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On the other side of change:

**Exploring the role that design can play in
retaining sustainable doings**

Wanjun Chu

Retain Change

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On the other side of change

Exploring the role that design can play in
retaining sustainable doings

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To my family and friends

“Beneath this mask there is more than flesh,
beneath this mask there is an idea,
and ideas are bulletproof.”

-- V for Vendetta

Abstract

The world keeps changing more rapidly. Induced by context change disruptions such as individual life-course changes and macro socio-economical events, the way people carry out their everyday life doings is also undergoing a dynamic transition process, which may open up windows of opportunity for design to transit people's behavior in a more sustainable direction.

A successful behavior transition entails not only changing people's wrongdoings but also retaining the existing desired doings. However, over the last decade, the field of Design for Sustainable Everyday Life seems to have grown accustomed to the concept of change. The potential role that design may play in retaining people's existing sustainable doings has been ill-addressed. This dissertation aims to develop an activity-based theoretical approach to help design researchers and practitioners better understand how people transit behavior when they undergo context change disruptions, and further explore design implications informed by the sustainable behavior retention perspective.

The study comprises two parts. In the first part, six explorative case studies were used to investigate the applicability of adopting activity theory (AT) as a theoretical lens for understanding context change-induced behavior transition phenomena. As a result, an AT-based framework was iterated, developed and validated. In the second part, by incorporating the proposed framework with the theoretical understanding generated from a prescriptive meta-synthesis study, an AT-informed toolkit prototype was developed and evaluated.

Three key findings can be identified. First, at a conceptual level, the study reveals that the design for sustainable behavior retention perspective may complement the design for behavior change perspective by facilitating a bottom-up and context-focused relative approach to achieve sustainability. Second, at a design analytical level, three dimensions of AT: i). hierarchical structure, ii). long-term development and iii). reality-based contextual scales of analysis are especially useful for systematically analyzing the impacts of context change disruptions on people's everyday life doings. Third, at a design synthesis level, the AT-informed design toolkit prototype and the extracted design implications can provide a systemic view that helps designers take both sustainable behavior change and retention perspectives into early-stage design ideation.

The contribution of the dissertation is two folds. First, it introduces the perspective of sustainable behavior retention into the field of Design for Sustainable Everyday Life. Second, it provides an activity-based theoretical framework as a potential lens for designers to better cope with context change disruptions.

Keywords: Design for sustainable behavior, behavior retention, behavior change, sustainable design, context change, activity theory

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Linköping, December 2020
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Appended papers

Paper I

Chu, W., Glad, W., & Wever, R. (2019). Embracing Change While Retaining the Existing: Sustainable Behaviour Design Insights from Astronaut Food Consumption Transitions. In *Proceedings of 8th International Congress of International Association of Societies of Design Research: Design Revolutions*, 2-5 September 2019, Manchester, UK.

Contribution: Chu conceived the study, carried out the data collection and analysis, and wrote the paper with feedback from the rest of the authors throughout the research process.

Paper II

Chu, W.; Steenstra, P.; Glad, W.; Wever, R. Understanding context change: An activity theoretical analysis of exchange students' food consumption. In *Proceedings of the NordDesign 2018: Design in the Era of Digitalization*, 14–17 August 2018, Linköping, Sweden.

Contribution: Chu and Steenstra conceived the study, Chu performed the data analysis with Steenstra, developed the 1st version of the AT-based theoretical framework used in this study, and wrote the paper with feedback from the rest of the authors throughout the research process.

Paper III

Chu, W., Williams, H., Verghese, K., Wever, R., & Glad, W. (2020). Tensions and Opportunities: An Activity Theory Perspective on Date and Storage Label Design through a Literature Review and Co-Creation Sessions. *Sustainability*, 12(3), 1162. DOI: 10.3390/su12031162.

Contribution: Chu conceived the study, carried out the systematic literature review, conducted design co-creation sessions including interviews and workshops, performed the analysis of findings, and wrote the paper with feedback from the rest of the authors throughout the research process.

Paper IV

Chu W., Wever R., Verghese K., & Williams H. (2019). Thinking on the Box: Design On-pack Information Attributes to Influence Consumers' Food Waste Behavior. *In proceedings of 21st World Packaging Conference of International Association of Packaging Research Institutes*, 11-14 June, Enschede, The Netherlands.

Contribution: Chu conceived the study, carried out the data collection and analysis, designed and developed the prototype of the Augmented Reality-based mobile application, and wrote the paper with feedback from the rest of the authors throughout the research process.

Paper V

Chu, W., Glad, W., & Wever, R. (forthcoming). A meta-synthesis of the use of activity theory in design for sustainability studies. Manuscript submitted.

Contribution: Chu conceived the study, carried out the qualitative meta-synthesis of literature, performed the analysis of findings, developed the 2^{ed} version of the AT-based theoretical framework, and wrote the paper with feedback from the rest of the authors throughout the research process.

Paper VI

Chu, W., Glad, W., & Wever, R. User Activity Matters: An Activity Theory Informed Design Toolkit for Sustainable Behavior Design. *EcoDesign and Sustainability II*, 79-95.

Contribution: Chu conceived the study, carried out the narrative literature review, developed the 1st version of the AT-informed toolkit, conducted the design ideation workshops, carried out the analysis of findings, and wrote the paper with feedback from the rest of the authors throughout the research process.

Table 1. An overview of the studies, the themes and research outcomes included in this dissertation.

Study	Themes	Research outcomes
Study Alpha	A narrative review of sustainable behavior retention	Documented in Section 4
Study A-I	Astronauts' food consumption on ISS	Paper I
Study A-II	Exchange students' food consumption	Paper II
Study B-I	Studenthuset microwave room redesign	Documented in Section 5.3.2
Study B-II	Sustainable kitchen activity design	Documented in Section 5.3.3
Study C-I	Date labelling and household food waste: systematic literature review and co-creation	Paper III
Study C-II	Date labelling and household food waste: design explorations	Paper IV
Study D	Household food consumption activities under Covid-19 lockdown	Documented in Section 5.5
Study E-I	A meta-synthesis of the use of Activity Theory in design for sustainability	Paper V
Study E-II	AT-informed design ideation toolkit	Paper VI

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1

Introduction

1.1 Design for sustainable everyday life

As many socio-ecological sustainability issues that the society is facing today are the direct consequence of a consumerism lifestyle, it is becoming more prominent to guide people to adopt a sustainable everyday life (Jackson et al., 2005). Design, given the transformative nature that it can bring to human doings, thus plays a critical role in supporting the transition towards a sustainable lifestyle (Thorpe, 2010). Design's responsibility for tackling sustainability issues has developed from focusing on technical and material aspects of the design (e.g., Green Design, EcoDesign and Cradle to Cradle Design) to the sociotechnical and user-oriented aspects of design (e.g., Design for Sustainable Social Innovation and Sustainable Product-Service System Design) (Ceschin & Gaziulusoy, 2016).

Under this trend, with the specific goal to reduce the negative environmental and social impact of products and services in the consumer usage phase, the field of Design for Sustainable Behavior (DfSB) emerged a decade ago (Lilley, 2009; Lockton, Harrison, & Stanton, 2008; Wever, van Kuijk, & Boks, 2008). The fundamental concept of DfSB is that products and services can be designed in a way to facilitate or constrain users to perform particular socio-ecologically desired or undesired behavior (Wever & Vogtländer, 2015). Various toolkits have been developed to provide designers with practical guidance for influencing users' behavior in a more sustainable direction. A sample of toolkits includes Design with Intent developed by Lockton, Harrison, & Stanton (2010), Behavior Change Design Sprints developed by Colusso, Do, & Hsieh (2018), Dimensions of Behavior Change developed by Daae & Boks (2014), and Change Points developed by Hoolohan & Browne (2020).

However, with the fast development of the DfSB in recent years, the research field has expanded from focusing on the user behavior aspect of design to covering the broader socio-environmental aspect of people's everyday life (Joore & Brezet, 2015). Following this trend, DfSB seems to be evolving into the new field of Design for Sustainable Everyday Life. Compared with DfSB, Design for Sustainable Everyday Life shares the same overarching aim for promoting a sustainable consumption lifestyle. However, Design for Sustainable Everyday Life seems to bring in two important dimensions to the original scope of DfSB: 1). a spatial dimension that highlights the sociocultural contexts in which people's everyday life doings situate, and 2). a temporal dimension that highlights the long-term dynamic and evolving feature of people's everyday doings.

In the spatial dimension, products nowadays often function with other products and other people, forming a complex network that connects individual users with the macro sociocultural system (Mankoff et al., 2007; Wever et al., 2008). In order to be able to cope with this complexity from a system perspective, the focus of design thereby shifts from single products (e.g., energy efficiency and usability problems of a product) to tackling challenges at a sociocultural level (Adams, Jeanrenaud, Bessant, Denyer, & Overy, 2016). When this shift of focuses comes down to the practical level of design, it implies that design practitioners need to not only analyze the interaction between an individual user and a designed artefact, but also take into account why and how a specific behavior can be influenced by the real-life sociocultural settings (Boon, Wever, & Quist, 2015; Brynjarsdottir et al., 2012).

For instance, in her study about comparing the usage of washing machines in Germany and India, Honold (2000) found that a washing machine designed with the intention to promote users' sustainable energy and water consumption behavior in Germany resulted in countereffects in India. Based on this finding, they noted that people's laundry behavior is not only determined by product design of the washing machine, but also shaped by the sociocultural contexts such as the local climate, living conditions, division of labor and cultural values in which the laundry activity operates. Looking at this phenomenon from the spatial dimension of Design for Sustainable Everyday Life, it encourages designers to understand sustainability as a property embedded in the sociocultural system, rather than just treating it as an additional element added onto the designed artefacts (Ceschin & Gaziulusoy, 2016).

In the temporal lens, traditionally, the meaning of sustainability in design tends to be oversimplified to and interpreted as an ultimate state where the negative impacts of people's behavior are reduced to minimums (Faber, Jorna, & Van Engelen, 2005). As a consequence, in order to achieve the ultimate sustainability state, design strategies and principles derived from DfSB focus on either promoting particular desired behavior or changing the undesired ones (Niedderer et al., 2014). Although these design strategies are proved to be effective for a certain period of time, how users might transform their behavior over the long-term still remains relatively seldom considered in DfSB (Coskun, Zimmerman, & Erbug, 2015).

The temporal dimension provided by Design for Sustainable Everyday Life suggests that the ultimate state of sustainability only exists in a static context where everything remains unchanged. By contrast, in reality, the context in which people perform their everyday life doings is dynamic and ever-changing. Consequently, a design intervention that works at one specific point in time does not necessarily mean it would lead to the same outcome at another point in time. When it comes down to the practical aspect of design, the temporal lens implies that designers need to take a long-term perspective to study how people evolve or transform their doings over time (Coskun et al., 2015; van Dam, Bakker, & van Hal, 2010). In other words, instead of setting the aim to achieve the static and ultimate state of sustainability, more focuses should be put on how to make constant improvements and adjustments of people's doings towards sustainability from a design perspective.

1.2 Context change disruptions

As pointed out in the preceding section, the spatial-temporal dimension brought by Design for Sustainable Everyday Life emphasizes the importance of understanding the dynamic nature of people's daily life contexts. Nowadays, the world is under a rapid changing process more than ever. Consequently, people's everyday life doings keep evolving as responses to this changing context.

Two types of context change disruptions commonly exist. First, individual life-course events such as leaving parents' home for the first time, new employment, residential relocation, and transition to parenthood, constitute a moment where existing habits of individuals can become disrupted (Verplanken, Walker, Davis, & Jurasek, 2008; Verplanken & Wood, 2006). Second, the macro socio-economical transitions such as the credit crunch and economic crisis in 2008 and the ongoing

Covid-19 pandemic, can also shape how individual perform their everyday life doings (Thompson et al., 2011).

Looking at the phenomenon from the perspective of Design for Sustainable Everyday Life, the context change disruptions are regarded as windows of opportunity to intervene in people's behavior and habits towards a more sustainable direction (Verplanken & Wood, 2006). According to Wood, Tam, & Witt (2005), people tend to perform their habitual behavior under a stable interaction with the surrounding contexts. When certain contextual cues are disturbed by the changes that take place in the surrounding contexts, the corresponding habitual behavior might also be influenced. As a result, people may become more likely to reconsider their existing habitual behavior when they undergo context change disruptions (Verplanken & Roy, 2016). However, how to utilize these disruptions that take place naturally or inevitably in individuals' daily life to promote a transition towards sustainability, especially from a sustainable design perspective, has been seldom explored. Moreover, as context change disruptions can open up a window of opportunity to change people's undesired behavior and habits, the existing socio-ecologically desired behavior and habits can also be influenced. Therefore, besides facilitating change, are there any needs for design to consider retaining people's existing desired behavior when they are undergoing context change transitions?

1.3 Design for sustainable behavior retention

When design meets the windows of opportunity to intervene in people's behavior, change has always been the fashionable term used in policymaking, business development and academic research (Lockton, 2017). This particular feature of design is not strange given that design has long been regarded as an efficient way to change the existing situations into preferred ones (Simon, 1969). Over the past decades, the particular focus on design for behavior change has dominated the research explorations in the DfSB field. A variety of design guidelines and toolkits have been developed with a specific aim to help designers to change people's undesired and unsustainable doings. A list of examples included but not limited to the Design with Intent Toolkit developed by Lockton, Harrison, & Stanton (2010), Behavior Change Design Sprints developed by Colusso, Do, & Hsieh (2018) Dimensions of behavior change developed by Dae & Boks (2014), and Change Points developed by Hoolohan & Browne (2020). Consequently, as most of the knowledge and strategies generated in the field of DfSB revolve around changing people's wrongdoings, the question of how to apply design as a potential means to retain people's existing desired and sustainable doings remains long neglected.

What does design for sustainable behavior retention mean exactly? If one just interprets its meaning literally, then it might lead to a misconception that retention simply means maintaining things as they were, keeping people's daily doings to stay at the current status, or prohibiting potential changes from happening. To avoid such misinterpretation, it is crucial to set up the meaning of design for sustainable behavior retention. In this dissertation, the initial definition of the concept of design for sustainable behavior retention is:

To maintain and adjust people's existing socio-ecologically desired doings before the unsustainable ones become embedded when people undergo context change disruptions.

Although this definition is preliminary in this stage, it would help to build a common ground for readers to understand the research aim and questions proposed in the dissertation.

Building upon the preliminary definition indicated above, the next question comes to what does a retention perspective imply for sustainable behavior design? Take mobility for instance. Nowadays our society is facing a growing usage of private automobiles. Looking at this sustainability challenge from a design for behavior change perspective, the corresponding design interventions mostly emphasized reducing people's overreliance on private automobiles. However, we seem to have neglected the fact that most people who become frequent users of private automobiles must have had undergone a transition process from biking or taking public transportations to driving. This transition might be triggered by various reasons associated with context change disruptions, such as relocating to another residential area, getting a baby, finding a new job, becoming middle class and so on. By taking a sustainable behavior retention perspective, the design focus can then be placed on exploring how to retain people's existing green commuting doings and further support people in adjusting the sustainable doings while they are undergoing a transition process, thus preventing the undesired and unsustainable behavior patterns from happening in the first place.

1.4 Research motivation

Before we begin exploring the behavior retention perspective in Design for Sustainable Everyday Life, one question that still remains explained is: why does a sustainable behavior retention perspective matter? In other words, what would be the benefits that the investigation of design for sustainable behavior retention might bring for the overall sustainable development of the society?

Discussions around the potential societal contribution of the study are elaborated in the conclusion chapter of the dissertation. This section only describes why I am motivated to choose this particular research topic. For readers who are holding the dissertation right now, knowing the motivation behind my research can hopefully help you gain a better view of the overall concept underlies this dissertation.

My research motivation comes from what I had seen and experienced when I grew up. I was born in Wuhan, China. I remembered when I was a little kid, in the 90s, people used to live in harmony with the surrounding environment. For example, in terms of food consumption, fridge and stove back then were much smaller with less function than the ones we use today. Nevertheless, almost nothing got wasted at that time as food items were always preserved and utilized smartly and efficiently. Moreover, there were no modern garbage classification facilities in the local community where I lived. Like many families in the community, my family separated organic food waste from other types of waste so that nutrition in food residue can be returned to the field to fertilize the soil. However, as we moved into newly constructed apartment buildings in the urban area, all of these desired sustainable doings have gradually faded away along with time.

This personal experience makes me wonder that besides changing people's undesired and unsustainable doings, are there any needs or possibilities for design to take the responsibility to retain people's existing desired sustainable doings when they are undergoing context change transitions? Furthermore, what insights this particular retention perspective might offer to better cope with the current sustainable consumption lifestyle challenges that the society is facing today?

1.5 Knowledge gaps and research focus

In summary, this dissertation departs from the general inquiry: if sustainable behavior design is not only aimed at creating behavior change, but also takes the role of retaining people's existing sustainable behavior when people are undergoing context change disruptions, then what new sustainable design implications can be informed? Can this behavior retention perspective open up new opportunities for design to guide people's daily doings in a more sustainable direction? More precisely, this dissertation aims at addressing two specific knowledge gaps in the field of Design for Sustainable Everyday Life (see Figure 1).

Figure 1. The knowledge gaps that this dissertation aims to address within the scope of Design for Sustainable Everyday Life.

