the framework (experiences, knowledge, attitudes, behavior, and quality of life and society) are further removed from product interaction—in other words, the influence of a design is typically smaller and more indirect, and more difficult to anticipate or predict because there will always be many other, situational factors at play. Designing for these levels therefore requires specialized knowledge, such as how behavior is influenced, how experiences are shaped, and what constitutes human happiness. Fortunately, the human sciences have produced a wealth of insights about these concepts. Design researchers should be informed by these validated models, instead of working from outdated or unproven ideas, or worse, trying to reinvent the wheel.

Integrating insights from fields like psychology and sociology into design can be a challenging undertaking. There is a vast amount of information available, which is typically scattered across thousands of publications. Moreover, the human sciences are by no means finished—there are gaps in understanding and competing theories to explain phenomena. Nevertheless, collectively these theories represent our best current understanding of the human faculties. There are several sensible starting points to gain knowledge, such as handbooks that summarize the most replicated findings and best accepted theories.

Specific applied domains have also generated much knowledge about different impact areas. Examples are the insights from educational science & technology about learning (knowledge change) or the insights of media studies about influencing of opinion (attitude change). These findings should be applied beyond the borders of these domains.

3. Create Models that are Concretely Applicable and also Generalizable

Compared to models from the human sciences, design research models must meet an additional criterion: they should not just accurately represent our current reality, but also enable designers to create new realities. They should include metaphorical knobs and dials that the designer can turn to achieve their aims. Without these, the designer will perhaps gain understanding but not the capacity to influence. Consider a behavior model that simply states, "People are more likely to do something if they feel motivated." Although this principle is valid in most situations, it is arguably of little use to designers wishing to change behavior, unless they already know how to influence motivation. The model shows a link between two phenomena, but neither is directly accessible through design.

Another important characteristic of a model is its generalizability—how broadly valid its inferences are for different phenomena, people, and situations. For example, a model that describes the influence of bad moods on people's behavior in traffic is less generalizable than a model that describes the influence of mood on behavior in general. In design research, generalizability translates to versatility: an increase in the number of design challenges and contexts to which the model potentially applies. A versatile model is more usable, and this utility increases the chances that designers will choose to use it—they don't need to look for a new model every time a new challenge arrives.

Generalizability and concrete applicability are often at odds with each other. There are many models that are very concretely applicable but not very generalizable, for example, the influence of plate size on how much food people serve themselves (Wansink et al., 2006), or the influence of the camera angle on the perception of luxury of a product (Van Rompay et al., 2012). On the other hand, the human sciences have produced many theories about human functioning that are broadly valid, but have little concrete applicability for designers. In order to create T.3 models that are useful for design, design research needs to work towards models that are both concretely applicable and generalizable.

4. Employ a Variety of Research Methods to Develop and Validate New Models

The development of T.1, T.2, and T.3 models each requires different types of research. T.1 models primarily require qualitative research that identifies and explores the relevant variables. For example, Desmet (2012) used respondents' stories about positive experiences with products to create a typology of 25 positive emotions. After the phenomenon has been adequately defined in a T.1 model, one can start to create T.2 models of the various factors that may affect it. Numerous cycles of theorizing and quantitative testing slowly develop a picture of these influences of various factors. The most typical method at this stage is experimental studies in which the factor is studied in isolation. Finally, to build a T.3 model, the relative magnitudes of these factors and their interdependencies are studied. Now one tries to numerically study as many factors as possible together to see which factors dominate and map the network of causal relationships. Typical methods at this stage are meta-analysis, multivariate analysis, and path analysis. Recent examples include the meta-analysis of Wouters et al. (2013) on the effects of serious games, or a study by Wiese, Pohlmeyer, and Hekkert (2019) who examined most of the paths from product properties and product experience qualities to seven activities that are known to be conducive to long term well-being.

We observe that many design researchers use qualitative methods or contextualized user testing, but few employ experimental and statistical methods required to develop T.2 and T.3 models. It is (relatively) easy to propose a hypothetical T.3 model with all its potential factors included, and we see many of these in the design literature; it is however very hard to test such models in their entirety. For the development of design research as a mature and evidence-based discipline, it is essential that models are quantified and empirically tested.

To conclude, we believe the impact-centred design framework presented in this paper can be a valuable resource and guide for designers and design researchers aiming to deliberately impact the lives of people beyond the immediate joy we attain from owning and using products. That impact—if realised succesfully—reflects a humanistic orientation in design, where design is treated as a powerful process and instrument to change things *for the better*.

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Endnotes

1. Throughout the paper, the word *product* expresses any person-designed object or structure, including but not limited to physical products, digital products, services, and built environments.
2. While our work emphasizes the human dimension, we acknowledge that products can also have an enormous impact beyond the human, in that they affect our climate, environment, or economic systems, for example. This impact is, however, only possible because people desire, purchase, use, adopt, or discard a product.
3. The first series of workshops led to a preliminary version of the framework, which was presented at the Conference of Design Research Society (Fokkinga et al., 2014).
4. Evidently, each of these events can trigger emotions or other affective responses in the user. The framework places these responses in subsequent levels.
5. See Appendix for background information about these design projects.

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Appendix: *Design Projects*

Tovertafel

Hester Anderiesen Le Riche designed the Tovertafel (Figure 2) as part of her PhD thesis *Playful design for activation: Co-designing serious games for people with moderate to severe dementia to reduce apathy* with Richard Goossens as supervisor and Marieke Sonneveld as co-supervisor. In 2017, she successfully defended the project that was financed by the OCW Creative Industry Scientific Programme (CRISP) and Woonzorgunie Veluwe.

Mindful Bites

Alev Sonmez developed Mindful Bites (Figure 3a) in 2017 at the Delft Institute of Positive Design, TU Delft, as her thesis project for the Master's in Design for Interaction. The project was her own initiative and part of a larger study into designs that foster interactions between people and animals. Thesis supervisors were Pieter Desmet and Natalia Romero Herrera (TU Delft).

H5N8 Collection

Emilie van Spronsen designed the H5N8 collection (Figure 3c) in 2015 as her thesis project for the Master's in Design for Interaction at TU Delft. The project was her own initiative and sought to design meaningful, aesthetically pleasing embodiments of materials retrieved from chickens that had been culled as part of an H5N8 bird flu prevention measure. Thesis supervisors were Paul Hekkert and Odetta da Silva (TU Delft).

Carlo

Kristel Breukers designed Carlo (Figure 3e) in 2016 as her thesis project at the Pon Tyre Group (Barneveld) for the Master's in Design for Interaction at TU Delft. The project was part of an initiative to support consumers in their understanding of the value of proper tyre conditions. Thesis supervisors were Gert Pasman, Sylvia Mooij (TU Delft), and Inge Janse (Pon Tyre Group).

KaboogaBike Building Kit

Wanda Bloemers designed the Bike Building Kit (Figure 3g) for KaboogaBike (Haarlem) in 2016 as her thesis project for the Master's in Design for Interaction at TU Delft. The aim was to develop a building experience that would stimulate parent-child bonding via an engaging bike building process. Thesis supervisors were Dicky Brand, Mathieu Gielen (TU Delft), and Jan B. Mwesigwa (KaboogaBike).