Gap (a). Impacts and opportunities of context change disruptions

The daily doings that people perform in their everyday life contextual settings are not static but under a dynamic transition process. As presented in the preceding section, both socio-economic events and individual life-course events can, to a certain degree, disrupt people's existing habitual behavior. The underlying impacts and opportunities that context change disruptions can bring to people's sustainable behavior have been ill-addressed. This dissertation thus looks at the research topic of design for sustainable everyday life with a particular focus on how people transit their doings when undergoing context change disruptions (as shown in Table 2).

Gap (b). Design for sustainable behavior retention

Over the past decades, the field of design for sustainable everyday life seems to have grown accustomed to the concept of changing people's wrongdoings. However, there has so far been little attention to exploring the opportunities and implications that design can bring in retaining people's existing desired and sustainable doings. A successful sustainable behavior transition entails not only

changing the undesired doings, but also retaining the desired ones (Jotte I.J.C. de Koning, Ta, Crul, Wever, & Brezet, 2016; Jotte Ilbine Jozine Charlotte de Koning, Crul, Wever, & Brezet, 2015). This dissertation thus explores how to better guide design researchers' and practitioners' empirical analysis of and design explorations on sustainable behavior retention (as shown in Table 2.1).

Table 2.1. The knowledge gaps that this dissertation aims to address.

Knowledge gaps	Wider consequences	Research focuses of this study
a). Lack of understanding of the underlying impacts and opportunities that context change disruptions can bring to sustainable everyday doings.	Miss the windows of opportunity to enhance people's existing sustainable doings.	Explicitly focusing on studying how people transit their doings when undergoing context change disruptions.
b). Lack of explorations on the opportunities and implications that design can bring in retaining people's existing desired and sustainable doings.	Solely focusing on changing the undesired outcomes of people's doings but neglect the importance of retaining the desired ones.	Explicitly focusing on exploring the role that design can play in retaining people's existing sustainable doings during context change disruptions.

Food consumption is chosen as the practical field of application in this study. Food consumption is chosen due to two reasons. First, food consumption acts as a node that connects various doings that people perform in different aspects of everyday life. For example, purchasing and transporting food requires mobility; storing and cooking food in household environments involve the use of fridges and stoves thus energy consumption. Second, how people carry out food consumption is not static but under a constant dynamic transition process. For example, an individual who moves from his/her country of origin to another country may need to adapt to a new food consumption system, thus resulting in the development of a new food consumption routine. The food consumption doings of a kid who brings lunchbox to school every day is certainly different from the doings when she/he performs turns into an adult. Therefore, this unique characteristic makes food consumption an ideal area to explore how people transit their existing doings when undergoing context change disruptions.

1.6 Aim and research questions

Given the knowledge gaps and research focuses identified in the preceding section, the thesis aims to:

Develop a theoretical approach to support design researchers and practitioners in better understanding how people transit behavior when they undergo context change disruptions, and explore what design implications can be informed by highlighting sustainable behavior retention aspect in the transition process.

The overarching aim of the study is broken down into three objectives, disrupting across three levels of research inquiry: conceptual level, design analytical level, and design synthesis level (as shown in Table 3).

Objective1 focuses on the conceptual exploration of the topic of design for sustainable behavior retention. Specifically, it aims to develop an overview of to what extent is the topic of design for sustainable behavior retention explored in the current body of research on design for sustainable everyday life. Objective1 leads to the first research question:

RQ 1: What is the status of current knowledge of sustainable behavior retention in the existing body of literature in the field of design for sustainable everyday life?

Understanding the behavior retention aspect would first require a theoretical lens that can help analyze how people transit their behavior when undergoing context change disruptions. Therefore, objective2 aims to develop such a theoretical framework. By focusing on the analytical level of design, the second research question sets out to explore:

RQ 2: From the perspective of design for sustainable everyday life, how to systematically describe and analyze behavior transition induced by context change disruptions?

Objective3 aims to synthesize the conceptual understanding generated in objective1 with the theoretical framework developed in objective2 into a more practically applicable form for designers to use. An AT-informed idea generation toolkit prototype is developed and evaluated to facilitate structured design exploration in response to sustainable behavior retention. Two research questions arise from objective3:

RQ 3.1: How might the proposed AT theoretical lens be incorporated into a toolkit to highlight the behavior retention perspective in sustainable design explorations?

RQ 3.2: Building upon the AT theoretical lens, what are the design implications that sustainable behavior retention perspective can bring to the field of design for sustainable everyday life.

The distribution of the research objectives and questions in relation to the research inquires in different levels is presented in Table 3.

Table 2.2. An overview of the distribution of the research objectives and questions in relation to the research inquires in different levels.

Level of inquires	Overall focuses	Specific objectives	Research questions
Conceptual level	Conceptual exploration on the topic of design for sustainable behavior retention	Develop an overview of to what extent is the topic of design for sustainable behavior retention explored in the current body of research on design for sustainable everyday life.	RQ 1: What is the status of current knowledge of sustainable behavior retention in the existing body of literature in the field of design for sustainable everyday life?
Design analytical level	Develop and validate an AT-based theoretical framework to understand behavior transformation	Explore how an AT-based theoretical lens can be used to guide empirical analysis and inform design implications for retaining people's sustainable doings through context change disruptions.	RQ 2: From the perspective of design for sustainable everyday life, how to systematically describe and analyze behavior transition induced by context change disruptions?
Design synthesis level	Develop an AT-informed ideation toolkit to support sustainable activity design	Enable design practitioners to take into account the sustainable behavior retention perspective in the early ideation stage of their sustainable design explorations.	RQ 3.1: How might the proposed AT theoretical lens be incorporated into a toolkit to highlight the behavior retention perspective in sustainable design explorations? RQ 3.2: Building upon the AT theoretical lens, what are the design implications that the sustainable behavior retention perspective can bring to the field of design for sustainable everyday life?

1.7 Outline

The dissertation is based on the works presented in the appended papers. Given the variety of the themes covered in the papers, to better connect the themes in a more coherent manner, the key findings and reflections of each paper are presented in the dissertation. An overview of the research outline is illustrated in Figure 2.

Figure 2. An overview of the research outline

A short summary of the eight chapters in this dissertation is presented below:

- Chapter 1: Presentation of research background, motivation, research gaps, aim and research questions.
- Chapter 2: Presentation of the theoretical lens adopted in the dissertation. The focus of this chapter is to introduce and discuss the key theoretical concepts and principles of AT. For clarification, as a comprehensive introduction of AT has already been provided in Paper V, this chapter is adopted from the theory section of Paper V.
- Chapter 3: Presentation of the methodology and selected methods in the dissertation. This chapter focuses on describing how the study is constructed and carried out.
- Chapter 4: Focus on answering RQ 1. Specifically, a narrative literature review investigating the current knowledge status of behavior retention perspective is reported in this chapter.
- Chapter 5: Focus on answering RQ 2. It presents the detailed development, iteration and application of the AT-based theoretical framework.

- Chapter 6: Focus on answering RQ 3.1 & RQ 3.2. It presents how the proposed theoretical framework is developed into an AT-informed ideation toolkit.
- Chapter 7: Discussion on the design implications that a behavior retention perspective can provide for the field of Design for sustainable Everyday Life. Furthermore, reflections on the research approach and knowledge generation process of this PhD study are also discussed.
- Chapter 8: Presentation of answers to each research question and the potential contributions of the dissertation.

2

Theoretical Background

Chapter 2 focuses on introducing the theoretical, background, key concepts and principles of Activity Theory from a design perspective. For clarification, as a comprehensive introduction of AT is presented in Paper V, the major part of this chapter is adopted from the Activity Theory section of Paper V.

2.1 Theoretical background of Activity Theory (AT)

The conceptual origins of AT can be traced back to the work conducted by psychologist Lev Vygotsky and Sergei Rubinshtein in the 1920s and 1930s (Kaptelinin & Nardi, 2006). According to Vygotsky (1978), the human activity is comprised of three key components: subject –the performer of the activity who is driven by a specific need to carry out an activity; object – the goal that the subject aims to achieve; artefacts – the tools which are used by the subject to achieve the object. Building upon the interaction between these three components, an activity is interpreted as purposeful need-based relationships between the subject and the object mediated by the use of artefacts (as shown in Figure 3).

Figure 3. Vygotsky's first generation AT model.

Established on Vygotsky's classic triangle AT model, a variety of models have been developed. As illustrated in Figure 4, Leontiev's hierarchical structure model (Leont'ev, 1974; Leont'ev, 1978)(referred to as the second generation of AT model) and Engström's Cultural-Historical Activity Theory model (Engestrom, 1987) (referred to as the third generation AT model) have been widely applied in the current research.

Specifically, Leontiev's AT model introduced the principle of hierarchical structure and expanded Vygotsky's AT model from a single layer to multiple layers, indicating that human activities comprise three hierarchical layers: activity layer, action layer, and operation layer.

- *Activity layer*: The activity layer is oriented towards a motive to achieve an object. It provides insights into why an activity is carried out.
- *Action layer*: Under the activity layer, the action layer is directed by intentional goals. It presents how goals within the activity are fulfilled.
- *Operation layer*: Under the action layer, the operation layer represents how a series of actions are adjusted into routinized operations.

Engström sets an explicit focus on collective activities by exploring how human activities are structured and carried out in socio-cultural contexts. He expanded Vygotsky's AT model by introducing the components of communities, rules and division of labor into the theory. A detailed description of the theoretical development process of AT can be found in Kaptelinin & Nardi (2012).

Figure 4. Leontiev's hierarchical structure model (adopted from Leont'ev, 1978) and Engström's cultural-historical activity theory model (adopted from Engestrom, 1987).

2.2 AT's applicability for design research

Originating from a socio-cultural tradition in psychology, two distinguishing features make AT applicable for design research. First, unlike most of the behavioral and psychological theories which provide researchers with models to predict people's behavior, AT aims at supporting design researchers in formulating sensible inquiries based on the descriptive accounts of why and how people carry out a specific activity in a specific context to achieve a specific goal (Bødker & Klokmoose, 2011; Kaptelinin, 2014; Li & Landay, 2008). In this respect, AT works as a theory-based conceptual framework that guides design researchers to generate and structure research inquiries rather than a traditional theory for making predictions (Karanasios, 2014).

Second, as Engeström (1999: p 29) noted that "activity theory has the conceptual and methodological potential to be a pathbreaker in studies that help humans gain control over their own artifacts and thus over their future." AT's particular focus on the role that artefacts play in people's activity system is in accordance with the design's tradition in understanding and shaping human-artefact relationships (Duignan, Noble, & Biddle, 2006; Kuutti, 2011). Some recent works also pointed out that AT is a promising theoretical lens, especially when used in DfSB research (Renström, 2019; Selvefors, 2017). Five theoretical principles of AT have become the cornerstones that underpin the application of AT in design research (Kaptelinin, Nardi, & Macaulay, 1999):

- Mediating artefact
- Subject-object relationships
- Tensions and contradictions
- History and development
- Sociocultural contexts.

Furthermore, approaching design for sustainability from the field of Human-Computer Interaction, Kaptelinin & Nardi (2012) pointed out that AT's historical sensitivity, attention to complex systems, and reality-based solutions may be useful for tackling design-related sustainability problems. However, despite the wide application of AT as a theoretical lens in design research, how the above-mentioned theoretical principles of AT can support design researchers in understanding and addressing complex sustainability challenges remain ill-addressed.

2.3 Rationales behind choosing Activity Theory (AT)

As noted in the introduction chapter, Design for Sustainable Everyday Life highlights two crucial dimensions: 1). The spatial dimension, that is, the sociocultural contexts in which people's everyday life doings situate, and 2). The temporal dimension, that is, the dynamic and evolving feature of people's everyday life. Consequently, the Design for Sustainable Everyday Life perspective seems to extend the sustainable design focus from user behavior to the long-term, multi-level and complex features of users' doings. To facilitate people's behavior transformation towards sustainability, a theoretical lens that systemically contextualizes people's doings in a spatio-temporal lens is thus needed. Activity theory (AT), given its primary focuses on the role that artefacts (and design of artefacts) can play in purposeful need-based human activities, along with its' spatio-temporal lens to interpret the dynamic development of human activity systems, is regarded as one of the leading candidates to systematically describe and analyze behavior transition induced by context change disruptions.

2.4 A brief introduction to AT's five key theoretical principles

In this section, the meaning of each theoretical principle of AT is briefly introduced from a design research perspective. How the theoretical principles may be potentially used to investigate sustainability issues is addressed in this section.

2.4.1 Mediating effects of artefacts

The theoretical concept of mediating artefacts plays a central role in AT. According to Vygotsky (1978), all purposeful interaction between the subject and the world is mediated by artefacts. The mediating artefacts include both external material tools (e.g., hammers, computers and digital interface) and internal immaterial tools (e.g., language, symbols and models) (Kaptelinin, 2014). This conceptualization of artefact is in line with the classic definition of artefacts proposed by Herbert Simon, that an artefact can take any forms on the continuum between abstract and concrete and act as a bridge between an internal and external environment (Simon, 1969). In reality, the human activity is seldom mediated by a single mediator. Rather, the real-life mediation process consists of a network of interconnected mediators involving both internal and external artefacts, forming a complicated ecological system (Bødker & Andersen, 2005; Gay & Hembrooke, 2004). As a result, the replacement of an existing artefact or the introduction of a new artefact in the activity system can potentially shape how the target activity is carried

out. In turn, the artefacts are simultaneously reshaped and adapted to the target activity (Bødker & Klokmoose, 2011).

2.4.2 Subject-object relationships

The concept of subject-object relationships is regarded by many theorists as one of the fundamental notion underpinning the development of AT. In the view of AT, subjects can be individual (e.g., individual users) and collective (e.g., different stakeholders, organizations and communities). Correspondingly, the object involves both tangible biological needs (e.g., eat food) and intangible psychological needs (e.g., comfortable living) of human life. When a specific need of the subject is coupled with a specific object, a motive is formed, and at the same time, an activity emerges. AT argues that it is the subject-object relationship, rather than the individual component of subject or object, that determines how an activity is carried out (Gay & Hembrooke, 2004). As Kaptelinin & Nardi (2006) indicated, when used in product and service design, this concept can enable designers to expand the scope of analysis from users' interaction with a specific product or service to how subjects carry out a meaningful motive-oriented activity.

2.4.3 Tensions and contradictions

Tensions and contradictions are broadly defined as misfits, problems, incoherencies and inconsistencies that subjects encounter in the target activity systems (Kuutti, 1996). When this concept was applied in design research, in some cases, it was only used to identify product usability problems. However, that is an oversimplification as tensions and contradictions do not only exist in the interaction between users and artefacts, but also can be found within and between different components of an activity system. It is due to this reason that understanding tensions and contradictions might provide design researchers with a systemic perspective of how sustainability problems take place at different levels of an activity system. Specifically, according to Engestrom (1987: p 98), four types of tensions and contradictions can be identified. Primary contradictions exist in each individual component of an activity system; Secondary contradictions exist between different components of an activity system; Tertiary contradictions take place between an existing activity system and a newly established competing activity system. Quaternary contradictions take place between the target activity system and its neighboring systems, which share the same objects.

2.4.4 History and development

The triangle presentation of the activity systems may bring a misperception that all human activity systems are steadily constructed. In fact, the relationships between different components of an activity system are ever-changing (Gay & Hembrooke, 2004). When subjects begin to cope with the tensions and contradictions within and between activity systems, the activity system might undergo a development process (Engeström, 1999). This development process does not just last for a certain period. On the contrary, in the view of AT, activities are under constant development and evolution (Kuutti, 1996). Based on this view, how we carry out a specific activity at a specific point in time is influenced by the historical evolution of the relevant activities. The present activities would also inevitably bring impacts to the future development of the activities (Kaptelinin & Nardi, 2006). From the perspective of Design for Sustainable Everyday Life, two main features of this theoretical principle are relevant: First, AT has a special view for interpreting changes. It views changes as elements that naturally embed in human activities, driven by tensions and contradictions that take place in people's activity systems. When tensions and contradictions become materialized at a given point in time, the subject of the activity system may attempt to find temporary solutions to address the contradictions, it is under these moments that the activity undergoes a transformation process (Blackler, Crump, & McDonald, 1999; Boer, van Baalen, & Kumar, 2002). Second, unlike other mainstream behavior change theories which model changes according to behavior determinants such as norms, attitudes and perceived behavior control, AT postulates in its theoretical nature that a typical way to induce intentional changes is through re-mediation, that is, redesigning artefacts (such as products and services) to influence the way how subjects achieve the original object (Bødker & Andersen, 2005; Nardi, 1996).

2.4.5 Sociocultural contexts

Gay & Hembrooke (2004) connect AT to an ecological perspective and posit a human activity at three levels: the *micro-level* represents independent activities carried out by each individual, the *meso-level* represents collective activities carried out by a group of individuals or a community, and the *macro-level* represents broader sociocultural contexts. They argued that when an activity system is analyzed at one particular level or context, its relations with activities at other contextual levels (educational systems government, state and local processes) should also be taken into account. From the perspective of Design for Sustainable Everyday life, the sustainability effects of a product and service should not be limited to its

environmental performance or its influence on individual user behavior. Instead, since the majority of people's daily life activities involve multiple motives and different mediating artefacts, which are all shaped by specific socio-cultural contexts, it thus becomes vital for design researchers to analyze or envisage the potential impacts of a particular sustainable design intervention on different sociocultural levels, covering individual to broader sociocultural contexts. Moreover, the theoretical concept of sociocultural contexts also highlights the importance of understanding people's behavior in real-life settings rather than task-based laboratory settings (Kaptelinin & Nardi, 2006: p 35).

3

Research Approach

This chapter first presents the overall research methodology employed in the study and the research outlines. Following that is a brief introduction to the selected research methods and the rationales behind adopting these methods.

3.1 Philosophical stance, ontology and epistemology view

I see myself as a pragmatist. This self-identity led me to choose a pragmatic philosophical stance in my research. Pragmatism originated from the United States in the 19th century. The origination of Pragmatism is, to a large extent, inspired by the Theory of Evolution proposed in the 19th century. Pragmatism believes that evolution is not only a biological feature; it can also be generalized to understand all the other aspects of nature as the whole universe is subject to an evolutionary process. Based on this worldview, pragmatism argues that truth is relative, dynamic and ever-changing (Johnson & Onwuegbuzie, 2004). In other words, the reality that exists at one particular point in time and space might be radically different from the reality that exists at another point in time and space. Therefore, some of the knowledge that is useful in one particular in time and space may not be useful in another particular point time and space. Pragmatism's ontology view is partially in line with Social Constructivism, which argues that reality is subjective and has no absolute or stationary states (Guba & Lincoln, 1994). Different understandings and knowledge thereby can co-exist (Creswell, 2003). In terms of epistemology, pragmatism claims that when researchers investigate the reality, they should remain open-minded and be willing to accept changes (Hicks, 2009). Reflecting on this epistemology stance from a design research perspective, it implies that when researchers investigate a particular phenomenon, they need to be ready to acknowledge the dynamic interplay between observation and analysis, gain direct access to participants, and be open to co-construct knowledge with the participants. This personal reflection of Pragmatism guides me to choose a combination of

different research methods, including probes, observations, interviews, systematic literature review, and meta-synthesis.

Instrumentalism is closely connected to Pragmatism. It is commonly seen as a methodological view rooted in the epistemology of Pragmatism for acquiring knowledge. It explicitly argues that theories are instruments or tools by which we know reality. Theories are useful for predicting, categorizing, understanding, and modelling particular phenomena. They are derived from practices and applied to practices. Following this view, in the context of my PhD research, I adopt AT as the instrument to understand how people transform their doings when undergoing context change disruptions. As I tested the use of AT in different case studies, I adapted and further revised the theory to fit into the goal of my research and answer the research questions proposed in this dissertation. This epistemology view based on Pragmatism and Instrumentalism also guides me to choose a Design Research Methodology (DRM), which emphasizes developing understanding of empirical phenomena and translating the generated understanding into the design in an iteration manner (Blessing & Chakrabarti, 2009).

3.2 Design Research Methodology (DRM)

According to Blessing & Chakrabarti (2009), design research typically consists of two interconnected components: the development of understanding and the development of support. The objective of the first component is to obtain an in-depth understanding of a specific phenomenon which is of design interests. Such understanding can be formulated and validated in the form of theories, frameworks and models. The second component focuses on translating the understanding into various support to improve design practices. Such support can be developed as design knowledge, implications, guidelines, strategies, methods and tools to help design practitioners better attain the intended design outcome.

DRM comprises four research stages with different research focuses: Research Clarification, Descriptive Study I, Prescriptive Study, Descriptive Study II. Research Clarification and Descriptive Study I focus on developing an in-depth understanding of the targeted phenomenon, while prescriptive study and descriptive study II focus on developing support for design. The goals, basic means and deliverables of each stage are elaborated in the following.

Research Clarification is a preparatory stage. It helps researchers working with design challenges develop an overall understanding of the current scientific

knowledge of the research topic, identify relevant research areas, clarify research aim and questions, and set up a research plan for the subsequent research stages. The basic means used in this stage is the review of existing studies.

Descriptive Study I (DS-I) aims to increase the understanding of the specific phenomenon clarified in the previous stage and identify key factors that influence the phenomenon. This is achieved by systematically summarizing relevant insights from existing literature review and undertaking empirical studies. The deliverables of this stage include the highlights of design-related problems, the key impact factors, and the corresponding implications that may determine the success of the design.

Prescriptive Study (PS) aims to transform the increased understanding developed in the previous stages to practical support that can improve the targeted design practices. This is achieved by synthesizing empirical results obtained from DS-I with literature insights from RC to formulate a model/framework that represents the desired situation in design, along with key implications/actions that would support the transformation of the situation from the current to the desired status. The deliverables of this stage comprise the development of the *Intended Support and Actual Support*. It has to be noted that the *Intended Support* and *Actual Support* have a different emphasis. The *Intended Support* demonstrates the core concepts to improve the design. It is mainly in the form of frameworks and models. The *Actual Support* is the prototype of the *Intended Support*. It can take the form such as methods, guidelines, checklists, software and toolkits, in which the core concepts of the intended support are sufficient to be evaluated.

Descriptive Study II (DS-II) focuses on evaluating the effects of the proposed *Intended Support* and *Actual Support*. Note that DS-II is not merely a revision of DS-I. While DS-I aims to develop an in-depth understanding of a phenomenon, DS-II focuses on analyzing what and how the proposed support may have actual effects on the targeted phenomenon. This is mainly achieved by evaluating the effects of the support through three criteria: usability, applicability and usefulness. The deliverables in this stage include the evaluation results and implications to further improve the proposed support.

DRM is chosen as the leading research methodology due to three reasons.

- First, as indicated in the introduction section, the goal of the study mainly comprises two parts: 1). developing an understanding of the behavior retention phenomenon, and 2). incorporating the generated insights into a toolkit for designers to use in their early-stage ideation process. This aligns with the *Understanding* and *Support* component of the DRM mentioned earlier.
- Second, DRM provides design researchers with a clear division of different research stages with detailed guidance of what the goal is in each stage and how to achieve the goal. Moreover, it also highlights the connections between different research stages, for example, how the deliverables of the previous stages can be used to inform the research explorations in the subsequent stages. This methodological feature can systematically construct and translate the generated theoretical knowledge into practical design implications.
- Third, the methodological nature of DRM is heuristic rather than algorithmic (Blessing & Chakrabarti, 2009 p: 14). It does not necessarily require researchers to strictly follow its methodological procedures and take an equal depth of investigation in each research step. Rather, it acknowledges the diversity of the research topics that researchers deal with in the design discipline and allows design researchers to flexibly adapt the methodology to suit different study focuses. Therefore, in the context of this study, instead of carrying out the research exploration in a step-by-step linear fashion, several studies were conceived and conducted in parallel, each of which informed the planning and development of the others. Some of the parallel studies belong to the same research stage (e.g., connections between Study A-I and A-II, Study B-I and B-II), while some across different research stages (e.g., connections between Study C-I and Study E-I). The main reason behind this study set-up is to effectively integrate the understanding generated in different types of studies (including review-based study and empirical case study) within the limited time of the PhD study.

3.3 Overall research design

Following the methodological procedures suggested by DRM, the study is divided into four stages: Stage 1 - Research clarification (RC), Stage 2 - Descriptive Study I (DS-I), Stage 3 - Prescriptive Study I (PS-I), Stage 4 - Descriptive Study II (DS-II). Figure 5 illustrates the methodological procedures of the study.

Figure 5. An overview of research stages, basic means and deliverables in each research stages.

Stage 1 - Research clarification (RC):

Following the DRM guideline presented earlier, in the initial stage of the research, efforts were made to 1). Conduct a narrative literature view in the field of design for sustainable everyday life to identify relevant studies, along with candidates of potential theoretical perspectives to analyze behavior transformation phenomena induced by context change disruptions. 2). Summarize findings from existing research and formulate preliminary research inquiries.

Stage 2 - Descriptive Study I (DS-I):

Building upon the overview of the research topic and the potential theoretical perspectives identified in RC, the aim of DS-I is to develop understanding of the effects that context change disruptions may bring people's everyday doings. This aim is achieved by developing a theoretical framework for design researchers and practitioners to better describe and analyze the behavior transformation phenomena.

Study A, B, C, D were undertaken in this stage. In these studies, I adopted activity as the unit of analysis and applied an AT theoretical perspective as the analytical lens to interpret the empirical phenomenon. This theoretical perspective later became the guiding lens that directs the subsequent development of the AT-based framework and AT-informed toolkit later proposed in the PhD study.

To be more specific, first, in Study A, two case studies, one concerning astronauts' food consumption on the International Space Station (Study A-I, see Paper II) and the other concerning exchange students' food consumption (Study A-II, see Paper I), were undertaken. The deliverable of Study A led to the development of the first version of the AT-based theoretical framework. Similarly, two case studies, Study B-I and Study B-II were undertaken in Study group B, which led to the development of the second version of the AT-based theoretical framework. Following that, results of study C-I, which focuses on investigating the interplay between on-pack date labelling and household food waste (see Paper III) led to the third version of the framework. The framework was then validated in Study D, which aims to uncover household food consumption transformation under lockdowns caused by the Covid-19 pandemic.

Stage 3 - Prescriptive Study I (PS-I):

Following the definition of Intended Support and Actual Support in DRM, while DS-I focuses on developing, iterating and validating the Intended Support (AT-based theoretical framework), PS-I focuses on translating the framework to a design toolkit to provide the Actual Support for design practitioners in their sustainable design practices. Study E-I was carried out in this stage.

As the insights and reflections regarding the theoretical framework resulted from the DS-I still largely rely upon findings from the case studies, to make the AT-

based theoretical framework more generalizable, a more solid theoretical grounding is still needed. Therefore, I conducted a meta-synthesis study to systematically investigate the potential use of AT as a theoretical lens for guiding empirical analysis and design explorations in design for sustainability (see Paper V). The results of the meta-synthesis study then led to both theoretical and design implications that support design researchers in better framing and addressing design challenges concerning people's sustainable behavior in the context of people's activity systems.

Stage 4 - Descriptive Study II (DS-II):

The deliverable of PS-I and DS-II is an AT-informed toolkit prototype which aims to support design practitioners in incorporating sustainable behavior retention perspective into the ideation stage of their sustainable design practices. More precisely, while the focus of PS-I is to develop and iterate the AT-informed toolkit prototype, DS-II focuses on evaluating the applicability and usability of the prototype. In line with the overall topic of the other case studies included in the thesis, the evaluation was undertaken in the area of sustainable household food consumption.

3.4 A brief introduction to the selected research methods

As summarized in Table 3, the study is divided into four research stages with different research focuses. Answering the research questions in each research stage thus requires the application of different research methods. This section gives a brief overview of the methods applied in each research stage. It has to be noted that detailed information regarding how the methods was employed is also presented in the result chapter. This section focuses on describing the background and detailed set-up of each method. The focus of the method sections in the result chapter is on how different methods were combined and employed together in each case study.

Table 3. The research focuses, research questions and methods applied in each research stage.

Research stages	Focuses	RQs	Methods applied
Research Clarification (RC)	Formulate preliminary research inquiry and identify relevant theoretical perspectives	RQ 1	Narrative literature review
Descriptive Study I (DS-I)	Develop and validate a theoretical framework to systematically analyze behavior transformation induced by	RQ 2	Diary probes; In-practices studies;

context change disruptions from a design perspective		Systematic literature review	
Prescriptive Study I (PS-I)	Develop an AT-informed ideation toolkit to support sustainable activity design	RQ 3.1	Narrative literature review; Qualitative meta-synthesis
Descriptive Study II (DS-II)	Evaluate the applicability and usability of the toolkit prototype	RQ 3.2	Co-creation

3.4.1 Narrative literature review

A narrative literature review is a comprehensive, critical, and objective evaluation of previous studies on a research topic (Machi & McEvoy, 2012). It is often used to summarize the current knowledge development in a research area and explain why a particular topic within the research area is worthy of exploring (Allen, 2017; Baker, 2016). In this study, two narrative literature reviews were conducted.

The first narrative literature review was conducted in the RC stage to address the first research question: what is the status of current knowledge of sustainable behavior retention in the existing body of literature in the field of design for sustainable everyday life? Consequently, the scope of this narrative literature review is within the design for sustainable everyday life. In addition to the focus on the aspect of behavior change and retention, another special focus is given to the theoretical perspective that each study uses to analyze and understand behavior transformation. Therefore, insight gained from this narrative literature review not only contributes to the formulation of a general research background of PhD study, but also helps to identify and summarize the relevant theoretical perspectives included in this dissertation. The other narrative literature review was conducted in the PS-I stage. The goal is to explore how the key AT theoretical principles are applied in design research to address sustainability-related challenges. This review has a particular focus on the overlapping area between three general fields: activity theory, design research, and sustainability.

3.4.2 Systematic literature review

Compared with narrative literature reviews, a systematic literature view aims to use rigorous criteria to identify, select, assess, and critically analyze all the relevant literature relating to particular research questions (Cronin, Ryan, & Coughlan, 2008). Depending on the specific features of each research area, different

systematic literature review guidelines have been proposed. For example, the PRISMA's systematic literature review checklist (Moher et al., 2009, 2016) has been widely used in medical research, Petticrew & Roberts (2008)'s systematic review guide has been widely adopted in social science disciplines. In this study, I adopted and adapted the systematic literature review methodological guideline developed by (Kitchenham, 2004). This systematic literature review guideline is chosen as it explicitly focuses on performing reviews in the field of engineering and design, which matches with the general background of the PhD study. Moreover, the guideline is potentially applicable to cover a wide range of research topics as it also draws on systematic literature review insights from medical and sociology research (Kitchenham & Brereton, 2013; Kitchenham & Charters, 2007).

A systematic literature review was conducted in Study C-I to compile existing knowledge regarding how consumers use date and storage labels in their food assessment activities. The systematic literature review is comprised of three phases: 1). Planning the review, 2). Conducting the review, 3). Reporting the review. Figure 6 shows a step-by-step procedure of the systematic literature review. A detailed description of how the systematic literature review was performed can be found in Section 5.4.1.2, also see Paper III.

Figure 6. Systematic literature review procedures adapted from Kitchenham & Charters (2007).

3.4.3 Qualitative meta-synthesis

The qualitative meta-synthesis is conducted in Study E-I to systematically synthesize AT as a theoretical lens for guiding empirical analysis and design explorations in design for sustainability. A qualitative meta-synthesis is a hermeneutic approach seeking to generate understanding about phenomena by integrating, comparing, and translating original findings from a number of interrelated qualitative studies into coherent ones (Sandelowski, Docherty, & Emden, 1997; Stern & Harris, 1985; Walsh & Downe, 2005). Unlike a narrative literature review and a systematic literature review, a meta-synthesis aims to transfer the findings from each independent primary study into more generalizable theoretical insights or conceptualizations that can be applied beyond the original study sample (Polit & Beck, 2006). Therefore, compared with the literature review, qualitative meta-synthesis is more tailored for theory development and higher-level abstraction of a particular phenomenon (Zimmer, 2006).

A variety of meta-synthesis methodological guidance have been proposed in different research fields (e.g., Finlayson & Dixon (2008) and Paterson, Thorne, Canam, & Jillings (2001)). In the context of this study, the qualitative meta-synthesis method was applied in the PS-I stage with a specific focus on developing an AT-informed ideation toolkit to support sustainable activity design. Based on the explicit focus on generating and translating the activity theory into practical design applications, I adopted and adapted the theory-generating qualitative meta-synthesis methodological guideline developed by Finfgeld-Connett (2018). This guideline is chosen due to its clear methodological procedures for identifying and synthesizing isolated and contextually distinct findings from each primary study into more generalizable theories and frameworks (Leary & Walker, 2018).

As illustrated in Figure 7, the theory-generating qualitative meta-synthesis is comprised of seven steps. A detailed description of how the meta-synthesis was performed can be found in Section 6.4.2 (also in Paper V).

Figure 7. Theory-generating meta-synthesis procedures adapted from Finfgeld-Connett (2018).

3.4.4 Diary probes

The diary probe method is one of the sub-methods derived from cultural probes. Diary probes are often used to collect data related to participants' actual doings, feeling and experiences in an exploratory way by allowing participants to report relevant data by themselves (Gaver, Dunne, & Pacenti, 1999). When used in design research, the strengths of diary probes are three fold. First, diary probes help researchers to understand users' subjective interpretations of the world. They are often used to explore a phenomenon from a design perspective rather than solving a problem (Hanington & Martin, 2012). Second, the use of diary probes can minimize the influences that the physical presence of researchers may bring to participants when they are performing their everyday life doings, thus reducing the potential interruptions in the data collection process (Mattelmäki, 2005). Third, the self-documentation feature of diary probes can help participants arrive at new levels of awareness about their behavior and experiences when they are documenting and reflecting on their data (Pink & Mackley, 2015).

However, participants' levels of engagement in self-reporting often vary from each other. Some may report their data in detail, while some may lack motivations for reporting. Avoiding these potential risks associated with the use of diary probes requires researchers to carefully test and revise the probes in pilot studies before

they are officially sent to participants. Drawing on this insight, the diary probes used in the context of this PhD study were all evaluated in pilot studies.

Specifically, diary probes were employed in two studies: Study A-II (also see paper II), which deals with the transformation of exchange students' food consumption activities, and Study D, which is about people's food consumption activities during strict city-scale lockdown measures caused by the Covid-19 pandemic. Both of the diary probes are seven-day diaries. Participants are supposed to document their food consumption patterns on a daily basis. The diaries comprise three parts: the first part is an instruction on how to report data in the diary. The second part is for participants to document their everyday food consumption doings in general. The third part is a set of reflective questions given by researchers with regard to participants' particular food consumption activities. There is a difference in the form of the diary probe used in these two studies. In Study A-II, a handwritten diary probe was sent to participants, while in Study D, a digital diary probe was used. Moreover, the handwritten diary was sent to participants and collected after seven days, while the digital diary was sent to and collected from participants daily.

3.4.5 In-practice studies of everyday human activities

In-practice studies are a suite of methods, such as interviews and field observations, interwoven with each other and conducted in the context where participants are doing their tasks (Pink, 2017). Unlike diary studies, in-practice studies require researchers to go into the field and collect empirical data when participants perform their daily doings in real-life settings (Pink, 2017).

The in-practice studies were used in Study A-II (see Paper II). As the topic of Study A-II is on food consumption, this method is referred to as participatory cooking. Specifically, the in-practice studies were conducted when participants visit local supermarkets and cook and eat at home individually. The purpose of employing this method is to gain a descriptive account of how participants perform their food consumption activities. First, a 30-45 minutes semi-structured interview was conducted to encourage participants to talk about how they carried out their food consumption activities in the context of their home university and during exchange study. After that, the researcher followed the participants in their food purchasing, and then joined in their cooking.

3.4.6 Co-creation

Co-creation usually takes place in a workshop setting where designers and people not trained in design (e.g., customers, executives, and staff) work together to solve a problem (Sanders & Stappers, 2008). Co-creation can be used in combination with many other methods (Stickdorn, Hormess, Lawrence, & Schneider, 2017). In this dissertation, co-creation refers to collaborative design workshops and brainstorming sessions. The goals of co-creation can be summarized into two folds: 1). to identify potential design directions, 2). to gather a wide range of perspectives in the design process.

Co-creation was employed in Study C-I (see Paper III) and Study E-II (see Paper VI) to achieve different goals. In Study C-I, co-creation was used to generate early-stage design ideas to address on-pack date and storage labelling issues. In Study E-II, it was used to evaluate the use of the proposed AT-informed design ideation toolkit from different perspectives.

4

Current knowledge of design for sustainable behavior retention

This chapter focuses on answering RQ 1. Specifically, a narrative literature review process and results regarding the current knowledge status of design for behavior retention perspective is reported in this chapter.

4.1 A narrative review within the field of Design for Sustainable Behavior

The goal of the narrative literature review is to develop an overview of how the topic of design for behavior retention is covered in the existing body of studies in the field of DfSB. The narrative literature review was conducted in March 2019. Scopus was used as the literature search database. Journal articles, conference papers, and book chapters published in all years till March 2019 are included in the literature search scope.

As shown in Table 4, the narrative literature review process comprises four steps: In step 1, two groups of search strings were used in the initial search. Group A focuses on the behavior change perspective. The search strings include a) “design for behavior(al) change and b) “sustainable behavior(al) change”. Group B focuses on the behavior retention perspective. The search strings include a). “design for behavior(al) retention”, b). “design to retain”, c). “(retain behavior OR maintain behavior)” AND “Design”, and d). “(behavior(al) retention” OR “behavior(al) maintenance”) AND “Design”. In step 2, after removing duplicated results, 233

articles remained. In step 3 abstract and content screening, two exclusion criteria were used:

- The article that is not focused on a design perspective is excluded.
- The article that is not related to the human or technological aspect of design is excluded (as some articles deal with the behavior of physical and biological material).

Table 4. The narrative literature search steps and results.

Literature search steps	Results
Step 1. Define search scope and determine search keywords	Search strings
Step 2. Carry out the literature search	233 articles after removing duplicated
Step 3. Abstract and content screening	129 articles remained <ul style="list-style-type: none"> • General DfSB: 53 articles • Behavior change-related: 69 articles • Behavior retention-related: 7 articles (tentative in this step)
Step 4. Full-text review	<ul style="list-style-type: none"> • Behavior retention-related: 8 articles

Step 3 results in 129 articles. Among the included articles, 69 articles were categorized into the behavior change perspective, while only 7 articles were categorized into the behavior retention perspective. In addition, 53 articles were categorized into the general DfSB perspective which might touch upon both change and retention perspectives, but they do not explicitly focus on any of the aspects. In Step 4, after full-text review, 8 articles were identified as behavior retention-related.

The results show that the meaning of retention is interpreted differently in the identified literature. For example, similar to the initial definition of behavior retention given in this dissertation (see Section 1.3), in their study about sustainable household fridge and freezer design, the concept of retention was used by Tang & Bhamra (2012) as enhancing and reinforcing an existing desired behavior. Specifically, they observed that some participants tend to check what food is stored in the fridge in order to decide what needs to be purchased. This specific behavior is regarded as a desirable environmental behavior that contributes to household food waste reduction. To promote and enhance this fridge-checking behavior, they redesigned the layouts and drawers of the fridge to provide consumers with a clear display of the content inside. In addition to that, with the goal to explore how technology system can be designed to avoid rapid obsolescence, the term retention was used by Garud & Kumaraswamy (1996) to refer to integrity, modularity and

upgradability of a technological system. More precisely, the concept of upgrading a system by replacing some components while retaining the others without having to design the entire system.

Shin & Bhamra (2016) referred to the concept of behavior retention as maintaining the stability of the changed behavior and minimize the need for repeated intervention. Similarly, the need to maintain the effects of behavior change over time is also pointed out in van Dam et al. (2010)'s study about the impacts of energy monitors on people's energy saving behavior. They found that participants tend to revert to their old energy consumption behavior patterns after medium-term. With a specific focus on promoting physical exercise, health and well-being, Zhou et al. (2018), Mitchell, Schuster, & Drennan (2017) and Zhang & Lowry (2016) also highlighted the importance for design interventions to consider how to maintain users' motivations of behavior changes and achieve long-lasting sustainable effects.

The concept of sustainable behavior retention was implicitly touched upon by Hielscher, Fisher, & Cooper (2009) to explore opportunities in hair care sustainable product design. Drawing on a historical review of people's past hair care practices, they concluded that there is an opportunity to combine conventional hair care approaches (e.g., brushing, combing and dry-shampooing) with the modern chemical products-based hair care approaches to achieve less resource intensive practices. However, the focus on how people carried out the hair care practices in the past does not mean to retrieve the past. Instead, it is used in the study to discover new design opportunities by learning from the sustainable aspect of people's pre-existing doings.

In summary, the narrative literature review results confirm that, compared with the design for behavior change perspective, the behavior retention perspective remains relatively barely covered in the existing body of DfSB studies. Moreover, the retention perspective is applied differently when dealing with different research topics. The concept of retention is commonly applied to maintain the positive effects of behavior change for a long-term time span, especially in the studies that focused on introducing sustainable design interventions to promote health and well-being. Other included studies implicitly used the concept of retention as a way to identify design opportunities based on sustainable elements embedded in people's existing and past doings. However, based on the review results, the specific question of how to retain people's existing desired and sustainable doings when they undergo context change disruptions, which is the research focus that this dissertation

revolves around, has not been explored in DfSB studies both from theoretical and practical aspects.

5

Development of the AT-based framework

This chapter presents the detailed development and application results of the AT-based theoretical framework. As shown in Figure 8, the framework underwent three iterations and one validation:

- The initial framework (version 0.1) is established on AT's theoretical principle of hierarchical structure, which has already been widely applied in previous design for sustainability relevant studies.
- Following that, with a particular focus on AT's principle of mediating artefacts and developmental perspective, the first version of the framework (Version_1.0) is proposed based on results from Study A-I and A-II.
- Then, results from Study B-I and B-II are used to develop the second version of the framework (Version_2.0), which takes sociocultural contexts into account.
- After that, through incorporating AT's principle of tensions and contradictions, Study C-I iterates the framework to Version_3.0.
- Finally, Study D is used to validate the proposed framework.

Figure 8. The iteration process of the AT-based theoretical framework.

It is worth noting that the development and iteration process of the AT-based theoretical framework is presented in detail due to two reasons:

First, as described in Chapter 2, five key AT theoretical principles are identified. Incorporating all these theoretical principles into the framework at once may, to a large extent, limit the exploration of the analytical features that AT can provide. Therefore, based on this particular concern, I adopted a step-by-step iteration process to enable both an in-depth (in the sense of one or multiple studies focus on one theoretical principle) and a comprehensive (in the sense of integrating results from different studies) exploration of the AT theoretical lens in design for sustainable everyday life.

Second, the studies presented in this thesis are not in a linear relationship, where one builds on the other's results. Instead, each study is assigned, planned and carried out with different focuses. The theoretical focus of some studies overlaps with others (e.g., Study B-I and Study B-II all focused on sociocultural contexts), while some studies inform a further exploration of others (e.g., The insights generated from Study A-II informed and influenced the theoretical exploration in Study C-I). By distributing the key results of these studies to different iteration stages, it might allow readers of the thesis to better understand the content and structure of the overall PhD study.

To present the results in a more structured way, each study is presented in the following manner: First, background settings and specific goals of the study are introduced. After that, the applied research methods are briefly described. Then, key results and insights concerning the development and iteration of the AT-based theoretical framework are articulated. Table 5 clarifies the iteration of the AT-based theoretical framework in relation to the corresponding theoretical principles.

Table 5. The iteration of the AT-based theoretical framework in relation to different theoretical principles.

AT framework version	Corresponding theoretical principles incorporated into the framework	Sections
Version 0.1	Hierarchical structure	Section 5.1
Version_1.0	Mediating effects of artefacts & developmental perspective	Section 5.2
Version_2.0	Sociocultural contexts	Section 5.3
Version_3.0	Tensions and contradictions	Section 5.4
Framework validation	Validating the proposed theoretical framework	Section 5.5

5.1 AT-based theoretical framework: Version_0.1

As indicated in Section 2.1, the hierarchical structure of the activity system is one of the most fundamental theoretical principles in AT. This theoretical principle was previously applied in Selvefors (2017) and Renström (2019)’s studies to break down and analyze people’s sustainable (and un-sustainable) doings from a sustainable product and service design perspective. Other relevant works that deal with the use of AT in product and service design also highlight the importance of understanding people’s activity system in different hierarchical layers (Karlsson, 1996; Rexfelt, 2008).

Therefore, the hierarchical structure of the activity system is used as the foundation to begin the exploration of the potential use of AT in design for sustainable everyday life. As illustrated in Figure 9, the classic activity hierarchical structure model proposed by is adopted as the initial version of the AT-based theoretical framework (version_0.1).

Figure 9. The initial AT-based theoretical framework that this study builds upon.

5.2 Development of the AT-based theoretical framework: the first iteration

In the first iteration, two explorative case studies: astronauts' food consumption activities on the International Space Station (Study A-I) and exchange students' food consumption (Study A-II), were conducted to gather insights and reflections regarding the use of the initial AT-based theoretical framework mentioned above. The overarching aims behind these two case studies are two folds: First, to obtain a holistic understanding of the impacts of context change disruptions on people's pre-existing everyday life doings, specifically, people's food consumption-related behavioral patterns. Second, from a theoretical perspective, I intended to explore how AT can be adopted and adapted as a design-related

theoretical lens to systematically analyze the behavioral transformation during life event disruptions.

5.2.1 Case study A-I: Understanding the mediating effects of artefacts in the behavior transformation

5.2.1.1 Study set-up and goals

According to Stuster (2010), astronauts who have carried out long-term spaceflight expedition on the International Space Station (ISS) have experienced significant physical, social and psychological changes from Earth to a spaceflight environment. Therefore, the changes constitute a highly representative real case scenario where the subjects have to undergo a contextual transition and adapt to the new environment. Due to the contains of confined and microgravity living environment on the ISS. Food delivered to the ISS is mainly based on standard menus, which are pre-packed in thermostabilized foil pouches and cans for direct heating. However, to increase well-being, astronauts retained and further transformed their Earth-bound food consumption activity into what they called “space cooking”, which is combining and assembling food ingredients into a more personalized meal.

Based on this reason, I selected astronauts’ everyday food consumption activities on the ISS as the research set-up for this case study. In this particular setting, the goal of the study is to develop an overview of the mediating role that artefacts can play in transforming astronauts’ pre-existing food consumption activities through context change disruptions.

5.2.1.2 Methods applied

The particular challenge of the case study lies in the data collection process. Conducting direct interviews or observational studies with astronauts who on-boarded the ISS would be difficult. However, astronauts have documented their daily activities such as tasks and experiments, food consumption, exercises, leisure and entertainment activities, along with their subjective experiences and reflections in great detail in their expedition journals, some of which are available on NASA Life Sciences Database Archive, NASA Technical Report Server and Crews and Exhibitions page for public access. These expedition journals have already been used by NASA behavior scientists to study astronauts’ psychology and behavior issues during spaceflight missions (see for example, Stuster (2000, 2010, 2016)),

which laid a methodological foundation for the data collection and analysis of this study.

As this study sets a particular focus on astronauts' food consumption activities, relevant data regarding how astronauts carry out their food consumption, including meal preparation, eating and food disposal, were extracted from the aforementioned database. Both the primary sources (e.g., expedition journals, photos, and videoclips) and secondary sources (e.g., technical reports and research articles) were used as the empirical materials for analysis. An abductive approach was applied to analyze the collected data. Relevant data were extracted into segments in Excel sheets and later sorted into different themes. Themes with similar patterns were then organized in the same group and later abstracted at a higher level. After that, the AT-based theoretical framework (version_0.1) was used to analyze the results.

5.2.1.3 Results

As illustrated in Figure 10, by focusing on the mediating role that artefacts play in the hierarchical structure of astronauts' space cooking activities, two types of behavioral transformation that took place in astronauts' food consumption system can be identified.

Figure 10. The transformation of astronauts’ food consumption activities illustrated through an AT theoretical lens.

First, in the activity layer, the available artefacts that subjects used in their pre-existing activity system have been changed due to context change disruptions, while the specific goals that subjects aim to attain in their pre-existing activity system remain the same. Consequently, the artefacts available in the new context are adopted and adapted to retain the original subject-object relationship (as illustrated in the activity layer in Figure 10). For example, in the context change transition from an earth-bound environment to the ISS, the goal of making a personalized meal remains unchanged. However, since the ISS does not provide cooking tools such as cutting board, pans and ovens that people commonly use on the ground, in order to attain the pre-existing goal, astronauts have to use duct tape as small plates to adhere food from floating away, foil pouches and plastic bags are reused as disposal cutting boards to cut ingredients inside thus to prevent food fragments from spreading in the air, empty foil pouches and food cans are reused as containers for

heating the mixed ingredients in food warmers (see Figure 11). In addition to the transformation in the use of these external mediating artefacts mentioned above, they also improvised based on their Earth-bound cooking knowledge and developed space cooking skills.

Second, in the action layer, as the subjects underwent context change disruptions, they developed and adapted new goals from their pre-existing activity systems, while the original relationships between subjects and mediating artefacts used in the pre-existing activity system remain (as illustrated in the action layer in Figure 10). For instance, the astronauts' goal of cooking underwent a transformation process from earth-bound cooking to simply mix and combine different food ingredients on the ISS. In this transition process, the specific usage of certain artefacts, such as using plastic bags to temporarily store ingredients and using tortilla as plates to hold and mix different ingredients, remained the same (see Figure 11).

Figure 11. The mediating role that artefacts play in astronauts' space cooking activities.

5.2.2 Case study A-II: Framing the dynamic development of activities

5.2.2.1 Study set-up and goals

Study A-II focuses on understanding the transformation of exchange students' food consumption patterns during exchange studies. Previous studies conducted in behavioral psychology showed that moving to a foreign country for study constitutes a moment of change that disrupts the pre-existing habitual behavior that the subjects used to perform (Wood et al., 2005). Therefore, I chose Asian exchange students in Sweden as the target group of participants in this case study.

By investigating the influences that exchange study has on participants' daily food consumption activities, I aim to explore how an AT theoretical lens may uncover the dynamic development process of people's activity systems during the course of life event transitions.

5.2.2.2 Methods applied

In-practice studies of everyday human activity and diary studies were applied to collect relevant data. The rationale behind using the combined method is not only to learn about what has been changed and retained during the life event disruptions, but also to gain a descriptive account of how and why participants transformed some of their specific doings when they were facing these disruptions.

As illustrated in Figure 12, first, the in-practice studies, which comprises field observations and semi-structured interviews, were tested and revised in a pilot study. Following that, the in-practice studies were conducted with all the participants individually when they were visiting the local supermarket, cooking and eating at home. The results of the in-practice studies were used to formulate tailored questions in a seven-day food consumption diary. The diary was designed for each participant to document and reflect on their food consumption-related doings on a daily basis. We also used the diary to collect empirical data regarding some of the themes that emerged from the in-practice studies. For example, data regarding participants' specific food consumption behavioral patterns such as the frequency of shopping, the amount of food consumed in one week, the most consumed food categories, which participants were unavailable to give accurate answers during the in-practice studies, were thus collected in the diary studies.

The same abductive data analysis approach applied in Study A-I was adopted in this study. First, data collected from the diary studies and the in-practice studies of everyday human activity were analyzed inductively. Affinity diagram was used to summarize and identify themes that emerged from the raw data. Themes with similar patterns were organized into same groups. These groups were later categorized in a higher level of abstraction. Then, the Activity Theory (AT) model together with the key theoretical principles of AT were employed to analyze the results from the affinity diagram.

Figure 12. The data collection process in Study A-I.

5.2.2.3 Results

In total, six exchange students were recruited as the participants of the study. They all arrived at Linköping University in mid-January of 2017 with a planned stay for 5-6 months.

To better frame and describe how participants transformed their food consumption activities when they underwent life event disruptions caused by exchange studies, a development dimension is added to the initial AT-based theoretical framework. As shown in Figure 13, the newly proposed framework takes into account both the hierarchical layer and the development perspective of activity systems.

Figure 13. The development process of participants' food consumption activity systems illustrated according to an AT theoretical lens.

In line with the AT's development model proposed by Blackler et al., (1999), four development phases can be identified in this study: 1). Phase 1 is when

participants recognize tensions and contradictions within the pre-existing activity system, 2). Phase 2 is when participants begin to search and test tentative solutions to address the contradictions, 3). Phase 3 is when participants recognize tensions and contradictions within their newly developed tentative solutions, and 4). Phase 4 is when participants further adapt and improve their existing activity systems to fit into the new context. Table 6 elaborates on how participants transform their food consumption activity in each phase.

Table 6. The developmental phases and corresponding behavior transformation from an AT theoretical lens (for details see Paper II).

Transition phases	Corresponding results
Phase 1: Recognition of tensions and contradictions within the pre-existing activity system	<ul style="list-style-type: none"> Participants' food consumption activities underwent a transformation process from directly ordering ready-made meals at student canteens (before exchange studies) to regularly cooking meals in student corridor kitchen (during exchange studies). Participants' food consumption goals in both of the contexts were to eat affordable meals. However, the price differences of meals between their original university and exchange university were the major factors that triggered the transformation. To reduce costs, participants started to plan, purchase and cook their meals during their exchange study.
Phase 2: Search and test tentative solutions to address the contradictions	<ul style="list-style-type: none"> All the participants reported a significant difference between the type of food products they purchased in the supermarket in their original university and exchange university. Dairy products and snacks were what they usually bought back in their original university, while during the exchange study, they had to purchase raw food materials and ingredients such as vegetables and meat. None of the participants had enough cooking experience. To be able to cook, several solutions such as searching and learning from recipes on the internet, sharing recipes with friends, and checking food information on product packaging were adopted to gain relevant cooking knowledge and skills.
Phase 3: Recognition of tensions and contradictions within the tentative solutions	<ul style="list-style-type: none"> New tensions and contradictions emerged in the action layer of participants' food purchases and cooking. Regarding food purchasing, participants reported that they were not familiar with the products sold in the supermarkets. In addition to that, they also had particular concerns about the expenses spent on food. Regarding cooking, participants reported that the average time they spent for preparing each meal (including shopping and cooking) at the exchange university was significantly longer than the time they spent in their original university, where they can directly order food and eat at students' canteens.
Phase 4: Adapt and improve the existing activity system	<ul style="list-style-type: none"> To reduce expenses, most participants often purchase food ingredients that were affordable or on sales. Afterward, they would incorporate the purchased food ingredients into their familiar recipes.

- To reduce the time spent on meal preparations, participants started to adapt and improvise their cooking routines based on the knowledge and experiences gained in the previous phases. As a result, a stable meal preparation pattern was thus solidified. In some particular case scenarios where there was not enough time to make a meal, eating ready-made frozen meals was considered as an alternative.

5.2.3 Reflections and AT-based theoretical framework: Version_1.0

Reflecting on the use of AT’s hierarchical structure model in the two case studies presented above, along with the theoretical principles of mediating artefact and development, I developed the first version of the AT-based theoretical framework (version_1.0). As shown in Figure 14, by putting the hierarchical structure of an activity system (activity layer, action layer and operation layer) on the vertical axis, and the three major developmental phases (pre-existing activity, existing activity under transformation, and consolidation of the transformed activity system) on the horizontal axis, this version of the framework focuses explicitly on framing how activity systems develop and transform over time and describing the mediating role that artefacts play in this transformation process.

Figure 14. The first version of the AT-based theoretical framework.

5.3 *Development of the AT-based theoretical framework: the second iteration*

This stage aims to iterate the first version of the proposed AT-based theoretical framework by adding a sociocultural dimension to the framework. Therefore, when presenting the results and findings in this stage, I will put a particular focus on discussing how to incorporate AT's theoretical principle of sociocultural contexts into sustainable design considerations.

Specifically, this stage consists of two studies: Study B-I and Study B-II. Both studies are student design projects under my supervision. Study B-I is a Design for Sustainable Everyday Life Course Project. The topic is on the sustainable usage of a microwave room in a newly constructed building at Linköping University. Study B-II is a degree project in the Master of Design and Product Development at Linköping University. The topic is on designing furniture for flexible and circular kitchen activities. Moreover, part of the key insights related to AT's sociocultural contexts extracted from Study E-I is also presented in this section as it lays the groundwork for the theoretical exploration.

5.3.1 Incorporating sociocultural contexts into sustainable design considerations

Results from the meta-synthesis of studies that applied AT as the theoretical lens in design for sustainability (see Study B-I) show that, the theoretical principle of the sociocultural contexts is commonly used to guide the analysis of sustainability-related issues at different sociocultural levels. However, as each study's research focus varies from each other, the division of the analytical levels of sociocultural contexts used in each study also differs. In general, three types of division can be identified: 1). individual and societal level, 2). institutional and community level, and 3). individual, collective (group or community), and societal level.

1. Individual and societal level:

In their project about designing and evaluating the effects of an ICT platform on promoting local community members' transition towards sustainable lifestyles in southern Chile, Aguayo (2016) and Aguayo & Eames (2017) applied AT to take into account the sociocultural elements regarding the use of technological interventions in influencing human behavior. They found that "individuals' motivations in terms of performing sustainability actions are directly related to their sociocultural contexts, such motivations can be more meaningful to users when they are linked with users' socio-cultural reality." This finding emphasized that

individual users' characteristics and needs cannot be fully understood if they were analyzed separately from the social, cultural, and historical context of the activity system.

Similarly, AT was chosen by Smith & Turpin (2017) as the theoretical framework to guide the evaluation of an ICT platform designed to empower elderly women in a rural community in South Africa. Their reflections showed that the sociocultural aspects of AT helped them to make the social and political dimensions of the local community and the relationship between the user (elderly women) and the design intervention (the installed ICT platform in the local community) visible to design researchers. They further pointed out that: "By emphasizing socio-cultural factors, the interaction between human actors and their environments, and the concept of tool mediation, activity theory can provide a suitable foundation for the Design & Development and Demonstration activities of this research project." Unvoiced sociocultural problems, such as elderly women's limited access to the ICT platform installed within the community and the needs for financial support to use and maintain the platform, were thus revealed and incorporated into sustainable design considerations.

Furthermore, Khan et al. (2015) employed the theoretical concept of sociocultural contexts to solve environmental management issues of electric and electronic waste. AT was used in their study to involve all the relevant actors in the decision-making process of waste management to gain sustainability at the system level and simultaneously create behavior change at the individual level. Drawing on the use of the sociocultural perspective of AT, they noted that one of the strengths of AT is that "[AT] works as a magnifying lens in dealing with the problems that are generated in the domain of sociocultural and sociohistorical environment through which designers can visualize and analyze human activity systems in a broader sense."

2. Institutional and community level:

In the study conducted by Ssozi-Mugarura et al. (2016), they reported that by focusing on understanding the sustainability effects of technology-based design interventions on people's water management in rural Uganda, AT's sociocultural contexts were applied to evaluate the design intervention at two levels: institutional level and community level. The analysis at the institutional level focuses on the broader technology engagement of the design intervention, while the community

level focuses on the interaction that takes place between the individual user, the introduced design intervention, and other users within the community.

3. Individual, collective (group or community), and societal level:

In their study about developing new sustainable telehealth services, Lin & Hsieh (2014) applied AT in three levels of analysis: individual, group and institutional levels. They noted that the theoretical concept of sociocultural contexts can help design researchers to better understand the relationship between the individual and the broader sociocultural levels, particularly when individuals and societies undergo a transformation process. Similarly, in Hansan et al. (2017)'s study about the potential of using IS to support the planning and execution of design interventions for climate change adaptation, the climate change adaptation problems were also analyzed at three levels, from global concerns to local governments' measures to individual behavior change.

In summary, insights extracted from the above studies showed that, AT's theoretical principle of sociocultural contexts can help design researchers to put sustainability issues in the perspective of both individuals' needs and the macro sociocultural contexts in which the target activity system situates. However, there lacks a consensus on the division of the analytical scale of sociocultural contexts. Drawing on the results presented above, I divide the contextual scale of analysis into three levels:

- Independent activity: The specific targeted individual activity that is carried out in a specific context. For example, cooking at home, working in an office, dining at a restaurant, exercising in a gym, etc.
- Neighboring or supporting activities: The activities which are directly connected to the independent activity. These activities can be in the form of a supporting activity. For instance, to carry out the cooking activity at home, one might need to first shop in grocery stores. In order to work in an office, one might need to commute from home to office. These activities can also be in the form of a directly related neighboring activity, for example, cleaning the kitchen after cooking, taking a shower in the gym after exercising.
- Implications at the societal level: The potential sustainability or unsustainability effects brought by the independent activity and the

neighboring or supporting activities on the societal level. For instance, unsustainable household cooking behavior may result in household energy and food waste, overreliance on private automobiles for commuting may lead to unnecessary CO₂ emissions and traffic congestion.

5.3.2 Case study B-I: Student microwave room intervention design

Based on the above result, Study B-I and Study B-II were conducted to test the three-level division of AT's sociocultural contexts.

5.3.2.1 Study set-up and goals

Finished in July 2019, Studenthuset is currently the largest and newest building at Linköping University. With an explicit focus on the sustainability aspect of design, the building has received the highest award in environmental classification. As a student center, Studenthuset offers a microwave room (in total 22 microwaves) on the ground floor for students to heat food (see Figure 15). However, the design of the room does not reflect the sustainability value of the building as it has received complaints from students regarding the chaotic usage of microwaves. Therefore, the goal of the project's goal is first to identify the sustainability-related problems that exist in the usage of the microwave room, and then propose design interventions to address the identified problems.

Figure 15. Student microwave room in Studenthuset, Linköping University.

5.3.2.2 Methods applied

The overall research process is illustrated in Figure 16. First, field observations and interviews were conducted to gather preliminary insights about how the students use the microwave room and its facilities. Following that, the insights were

used to inform questions in an online survey (sample number = 60). In-depth observations were later carried out to measure the average active running time of microwaves in rush hours. After that, the graffiti wall was used to gather qualitative data regarding students' overall experiences, difficulties, and suggestions when using the microwave room.

With a particular focus on identifying and solving the contextual factors that trigger the sustainability problems in the microwave room, AT's theoretical principle of sociocultural contexts was not only applied for analyzing the collected data but also for proposing potential design interventions.

Figure 16. An overview of the research process in the student microwave design project.

5.3.2.3 Results

As shown in Table 7, the empirical results were mapped according to the three contextual levels of analysis that I proposed in the preceding section.

Table 7. Problems and proposals for design interventions mapped according to the three contextual levels of analysis.

Levels of analysis	Targeted activities	Sustainability-related problems	Proposals for design interventions
Independent activity	Heat food in the microwave	Difficulties in identifying which microwave is occupied and which is currently available	Microwave design intervention: <ul style="list-style-type: none"> • Put on reminders and stickers on each microwave
Neighboring or supporting activities	Waiting and transitioning	<ul style="list-style-type: none"> • Long waiting time in the microwave room; • Unorganized operation area during rush areas. 	Workflow adjustment intervention: <ul style="list-style-type: none"> • Allocate a waiting area • Put on guidance on the floor • Install a digital notice board
Implications at the societal level	The use of the microwave room	Low resource efficiency	Spatial intervention: <ul style="list-style-type: none"> • Rearrange microwave placement • Put on efficient usage guide

1. Independent activity:

At the independent activity level, some respondents reported that when the room is crowded during the rush hours, the black cover on the microwave's door makes it difficult for them to judge whether the microwave is occupied or not. Moreover, the routinized habit of closing microwave doors when finish heating also worsens the situation. Some respondents also pointed out that it is sometimes difficult to remember the microwave in which they put the food. Therefore, the design interventions proposed at this level focus on improving the interaction between an individual user and the microwave. Interventions including reminders of leaving the door open when finishing heating food so that the next user can easily tell whether the microwave is available or not, animal stickers on the door of the microwaves to differentiate microwaves for users to remember the microwave in which their food is placed, were proposed to address the identified problems (see Figure 17).

2. Neighboring or supporting activities:

At the neighboring or supporting activities level, the unorganized operation area in the room was identified as the key factor that led to a long waiting time. Correspondingly, the design interventions proposed at this level include adjusting the workflow (e.g., allocating a waiting area, putting on signs and guidance on the floor to improve the workflow) and introducing a digital notice board to visualize which microwave is currently available, where the available microwave locates, and whether the microwave in which the food is placed is still in progress (see Figure 17).

3. Implications at the societal level:

While students are often waiting in queues for using the microwaves during rush hours, the microwave placed closet to the queue where students can see whether the microwave is occupied or not reaches an average of 71% of active running time. On the contrary, the active running time of the microwave which is placed in the middle of the room (away from the queues on both ends) is only 61%. Similarly, the microwave that stands in the corner of the room only has 64% of active running time during rush hours. This finding points out that the problems are not only associated with users' interaction with the microwave, but also related to the overall layout of the room. Therefore, the intervention proposed in this level focuses on spatial design, for example, rearrange the layout of the room, moving the microwaves from two sides to the center of the room, and putting up guidance on how to use the microwave in more efficiently (see Figure 17).

Figure 17. The proposed design interventions to guide more sustainable use of microwave room at different contextual scales.

5.3.3 Case study B-II: flexible kitchen activity design

5.3.3.1 Study set-up and goals

As people's food consumption activities keep evolving, so does the design of kitchen space and furniture. The kitchen nowadays is under a transformation process from a place designated for cooking and food handling to a center of the home where leisure and social activities take place. This project aims first to develop a holistic understanding of the activities that people carry out in the kitchen today, then propose kitchen furniture design guidelines that support people in carrying out these activities in a more sustainable direction in the future.

5.3.3.2 Methods applied

As illustrated in Figure 18, the research process of the project is divided into 4 phases. In phase 1, an online survey was first sent to collect data about what activities are often conducted in the kitchen today. Following that, field observations and semi-structured interviews were conducted in participants' home environments

to gather descriptive qualitative data regarding how people perform their daily activities in the kitchen and what problems exist in these activities. In phase 2, the collected empirical data were analyzed through an AT theoretical lens, focus group discussions and ideation workshops were conducted to translate the insights into design concepts, which were iterated in phase 3 concept development and phase 4 prototyping and concept realization. Similar to the microwave room case study, AT's theoretical principle of sociocultural contexts was applied not only for analyzing the empirical results, but also for proposing potential sustainable design guidelines to solve the identified problems.

Figure 18. An overview of the research process in the flexible kitchen activity design project.

5.3.3.3 Results

As shown in Table 8, similar to Study B-I, the empirical results were mapped according to the three contextual levels of analysis: independent activity, neighboring or supporting activities, and implications at the societal level.

Table 8. Problems and proposals for design solutions mapped according to different contextual levels of analysis.

Levels of analysis	Targeted activities	Problems	Proposals for design solutions
Independent activity	Prepare, cook and eat food	Various usages in different demographic groups	Improve the ergonomic design for different demographic groups of users
Neighboring or supporting activities	<ul style="list-style-type: none">• Cleaning• Socializing• Productivity• Entertainment	<ul style="list-style-type: none">• Lack of space in kitchen• Kitchen furniture does not support multiple activities	<ul style="list-style-type: none">• Design beyond cooking• Design for space-efficiency• Emphasize the social function of kitchen• Multi-functional kitchen furniture
Implications at the societal level	More integrated activities at homes	<ul style="list-style-type: none">• Compact living environment• Unsustainable consumption that takes place in kitchen	<ul style="list-style-type: none">• Flexible and adaptive kitchen design• Design for modular system• Incorporate technological innovations

1. Independent activity

Results indicated that the most commonly performed activity in the kitchen is to prepare, cook and eat food. However, as different demographical user group tends to use kitchen furniture in different ways, the design guidelines proposed in this category thus centers around:

- Improving the ergonomic design of kitchen furniture for different demographic groups of users.

2. Neighboring or supporting activities

Results showed that cleaning (e.g., dishwashing), socializing (e.g., spending time with family and hang out with friends), productivity (e.g., working), and entertainment (e.g., watching videos and playing games) are the main activities that the respondents carry out in kitchen besides cooking and food handling. However, the lack of space, including the operational surface and the overall kitchen space, creates difficulties for respondents to perform these activities. Moreover, the valuable space in the kitchen is often occupied with furniture that mainly serves single-purpose (e.g., dining table for eating food). Based on these identified problems, the corresponding design guidelines proposed in this level include:

- Allowing users to carry out other activities, especially productivity and entertainment activities in the kitchen.
- Applying kitchen island design as a potential solution to promote space-efficiency in the kitchen.
- Supporting kitchen in becoming the social focal center of the home.
- Developing multi-functional kitchen furniture to fit into other rooms for other usage purposes (e.g., working as tables in the living room).

3. Implications at the societal level:

Societal factors, including the compact living environment in urban areas and the linear consumption lifestyle, can largely shape how kitchen activities are carried out. Taking into account the potential impacts that kitchen design may bring to society and the environment, the sustainable kitchen furniture design guideline proposed in this category are:

- Supporting the development of long-lasting and adaptive features of the kitchen so that it can evolve as the owner undergoes different stages in life.
- The kitchen furniture needed for cooking, productivity, entertainment and socializing varies across each other; therefore, modular design is recommended. Old modules can be ungraduated or modified and new modules can be added to transform the function of the furniture.

- Adopting technological innovations such as the Internet of Things (IoT), digitalization and artificial intelligent agency to help with food handling activities that people perform in the kitchen.

5.3.4 Reflections and AT-based theoretical framework: version 2.0

In this stage, the AT-based theoretical framework is iterated with a particular focus on exploring how to incorporate the sociocultural contexts of activity into sustainable behavior design considerations. As a result, a third dimension, which represents the contextual scale of analysis, is added to the previously proposed framework (version 1.0).

The contextual scale of analysis consists of three levels:

- Independent activity: The specific individual activity that is carried out in a specific context.
- Neighboring or supporting activities: The related activities which are directly connected to the targeted independent activity.
- Implications at the societal level: The potential sustainable or unsustainable effects of the independent activity and its neighboring or supporting activities at societal level.

The three-level contextual analysis presented above is informed by the findings of the meta-synthesis study and further tested in the two case studies (Study B-I and B-II). Drawing on the insights of the studies conducted in this stage, the three-level contextual scale proved to be useful as it can allow designers to identify and analyze sustainability-related issues in different analytical levels, and inform corresponding design interventions specifically targeted in different levels. The second version of the AT-based theoretical framework resulted from this stage is illustrated in Figure 19.

Figure 19. The second version of the AT-based theoretical framework.

5.4 Development of the AT-based theoretical framework: the third iteration

Study C-I is conducted in this stage. When presenting the results of Study C-I, I will put a particular focus on discussing the potential use of the fifth theoretical principles of AT, that is, tensions and contradictions, for guiding empirical analysis and design explorations in design for sustainability studies.

5.4.1 Study C-I: Uncovering tensions and contradictions within the activity system

5.4.1.1 Study set-up and goals

Consumers' misunderstanding and misuse of on-pack date and storage labels is one of the significant factors that contribute to household food waste. Study C-I sets a particular focus on understanding the relation between date labelling and consumer household food waste behavior. Based on the AT theoretical lens, people's

food edibility assessment activity system, in other words, how people determine whether a food item is edible or not, is taken as the unit of analysis. The goal of the study is to systematically understand the tensions and contradictions that consumers encountered when using on-pack date and storage labels to assess food edibility, and to explore the potential opportunities for design to intervene in the interaction between consumers and date and storage labels to reduce household food waste.

Study C-I comprises of three phases: a systematic literature review, a co-creation with general consumers and food industry practitioners, and a cross-analysis of the empirical results. Figure 20 presents an overview of the research process applied in this study. To better align the results of Study C-I with the structure of the dissertation, the systematic literature review part is presented separately with the co-creation and cross-analysis. The results from the systematic literature review are presented in this section, while the co-creation and cross-analysis results are presented in Section 6.3.

Figure 20. An overview of the research process in Study C-I.

5.4.1.2 Method applied: a systematic literature review

The systematic literature review was comprised of 8 steps (see Figure 21): 1) identify relevant technical reports, 2) develop a literature search strategy and conduct the initial search, 3) eligibility screen, 4) title and abstract screen for, 5) first-round review, 6) perform a second-round review and data extraction, 7) snowballing, and 8) perform data analysis. To gain an overview of the method, only the key steps and results will be presented in the following.

Two types of sources were included in the review: technical reports and academic articles. The systematic literature review began with identifying technical reports that are relevant to the topic. Twenty-four technical reports were included in the review. Following that, the literature search was conducted in March 2019.

Scopus was chosen as the search platform. Book chapters, peer-reviewed conference papers and journal articles published from the 1960s to March 2019 are included in the review scope. As shown in Figure 21, 530 articles went through a systematic literature screening process. As a result, 27 articles were included in the final full-paper review. For a detailed description of the materials and methods, please see Paper III.

Figure 21. An overview of the systematic literature review procedures applied in Study C-I.

For data analysis, a similar abductive data analysis approach applied in Study A-I and A-II was also adopted here. To put it briefly, first, recurring themes with similar patterns or contradictory results were grouped and summarized. Following that, AT's key theoretical concepts, such as motivations, goals, meditating tools, contradictions and tensions, were applied to compile the identified themes (see Figure 22).

Figure 22. People’s food edibility assessment analyzed through an AT theoretical lens.

5.4.1.3 Results

Looking at people’s food edibility assessment from an AT theoretical lens, the overarching motivations behind consumers’ food edibility assessment activity can be broken down into three specific goals: assess food safety, assess food quality, and avoid unnecessary food waste. Correspondingly, three mediating artefacts: “Use by” date, “Best before” date, and consumers’ sensory perceptions, were commonly used to achieve these goals. According to AT’s definition of mediating artefacts, date labels such as “Use by” date and “Best before” date can be categorized as the external mediating artefacts, while the sensory perception that consumers use in their food assessment activities can be categorized as the internal mediating artefacts. In other words, both external mediating artefacts (in the form of on-pack date labels and institutionalized knowledge related to the use of date labels) and internal mediating artefacts (in the form of sensory perceptions and embodied knowledge related to food attributes) can be used to make a judgement regarding whether a food item should be discarded or not.

Building upon the food edibility assessment activity model described above, AT’s theoretical principle of tensions and contradictions was then used to further synthesize the literature review results (see Table 9). Findings from the literature review were then categorized into:

- Group 1: tensions and contradictions that take place in the action layer where individual subjects use on-pack date labels to judge food edibility (see A&B in Table 9).
- Group 2: tensions and contradictions that take place in the action layer where individual subjects judge food edibility based on their sensory perceptions (see C&D in Table 9).

- Group 3: tensions and contradictions that emerged in the operation layer where individual subjects need to use date labelling-related institutionalized knowledge to interpret products' shelf-life information (see E&F in Table 9).
- Group 4: tensions and contradictions that take place in the operation layer where individual subjects need to interpret products' sensory attributes based on their embodied food-related knowledge (see G&H in Table 9).

Table 9. Categorization of tensions and contradictions that consumers encountered in their food edibility assessment activities.

Hierarchical layers	Distribution	Specific tensions and contradictions
Action layer		<p>A1). A gap between labeling information presentation and information usage.</p> <p>A2). A variation in the effects of the "Use by" date, especially when consumers are unwilling to discard food items that passed the date.</p> <p>A3). A variation in the effects of the "Best before" date, especially when consumers hold excessive concerns on food quality.</p> <p>B1). An inadequate explanation of the labeling terminology on the packaging.</p> <p>B2). An inadequate date and storage guidance on opened products.</p>
Action layer		<p>C1). A lack of confidence in using sensory assessment in conjunction with date labels.</p> <p>C2). An overreliance on sensory assessments instead of strictly following the "Use by" date on the packaging.</p> <p>C3). Discard food items that passed the "Best before" date without assessing the item's quality attributes through sensory perceptions.</p> <p>D). A variation of sensory assessment criteria and methods used in different case scenarios with different food products.</p>
Operation layer		<p>E). Consumer confusion over the meanings of label terminology (e.g., the meaning of the "Best before" and "Use by" date).</p> <p>F). A lack of consistency and standardization of labeling content and display.</p>

By adopting the 2nd version of the AT-based theoretical framework, how the tensions and contradictions identified above manifest themselves in consumers' food edibility assessment systems is shown in Figure 23.

First, in the operation layer, the lack of knowledge on date labelling and sensory assessment (as identified in Group 3&4, see E, F, G and H) is the major tension and contradiction that consumers face. Consequently, consumers often need to search for relevant knowledge such as the meaning of the specific type of date labels, storage methods that can extend food shelf-life in the household environment and typical deterioration signs. Therefore, interventions that target providing such knowledge and convenience for consumers can be a promising solution to help consumers reduce labelling-related food waste. Meanwhile, the societal level offers insights regarding in which contexts such knowledge assistance should be provided. Existing literature indicates that strategically communicating relevant knowledge at consumers' actual food-handling contextual settings such as at the point of sale and meal preparation is more effective than just implementing general consumer education campaigns.

Moving up to the action layer, tensions and contradictions mainly center around the misunderstanding of "Best before" date and "Use by" date, misuse of sensory judgements, overreliance on one type of methods to make decisions (as presented in Group 1 & 2, see A to D). To solve these tensions and contradictions, consumers tend to look for other reliable channels (e.g., ask for family members' or friends' opinions) to help them in the food edibility assessment process. This gives rise to the opportunity of applying technological interventions such as time-temperature indicators to show product freshness in real-time. However, at the societal level, these technological solutions still cannot replace the wide usage of date labels due to technical difficulties and cost-related concerns held by the food and packaging industry. The standardization of label terminologies and consumer-friendly label presentations are still the most cost-effective solutions to solve the identified tensions.

In the activity layer, decisions made in consumers' food edibility assessment might influence the subsequent food consumption activities such as meal planning and cooking, leading to potential household food waste. Insights extracted from the existing literature suggest that, helping consumers better utilize the food that is close to the expiration date (e.g., incorporate the food into a meal) and manage food items stored in the household environment are promising solutions to avoid food waste. Although these solutions seem to be irrelevant to the design of on-pack date and storage labels, they reveal how other interventions can be used in combination with date labelling design to address the broader household food waste issues at a societal level.

Figure 23. Mapping tensions and contradictions that consumers encounter in food edibility assessment according to the AT-based theoretical framework.

5.4.2 Reflections and AT-based theoretical framework: Version_3.0

In summary, reflections from the above case studies indicate that the AT-based theoretical framework can offer two analytical strengths for sustainable design research:

1). By laying out tensions and contradictions according to the hierarchical layers of an activity system, it allows researchers to systematically identify and break down the sustainability challenges into smaller segments for analysis without losing a holistic view.

2). By mapping tensions and contradictions on the different contextual scales of analysis, it helps researchers understand the causes of sustainability issues within the scope of an integrated activity system. Meanwhile it can also support researchers in positioning the impacts of the targeted activity system on a broader sociocultural context.

Building upon the analytical strengths, the AT-based theoretical framework can also provide two strengths when it comes to practical sustainable design explorations:

1). As tensions and contradictions often manifest themselves differently in different hierarchical layers of an activity system, it implies that the corresponding sustainable design interventions should also have different emphases, specifically targeting at addressing one or multiple tensions at different layers.

2). In order to fully explore the potential design opportunities to tackle the identified sustainability challenges, design explorations should not only be focused on the targeted independent activity, instead, the relations between the targeted activity and its neighboring or supporting activities, as well as the societal level of the targeted activity, also need to be taken into account in the design ideation process.

As a result, based on the insights and reflections identified above, the third version of the AT-based theoretical framework was developed (see Figure 24). In this version, AT's theoretical principle of tensions and contradictions is incorporated into the framework (note that in the figure, the spring sign is used to conceptually represent the tensions and contradictions).

Figure 24. The third version of the AT-based theoretical framework.

Furthermore, to support the use of the proposed framework, a step-by-step guide is formulated. The guide is adopted initially from the AT-based methodological approach applied in Mwanza (2001), Uden (2007), and Boer et al. (2002). It is then tested, adapted and refined in the previous case studies.

- Step 1: Identify the three key components which constitute the activity system: subjects (users), objects (motivations and goals) and mediating artefacts (tools).
- Step 2: Break down the activity system into three hierarchical layers: activity layer, action layer and operation layer.

- Step 3: Distribute the activity system and its related effects across different contextual levels of analysis: independent activity level, neighboring or supporting activities, and implications at the societal level.
- Step 4: Illustrate how the target activity system develops over time: the pre-existing activity, existing activity under the influence of context change disruptions, and anticipated forms of activity shaped by design interventions.
- Step 5: Identify tensions and contradictions that take place within the different hierarchical structure and contextual levels of analysis, along with how the tensions and contradictions are resolved and how they may lead the future evolution of the activity system towards a more sustainable direction.

5.5 AT-based theoretical framework: validation

Study D, which is about the transition of household food consumption activity in lockdown and pos-lockdown, is used to validate the framework. This project is not initially planned in this PhD study. The idea emerged when the Covid-19 pandemic was spreading all over the world. Note that Study D is still ongoing when the thesis is written. Therefore, the key results presented in the thesis are only used to examine and validate the AT-based framework.

5.5.1 Study D: Household food consumption activities under Covid-19 lockdown

Looking at the crisis from the behavior transformation research perspective of this thesis, as the onset of the Covid-19 pandemic has already brought unprecedented impacts on the socio-economic development of our society and people's everyday life, it also offers a special moment from which we can learn a lot. On the one hand, design researchers' social responsibility motivated me to carry out a small-scale explorative case study to investigate people's food consumption under lockdown and post-lockdown. Since people are forced to transform their daily life doings to cope with the challenges and disruptions brought by the pandemic. It is a perfect real-world and ongoing case scenario to further examine and refine the proposed theoretical framework.

5.5.1.1 Study set-up and goals

The Covid-19 pandemic has already disrupted people's pre-existing daily life doings. Food consumption, as one of the most critical aspects of everyday life, is also undergoing a significant transition process. For example, due to social distancing,

remote working and lock-down regulations imposed globally, the pandemic has disrupted people's food consumption practices, forcing millions of people to consume meals at home while bringing new challenges to the fight against food waste. Existing studies have shown that during the early stage of the Covid-19 outbreak, household food waste increased due to factors such as shifts to in-home eating habits (Aldaco et al., 2020), panic buying of perishable food products (Sharma et al., 2020), and household hoarding (Fleetwood, 2020; ReFED, 2020).

At the same time, the pandemic has also opened up a window of opportunity where people became more likely to rethink their pre-existing food consumption behavior (Roe et al., 2018). Relevant studies showed that 89% of Tunisian consumers reported that they became more aware of food waste (Jribi, Ben Ismail, Doggui, & Debbabi, 2020). 36% of UK consumers reported that they discarded less food during the pandemic than usual. An increased focus on prudent use of food and leftovers has also been found among China and U.S. consumers (Dou et al., 2020; ReFED, 2020).

Evidence from the existing studies showed that under the impacts of Covid-19, people who entered lock-down improved their in-home food storage management, meal planning and leftover management skills (Bender et al., 2020; WRAP, 2020). Following this direction, this study takes an AT theoretical perspective and aims to:

- 1). *Identify the household food waste prevention-related doings that consumers developed during the strict lockdown caused by the pandemic.*
- 2). *Explore how people transit these doings in the post-pandemic time.*

The study investigates people's food consumption activities in Wuhan, where the Covid-19 outbreak in China was first reported and the first strict city-scale lockdown measure was imposed. Following the lockdown, all the public transportation services and public places except hospitals, supermarkets, farmers' markets, gas stations and drug stores were temporarily closed. People were strongly advised to stay at home as much as possible. The strict lockdown lasted for 77 days.

5.5.1.2 Method applied

As most of the existing studies investigating the impacts of the Covid-19 pandemic published so far (till September 2020) focus on employing quantitative approaches such as questionnaires and surveys to measure consumers' attitudes, awareness and preferences of food consumption. However, when it comes to

investigating people’s household food consumption doings, knowledge generated from the quantitative approach is likely to be insufficient. An in-depth and descriptive account of how individual consumers cope with the current situation in their actual food consumption contextual settings is needed. Therefore, an ethnography-informed qualitative research approach was chosen in this project.

The study started in the first month of the lockdown. The participants of the project are recruited based on my personal networks in Wuhan. All participants were informed about the overall purpose of the project. The participation is voluntarily. 7 participants joined the study. Diary probe, letters to food and semi-structured interview were applied in the data collection process. An overview of the data collection timeline is illustrated in Figure 25.

Figure 25. The timeline of diary studies, letters to food and semi-structured interviews conducted in this study.

First, a seven-times digital diary probe was sent to the participants. Participants were asked to document their food consumption patterns and send the diary back to the researcher on a daily basis. The diary probes used in this study were first evaluated in pilot studies. Two workshops were conducted to collect design researchers’ feedback about the diary probes.

- Each diary comprises three parts:
- The first part is an instruction on the daily theme of the diary. Each diary has a particular theme, such as food acquiring, cooking, and food storage.
 - In the second part, participants were encouraged to document anything related to food consumption that was impressive, fun, or even depressing. This is referred to as “casual talks”.

- The third part is a set of questions proposed by the researcher. The questions were formulated after reading through participants' diary of the previous day. Therefore, the questions included in each diary can be tailored designed for each participant based on their previous recordings.

Following the diary probes, "letters to food" was sent to the participants. This method is inspired by the "love letter and breaking up letter" method created in product and service design (Hanington & Martin, 2012). In the context of this study, the goal of "letters to food" is to encourage participants to write down their feelings, thoughts, experiences and reflections generated in their food consumption during the lockdown situation. Participants can select any food items (e.g., eggs, yogurt, milk, cheese, bread, meat and vegetables) that they have/had at home as the receiver of the letter, and then write a confession letter to the selected food item, describing how they got the food item, why they chose to purchase this particular item, the original plan of consumption, where they stored it, how they cooked it, what happened to the waste or left-overs, and so on. This method was previously tested and improved in a pilot study. Four participants accepted this task and each of these participants wrote two letters individually. In total, 8 letters were collected.

All the diaries were summarized into 'diary graphs' and sent back to the participants for review (see Figure 26). After that, semi-structured interviews were conducted with all the participants. Each interview lasted approximately 30 minutes. An interview protocol was tailored developed for each participant based on the collected data from diary probes. The interview serves two purposes: First, information that was not fully elaborated in the diaries was asked in the interview. In this respect, the interview can provide a complementary view of the diaries. Second, as the food diaries revealed participants' concrete doings, the interview was focused on uncovering why participants performed the particular doings, what participants think and feel about their food consumption activities in that particular context.

Moreover, three months after the lockdown was lifted, post-lockdown diaries were sent to the same group of participants. The purpose is to investigate how participants perform their food consumption doings after the lockdown in the context where the pandemic has already been ended in the city. The post-lockdown diary probes were made and used in the same way as the lockdown diary probes. 5 of the 7 participants joined the post-lockdown diary study.

In line with the other studies included in the thesis, an abductive data analysis approach was applied. Two rounds of data analysis were conducted. The first round was focused on categorizing the raw data into different themes. A particular focus was put on two types of data: one summarizes the concrete doings that participants performed, such as food acquisition, cooking, and food management; the other summarizes how participants feel about their doings, such as their subjective experiences and reflections. The second round was focused on using the previously proposed AT-based theoretical framework to categorize the identified themes.

Figure 26. An example of the digital diary graphs summarized from participants' daily diary documentation.

5.5.1.2 Results

Based on the AT-theoretical lens, seven themes emerged from the data analysis: 1). Awareness of food waste; 2). Food consumption routines; 3). Food acquisition; 4). Food storage management; 5). Food edibility assessment; 6). In-home meal preparation and planning; and 7). Leftover management.

In summary, all the participants reported that their attitudes towards food waste have changed when entering the lockdown. Unlike the pre-pandemic time when food is easily accessible, participants were especially concerned about the potential risk associated with food supply shortage due to the strict lockdown. As a result, participants were more aware of the importance of better utilizing food resources at home and avoiding food waste. This shift of attitudes is also in line with the results from the survey-based quantitative studies reported in some of the other lockdown situations around world. Instead of being driven by socio-ecological concerns, most of the food waste prevention measures that consumers undertook during the pandemic were triggered by socio-economic considerations such as fear of infection (Aldaco et al., 2020; Jung, Park, Hong, & Hyun, 2016), food shortage (Sharma et al., 2020) and income shocks (Niles et al., 2020).

Furthermore, during the lockdown, participants became more aware of what to eat and what to purchase. Their shopping frequency has dropped down significantly due to the strict lockdown policy. Moreover, since they had restricted access to supermarkets or grocery stores, they had to purchase food items online. In some cases, participants purchased much more food than they usually need, this was due to: 1). Some food was pre-packed in food bags and can only be delivered to customers in a large quantity during the lockdown. 2). Participants were worried about the risk associated with food scarcity caused by the lockdown. However, according to participants' reflections, the increased amount of food stored at home didn't lead to the increasement of household food waste. Instead, most of the food items were consumed before they went spoiled, and food was only discarded if participants think it would cause health issues. Almost all the participants reported that they learned new food handling techniques to extend food shelf-life and make the best of the food at hand. Moreover, participants noted that they developed a better estimation of how much to eat in each meal. They were able to make a weekly-based food consumption plan and pay more attention to food shelf-life and freshness status. A summary of the detailed measures in relation to food waste prevention that participants developed during the pandemic is presented in Table 10.

Table 10. A summary of the food waste prevention-related measures that participants developed during the strict lockdown.

Measures developed during the lockdown	Examples and quotations
Same food items came in a large quantity	"15 kg of garlic sprout came at once today. To better preserve them, I spent half of the day. I peeled off the skin, put some in the fridge while pickled the rest." (P5)
Develop new food handling skills	"Some tomatoes left unnoticed in the fridge looked bad. I don't want to waste precious vegetables in this hard time, so I will turn them into home-made ketchup which is easy to preserve.... Before the pandemic, I don't need to waste time in these common food items. But now, it offers more tastes to many different foods such as noodles, bread, and fries." (P7)
Attitudes towards food	"During the lockdown, we make different dishes by using flour and we use flour to compensate the rice. I used to take flour for granted, but after this, I will value it more." (P6)
Decide what to buy and eat based on food storage at home and food sold online.	<p>"Now, based on that I have at home and ordered online, I need to roughly divide them into 7 days portion. Before the pandemic, I didn't pay particular attention to how much to cook for each meal." (P2)</p> <p>"I usually buy what I want to eat. But now I buy fresh vegetables when I spot them online, and then decide how I should make them into a meal." (P3)</p>
Make weekly-based meal plans	"Before the pandemic, we visit grocery stores when needed. Food sometimes was discarded if we forgot it is there at home. In the lockdown, we buy the food for the whole week at once. In order to avoid unnecessary waste, we often make a weekly consumption plan" (P1)
Frequently check shelf-life and freshness status of food stored at home	<p>"During the lockdown, my grandmother moved in with us. When she cooks, she would first check the shelf-life and quality of food in the fridge, then decide what to cook. Before the pandemic, my parents and I didn't do this." (P1)</p> <p>"I found a bag of sun-dried mushroom which has been long forgotten in the shelf before. It would go expired if we didn't check the shelf due to the pandemic. We will use it in some dishes in the coming days." (P1)</p>
More tolerant for food edibility and taste	<p>"Before the pandemic, I would just discard the whole vegetable if it looks not fresh anymore. Now I cut off the bad part and cook the rest." (P4)</p> <p>"One day I found the vegetables in my fridge looked bad. But I didn't just throw them away. I searched through the Internet and then ate it as it wouldn't harm health." (P6)</p>

	"I have bought too many potatoes, although they have longer shelf-life, I used different ways to cook them in one meal. My family liked it a lot." (P6)
Make the best use of the food at hand	"Duck eggs arrived today, but some are already spoiled. I feel sad because they are really precious in the situation. I will make fried eggs, boiled eggs and salted eggs to avoid further waste." (P6)

5.5.2 Reflections on the use of the AT-based theoretical framework Version_3.0

In Study D, by adopting the AT-based theoretical framework and analytical approach proposed in the previous section, how people transit their household food consumption activity systems during the lockdown and after a strict lockdown can be clearly illustrated. With a particular focus on the household food reduction measures, insights extracted from the AT-based theoretical lens indicate that the participants tend to reconsider their pre-existing food waste behavior and continuously adjust their food consumption activities to cope with the dynamic situation during a lockdown, especially in the action layer. In addition, the framework also highlights that, as the onset of the pandemic has already opened up a window of opportunity that transformed people's food waste behavior, then ending the pandemic would constitute another window of opportunity, which can be used to support a continued reduction and prevention in household food waste in the post-pandemic era. By comparing participants' food consumption activity systems during and after the lockdown through the AT-based framework, we found that without any design interventions taken at the individual level, the desired food waste reduction measures that participants developed during the pandemic, such as in-home cooking skills, leftovers management, pre-shop planning, checking food storage conditions, would likely to fade away in the post-pandemic time.

6

Development and evaluation of an AT- informed sustainable design toolkit

This chapter presents how the proposed theoretical framework is developed into an AT-informed ideation toolkit prototype and AT-informed sustainable design implications for design practitioners to use in their early-stage design ideation. The development process is illustrated in Figure 27. Table 11 clarifies the input and outcome of each research step conducted in this stage.

Figure 27. The iteration process of the AT-informed design ideation toolkit and the development process of the sustainable design implications.

Table 11. The input and outcome of each research step conducted in this stage.

Inputs and corresponding studies	Main outcomes	Sections
AT's theoretical principles in relation to a design perspective (as presented in Section 2.4)	AT-informed design ideation toolkit prototype	Section 6.1
Date labelling project (Study C-II and Study E-II)	Evaluation results	Section 6.2
Meta-synthesis findings part 1 (Study E-I)	Extracting AT-based theoretical understandings	Section 6.3
Meta-synthesis findings part 2 (Study E-I)	Translating theoretical understandings into sustainable design implications	Section 6.4

6.1 AT-informed design ideation toolkit prototype

The AT-informed ideation toolkit prototype is in the form of a cube named “Activity Cube” and a deck of ideation cards named “Activity Design Cards”. The Activity Cube is bounded by six facets that match the six key theoretical principles of AT: 1). Motivations, goals, and outcome, 2). Sociocultural contexts, 3). Mediating

artefact, 4). Tensions and contradictions, 5). Internalization and externalization, and 6). History and development. The intention is to provide design researchers and practitioners with a physical object to interact with while enabling them to learn about the different aspects of human activity.

In line with the Activity Cube, the Activity Design Cards also comprise six categories, each category matches with one facet of the Activity Cube. As shown in Figure 28, each card consists of two parts: a design ideation question and a corresponding design example. For example, in the category of hierarchical structure, one of the cards asks the question: “Can you enable users to attain a series of different goals in a row within the targeted activity?” In the category of history and development, one of the cards asks the question: “Can you adopt some design features from the old tools that users previously used in the targeted activity to your current design?” A list of design ideation questions formulated based on AT’s theoretical principles is shown in Table 12. These questions were formulated based on the author’s interpretation of AT’s key theoretical principles (see Section 2.4). The corresponding design examples illustrated in the cards are extracted from the common products and services people use in everyday life contexts. For instance, Airbnb’s accommodation and sightseeing service is used to provide a clue to the question: “Can you enable users to attain a series of different goals in a row within the targeted activity?”. Similarly, keyboard layout of mechanical typewriters and modern computers is used to provide an example for the question: “Can you adopt some design features from the old tools that users previously used in the targeted activity to your current design?”. A total number of 24 Activity Design Card were developed in this version of the toolkit (see Appendix 1).

Table 12. A list of design ideation questions formulated based on AT's theoretical principles

Mediating artefacts		Tensions and contradictions	
1. What if your design can bring an entirely new way for users to attain their original goals?		1. Are there any user goals that are difficult for users to attain as they could not adjust the tools to meet their particular needs? What if your design can solve such a specific problem?	
2. What would happen if your design is flexible and easy to be adapted to different goals within the targeted activity?		2. Are there any user needs or goals that cannot be supported by the tools at hand, so that users have to find some other supportive tools to carry out the targeted activity?	
3. Can you design some features to support multiple actions that users usually perform within the targeted activity?		3. Can you design some features that offer users different ways to carry out the targeted activity?	
Subject-object relationships		History and development	
1. Can you enable users to attain a series of different goals in a row within the targeted activity?		1. Can you design some features to help users to immediately recognize how to use the design based on their past experiences?	
2. What would happen if your design requires users to put more effort into attaining their original goals, but in return, these efforts can bring users more benefits?		2. Can you predict the potential changes that may take place in the targeted activity based on how it has developed in history?	
3. What if your design limits users to attain some of their original goals?		3. What if your design can support the evolution of users' current activity into a more advanced one?	
4. What if your design can turn the outcome of the targeted activity into a win-win situation for different actors involved?		4. Can you adopt some design features from the old tools previously used in the targeted activity to your current design?	
5. Are there any unexpected user goals or needs that may become attainable through your design?		5. What are the changes that you aim to achieve/avoid in the targeted activity? Can your design induce/prevent such changes?	
Sociocultural contexts		Internalization and externalization	
1. Can you predict the potential technology advancement that may take place and incorporate the technology in your design?		1. Can you use metaphors to inform users how to use your design?	
2. Can you identify any social and environmental concerns that you want to facilitate or avoid within the targeted activity through your design?		2. Can you design some features that can help users to transform their planning to actual performance?	
3. Are there any cultural differences within the targeted activity? Can you learn from how people carry out the targeted activity in another culture?		3. Can you design some features so that the user is willing to learn how to use your design even it requires lots of effort and time?	
4. Can you improve the existing products and services that users use to fit into a specific sociocultural context?			
5. What if your design aims at making the targeted activity easy to collaborate between different actors?			

Besides the Activity Design Cards, two types of Activity Cube were developed: the dice and the Rubik's cube (as shown in Figure 29). Both of the cubes are based on the concept of randomness and play used in design ideation. The content of these two cubes is the same. The only difference lies in the play mechanism. For the dice, users are supposed to first roll the dice and then pick up a card from the corresponding card category. For the 4X4 Rubik's cube, each color of the cube refers to one card category, users are supposed to rotate the Rubik's cube and then draw four cards separately from the corresponding card categories.

Figure 28. Examples of the Activity Design Cards used in this version of the toolkit.

Figure 29. The AT-informed toolkit prototype. Left: toolkit in the form of a dice; Right: toolkit in the form of a Rubik's cube.

6.2 Evaluation of the AT-onformed toolkit prototype

6.2.1 Methods applied

The first version of the toolkit was evaluated in the date labelling project (for the background of the project see Section 5.4). Two rounds of co-creation sessions were conducted to evaluate how the toolkit can be used in designers' early-stage ideation process. The first round of co-creation sessions was conducted in collaborative design workshops where design experts were involved. The second round of co-creation sessions involved participants without prior design background in individual brainstorming settings. Table 12 shows the specific set-up of the evaluation. The design brief that participants received in these two sessions was the same, that is, to design products or services to promote consumers' correct usage of date and storage labelling information in household environments. The two types of the cube were evaluated separately. The dice form of the toolkit was evaluated in the collaborative design workshops as it can be shared and played by multiple participants at the same time, while the Rubik's cube was evaluated in the individual brainstorming sessions as it has the potential to bring randomness to the idea generation process performed by the individual.

Table 12. The set-up of the AT-informed toolkit prototype evaluation sessions.

	Collaborative workshop	Individual brainstorming
Participants	Group 1 & 2: Each with 1-2 design experts and 3-4 general consumers	4 food and packaging industry practitioners
Tested toolkit	Dice form	Rubik's cube form
Design brief	To design products or services that promote consumers' correct usage of date and storage labelling information in household environments	

In terms of collaborative design workshops, two workshop sessions were organized, each with 5-6 participants (1-2 design experts and 3-4 general consumers). Each workshop session lasted for approximately 75-90 minutes. In terms of individual brainstorming, 4 industry practitioners participated in the session separately. Each session lasted around 45 to 65 minutes. In both sessions, the AT-informed toolkit prototype was used to facilitate participants' design idea generation (the evaluation process is illustrated in Figure 30). A detailed description of the design workshops and brainstorming sessions can be found in Paper III and Paper VI.

Figure 30. Evaluation of the AT-informed toolkit prototype. Up: collaborative design workshop evaluation procedures; Down: individual brainstorming evaluation procedures.

6.2.2 Evaluation results and reflections of the first version toolkit

The design ideas generated through the use of the toolkit is presented in Table 13. In general, the design ideas can be categorized into three categories: 1). ideas revolving around improving date and storage information presentation, 2). ideas revolving around improving consumers' sensory assessment of food edibility, and ideas about employing technological innovations to help consumers to make better judgments.

Table 13. A list of design ideas generated through using the toolkit.

Category	Early-stage design Ideas for interventions
Improve date and storage information presentation	<ul style="list-style-type: none"> • A graphic presentation of product shelf life instead of only presenting date (e.g., timetable, visualization of the probability for bacteria to grow). • A visual aid of how the food item would look like if it is gone bad (e.g., a visual comparison between edible and spoiled food). • A description of how the food item would smell if it is gone bad. • "Use within X days after opening" label with a sticker to show when the product was first opened.
Improve sensory assessment	<ul style="list-style-type: none"> • Tips of which sensory perceptions are recommended to assess the edibility of a certain food product. • Packaging designed to encourage people to squeeze, smell and look inside.
Incorporate technological innovations	<ul style="list-style-type: none"> • Smart labels that can detect food status in real-time and change colors accordingly. • Intelligent fridge to help consumers to better manage food items in the fridge. • QR codes on packaging to inform consumers about product relevant information such as detailed date and storage guidance, production, transportation and brand identity. • Provide digitalized and tailored recipes for consumers to deal with food items close to the expiration date.

Based on the design ideas shown in Table 14, an AR-based mobile digital prototype that aims to support consumers in making better food edibility assessment was developed (see Paper IV). To be more specific, the AR prototype can transform the date labelling and storage-related information presented on the packaging to consumers' mobile devices. This feature can be used to solve the limitation of on-pack labelling space issue that food industry practitioners are concerned about. It can also provide consumers with a way to interact with the information in real-time. In other words, instead of purely being an information receiver, consumers can actively find knowledge and information such as product storage methods, shelf-life and recipes. Furthermore, as consumers noted that visual

representation of how the food item would look like if it is gone bad is especially helpful, the augmented 3D presentation of food items thus are able to offer such visual aid to help consumers make edibility judgement based on their sensory prescriptions (see Figure 31).

Figure 31. The Augmented Reality digital prototype developed to support consumers' food edibility assessment activities.

Furthermore, as shown in Table 13, although the theme of this design project is focused on the perspective of on-pack date labelling communication, the design ideas that participants generated not only center around date labelling design itself, they also covered different aspects of people's food edibility assessment activity system, ranging from improvements on visual presentation to technological supports. This finding sheds some light on the effects of the toolkit in terms of its usefulness to systemically inform activity-based design interventions to address sustainability challenges. Therefore, the toolkit has the potential to work as an entry point for designers to take activity as the unit of design and thus engage with complex sustainability issues in users' activity system. Besides that, the variety of the generated design ideas also indicates that the toolkit is applicable when it comes to supporting designers in developing early-stage design ideas.

Furthermore, the Activity Cube (both the dice and Rubik's Cube) was reported by participants as interactive and fun. However, the form of the Activity Design Cards was criticized by the participants. Three main limitations regarding the Activity Design Cards can be summarized:

- The text descriptions on Activity Design Cards were redundant.
- The layout of Activity Design Cards needed to be adjusted.
- Some of the design examples illustrated on the Activity Design Cards help to understand the question, while some brought extra difficulties for understanding the question.

6.3 Extracting AT-informed design implications

6.3.1 Study set-up and goals

Study E-I is conducted to explore 1). how have AT and its theoretical principles been applied in existing studies which focus on addressing design and sustainability challenges? And 2). what are the design implications that AT can offer for design researchers in the field of DfSB?

6.3.2 Methods applied: narrative literature review and theory-generating qualitative meta-synthesis

As illustrated in Figure 32, a narrative literature review was first conducted to gain an overview of the literature search scope and determine the literature search strategy. The results of the narrative literature review can be found in Paper VI.

Building upon the results of the narrative literature review, a systematic literature search and meta-synthesis was then carried out to analyze and synthesize the existing studies that applied an AT theoretical perspective for investigating design for sustainability issues. The meta-synthesis performed in this study was comprised of 4 steps: 1) develop workable definitions of key concepts and search scope, 2) identification of research, 3) study selection and quality assessment, 4) data extraction and synthesis.

Figure 32. An overview of the research process applied in this stage.

As shown in Table 14, peer-reviewed conference papers, journal articles and book chapters published until April 2020 were included in the literature search. After removing duplicated search records, 621 articles were identified. After the study selection and assessment process, 18 articles remained in the final selection stage.

Table 14. Search scope, search string and the corresponding search records in the meta-synthesis study.

Databases and search criteria	Scopus	Web of Science Core Collection
Document type	Article, conference paper, book chapter	Article, conference paper, book chapter
Language	English	English
Publication year	From 1990 to April 2020	From 1975 to April 2020
Search strings applied to	TITLE-ABS-KEY	TITLE-ABS-KEY
"activity theory" AND "sustainab*"	98 records	67 records
"activity theory" AND "behavior* change"	8 records	3 records
"activity theory" AND "environment*" AND "design"	243 records	148 records
"activity theory" AND "social*" AND "design"	294 records	156 records

Regarding the data extraction and synthesis, data from the included primary studies were first extracted into two categories: basic study characteristics and the specific use of AT. Then, the memoing method was adopted to analyze and synthesize the extracted codes. An overview of the data analysis and synthesis process is presented in Figure 33.

Figure 33. The analysis and synthesis process of qualitative findings extracted from the primary studies.

6.3.3 Results

In total, 18 articles are included in the final review. Table 15 shows a summary of the included primary studies. The general topics of the included articles cover five areas: 1). the design, development and evaluation of Information and communication technology (ICT) platform to solve social and ecological sustainability issues (see Aguoyo, 2016; Aguoyo & Emaes, 2017; Smith & Turpin, 2017; Ssozi, 2016; Sclater, 2016; Lally & Sclater, 2012; Hnasan & Meloche, 2013), 2). information system (IS) to tackle challenges associated with climate change (see Hansan et al. 2017; Hansan & Lonescu, 2017; Chen et al., 2009), 3). sustainable eHealth services (Svensson, 2020; Bai&Guo, 2011; Lin & Hsieh, 2014; Lin et al., 2012), 4). energy conservation artefacts and monitoring systems (Svelvefors et al, 2015, viktoirelius & Lundh, 2019), and 5). design related to sustainable consumption in general (Perold et al., 2019; Chu et al., 2020; Khan et al., 2015). It has to be noted that the design interventions that most of the included studies developed and evaluated were in digital form. This is not surprising given that AT has already been widely applied in the research field of ICT and HCI.

Table 15. A summary of the included articles' research area, topic, relation to sustainability and design, and engagement with AT.

Types of design intervention and fields of implementation	Included articles	Sustainability and design goal(s)	Overall engagement with AT
Information and communication technology (ICT)	Aguoyo, 2016; Aguoyo & Emaes, 2017;	Design and evaluate an ICT platform to promote local residents' understanding of the socio-ecological sustainability of a lake in southern Chile.	To analyze and guide the design, implementation and evaluation phase of the platform
	Smith & Turpin, 2017;	Design and evaluate an ICT platform to empower elderly women in a rural community in South Africa.	To describe the social and political dynamics in the community
	Ssozi-Mugarura et al., 2016	Evaluate an ICT intervention for sustainable water management in rural communities in Uganda.	To analyze the contextual factors that influence the mediation capacity of the intervention
	Sclater, 2016; Lally & Sclater, 2012	Evaluate the effects of a Technology Enhanced Learning platform on supporting pedagogies of socio-ecological sustainability in Art and Design education.	To understand how participants acted and developed when engaged in co-designed creative activities on the platform
	Hnasan & Meloche, 2013	Identify ICT-mediated opportunities in solving environmental challenges.	To interpret the key factors emerged from the collected empirical data
Information system (IS)	Hansan et al, 2017;	Explore the potential of using IS to support the planning and execution of design interventions for climate change adaptation.	To develop and analyze design interventions for solving complex climate change problems
	Hansan & Lonescu, 2017;	Design an online system to enable small businesses to track and reduce the environmental footprint of their business activities.	To identify business activities that have a significant environmental footprint

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	Chen et al., 2009	Explore the design of information technologies to address socio-economic emergency communication challenges.	To analyze the key issues in and understand the requirements for emergency communication system design.
eHealth services	Svensson, 2020;	Introduce innovative eHealth services at a municipal level to obtain a sustainable society.	To understand the voices of different actors and analyze their contradictory motives in eHealth work practice
	Bai&Guo, 2011;	Develop eHealth services for elderly care with an emphasis on sustainability properties.	To design the architecture of the system and identify the relationships between different components of the healthcare system
	Lin et al., 2012; Lin & Hsieh, 2014;	Evaluate and investigate what design factors affect the sustainability of telehealth services.	To identify the contradictions among the key actors of the telehealth system
Energy consumption and conservation	Svelvefors et al, 2015	Explore design implications and opportunities for supporting people's everyday energy conservation.	To understand how people perceive the possibilities to engage in energy conservation from a goal-oriented perspective
	Viktorelius & Lundh, 2019	Evaluate the design of an energy monitoring system and energy saving policy for improving energy efficiency in shipping.	To analyze and understand energy conservation and efficiency in the complex sociotechnical setting
Sustainable consumption in general	Perold et al., 2019	Design to support informal settlement residents' transitions toward sustainable urbanism in Southern African.	To analyze and identify contradictions between two co-existing design activity systems in architectural practice.
	Chu et al., 2020	Explore design opportunities to reduce date and storage labelling related household food waste.	To conceptualize subjects' interaction with mediating artefacts and the corresponding tensions and contractions
	Khan et al., 2015	Solve environmental management issues of electric and electronic waste by redesigning human interaction in socio-cultural perspectives.	To develop a framework to systemically solve electric and electronic waste issues.

As shown in Table 16, the key theoretical principles of AT were used either for analyzing the causes of sustainability-related issues and inform sustainable design implications (as presented in theme 1) or evaluating the effects of the proposed design interventions on solving the targeted sustainability challenges (as presented in theme 2).

Table 16. An overview of the AT theoretical principles used in each primary study.

Themes	Articles	Mediating artefacts	History & development	Sociocultural contexts	Tensions & contradictions	Subject-object relationships
Theme 1: Analyze the causes of sustainability issues and inform sustainable design interventions	Hasan & Meloche, 2013	√				
	Hasan et al., 2017	√		√	√	√
	Perold et al., 2019	√			√	
	Selvefors et al., 2015	√	√		√	√
	Bai & Guo, 2011	√				√

	Chu et al., 2020	√			√	√
	Khan et al., 2015	√		√		
	Chen et al., 2009	√		√		
Theme 2: Evaluate the effects of design interventions on solving the targeted sustainability challenges	Hasan & Ionescu, 2017	√				
	Lin & Hsieh, 2014	√		√	√	
	Slater, 2016; Lally & Slater, 2012	√	√			
	Ssozi-Mugarura et al., 2016	√	√	√		√
	Svensson, 2020	√			√	√
	Viktorelius & Lundh, 2019	√	√		√	
	Aguayo, 2016; Aguayo & Eames, 2017	√	√	√		√
	Smith & Turpin, 2017	√		√	√	

6.4 Translating the extracted design implications

Two steps were taken to translate the above design implications for designers with no prior theoretical knowledge of AT to apply.

In the first step, the AT-informed design implications were justified through the case studies (see Study A-I, A-II, B-I, B-II, C-I, D) included in the dissertation. Most of the implications extracted from the findings of meta-synthesis are already covered and supported in the case studies. For instance, the design implication under the sociocultural context category: “Investigate the effects of the proposed sustainable design interventions at an individual level, while informing opportunities of how the interventions might be incorporated into the targeted activity system on a broader scale” is used in Study C-I, B-I and B-II. Results from these studies also support that this particular design implication is useful when it comes to sustainable design explorations. Table 18 shows the connection between the design implications and the case studies included in the dissertation. In the second step, the abstract design implications were translated into more practical design questions. This is done by integrating the design implications with the results and reflections regarding the use of AT in each corresponding case study included in this dissertation.

1. ***Sustainable mediating effects of artefacts:*** As presented in Section 2.4.1, the theoretical principle of the mediating effects of artefacts may enable design researchers to find design interventions that facilitate the transformation of the

whole activity systems towards sustainability. Findings of the meta-synthesis specified this presumption by indicating that it can:

- Inform sustainable design interventions that take both the internal and external mediating effects of artefacts into considerations.
 - Envisage whether and how might subjects incorporate the proposed sustainable design interventions into their existing activity systems.
2. ***Directing sustainable subject-object relationships:*** As presented in Section 2.4.2, the theoretical principle of subject-object relationships is assumed to have the potential to expand the scope of analysis from users' interaction with a specific artefact to how subjects carry out meaningful motive-oriented activities. Findings of the meta-synthesis confirmed this presumption and further revealed that the theoretical principle can help design researchers to:
- Uncover the relations between the subject's primary motives in an activity system and the corresponding sustainable or unsustainable actions and operations that the subject performs.
 - Assess how the proposed sustainable design interventions might be compatible with subjects' existing motives and goals embedded in the target activity system.
3. ***Incorporating sociocultural contexts into sustainable design considerations:*** As presented in Section 2.4.5, the theoretical principle of sociocultural contexts may help design researchers to analyze or envisage the potential impacts of sustainable design intervention at different levels. Moreover, it suggests that empirical phenomenon related to sustainable behavior needs to be investigated in real-life contextual settings rather than task-based laboratory settings. Findings from the meta-synthesis confirmed the above presumptions and highlighted the importance to:
- Interpret individuals' needs in relation to the social, cultural and historical context of the targeted activity system.
 - Find an analytical balance between individual behavior and the sociocultural context to investigate the cause of sustainability issues.
 - Investigate the effects of the proposed sustainable design interventions at the individual level, while informing how the interventions might be incorporated into the targeted activity system on a broader scale.
4. ***Uncovering tensions and contradictions within and between the target activity systems:*** As presented in Section 2.4.3, when used in the context of

design for sustainable behavior, AT's theoretical principle of tensions and contradictions may provide design researchers with a holistic view to understand how tensions and contradictions within and between activity systems can cause sustainability problems. The findings of meta-synthesis explicated this statement by suggesting that it can enable design researchers to:

- Reveal tensions and contradictions within and between different constituents of the target activity system, and how these tensions and contradictions may affect the sustainability outcome of the activity.
 - Investigate why interventions particularly designed to promote people's sustainable behavior failed to achieve the intended outcomes.
 - Identify the contradictory motives and needs of different actors involved in the target activity system and the influences on the sustainability outcome of the activity.
 - Identify the potential conflicts between subjects' existing forms of activity and the preferred sustainable forms of activity intended by the design interventions.
5. *Understanding the dynamism of activities:* As presented in Section 2.4.4, activities are under a constant development and evolution process as the subject attempting to find temporary solutions to cope with the tensions and contradictions that took place in people's activity system. Therefore, the way how we carry out a specific activity at a specific point of time is influenced by the evolution of the targeted activity in the past, and it will also influence the future development of the activity. The findings from the meta-synthesis supported this argument, they also indicated that AT's theoretical principle of history and development can allow design researchers to:
- Analyze how subjects cope with existing tensions and contradictions in the target activity system and how this can lead to potential opportunities for sustainable design interventions.
 - Illustrate how the target activity system develops over time and what sustainability challenges, along with design opportunities, may emerge in this development process.
 - Envisage whether and how the proposed design interventions may lead to desired or undesired changes in the activity system.

Table 18. A summary of the design implications informed by the AT theoretical principles.

Design implications informed by the AT theoretical principles	Supported by which studies	Design implications informed by the AT theoretical principles	Supported by which studies
Sustainable mediating effects of artefacts			
Inform sustainable design interventions that take both the internal and external mediating effects of artefacts into considerations	Study A-II Study C-I	Reveal tensions and contradictions within and between different constituents of the target activity system, and how these tensions and contradictions may affect the sustainability outcome of the activity.	Study A-II Study C-I
	Envisage whether and how might subjects incorporate the proposed sustainable design interventions into their existing activity systems	Study C-I	Investigate why interventions particularly designed to promote people's sustainable behavior failed to achieve the intended outcomes.
Directing sustainable subject-object relationships			
Uncover the relations between the subject's primary motives in an activity system and the corresponding sustainable or unsustainable actions and operations that the subject performs.	Study A-I	Identify the contradictory motives and needs of different actors involved in the target activity system and the influences on the sustainability outcome of the activity.	Study C-I
Assess how the proposed sustainable design interventions might be compatible with subjects' existing motives and goals embedded in the target activity system.	Study C-I Study B-I Study B-II	Identify the potential conflicts between subjects' existing forms of activity and the preferred sustainable forms of activity intended by the design interventions.	Not covered
Incorporating sociocultural contexts into sustainable design considerations			
Interpret individuals' needs in relation to the social, cultural and historical context of the targeted activity system.	Study A-II Study B-II	Analyze how subjects cope with existing tensions and contradictions in the target activity system and how this can lead to potential opportunities for sustainable design interventions.	Study A-I Study A-II Study C-I
	Find an analytical balance between individual behavior and the sociocultural context to investigate the cause of sustainability issues.	Study B-I Study B-II	Illustrate how the target activity system develops over time and what sustainability challenges, along with design opportunities, may emerge in this development process.
Investigate the effects of the proposed sustainable design interventions at the individual level, while informing how the interventions might be incorporated into the targeted activity system on a broader scale.	Study C-I Study B-I Study B-II	Envisage whether and how the proposed design interventions may lead to desired or undesired changes in the activity system.	Not covered

7

Discussion

This chapter discusses the design opportunity and implications that a context change transition and behavior retention perspective can provide for the field of Design for sustainable Everyday Life. Furthermore, the research approach and knowledge generation process applied in this PhD study are also reflected in this chapter.

7.1 Revisit the concept of design for sustainable behaviour retention

Given the understanding of design for sustainable behavior retention through context change disruptions, the questions then come to what are the overlaps and differences between design for sustainable behavior retention and design for sustainable behavior change at a conceptual level? and how the behavior retention perspective and the behavior change perspective might complement each other in terms of facilitating people's behavior transition towards a sustainable lifestyle? These two questions will be discussed in the following section.

Overlaps and differences between change and retention

As shown in Table 19, both the behavior change perspective and the behavior retention perspective aim at introducing design interventions to facilitate a transition towards a sustainable lifestyle. However, a design for sustainable behavior change perspective explicitly aims at reducing the negative impacts of people's wrongdoings. In contrast, the sustainable behavior retention perspective aims at supporting people in maintaining and adapting the positive effects of their existing doings. The difference in overarching goal also determines that the focus of analysis between the two concepts varies from each other. A design for behavior change perspective focuses on identifying and analyzing what and how unsustainable doings are carried out by users. In contrast, a design for sustainable

behavior retention perspective emphasizes the importance of learning from the existing desired and sustainable doings that people have been performing.

Change and retention: complementarity to achieve sustainable behavior transition

The fundamental reason that causes the differences in these two perspectives may be ascribed to the different interventional approaches used to achieve sustainability. According to Faber et al. (2016), two approaches exist when designing sustainability-oriented innovations: an absolute approach and a relative approach. An absolute approach suggests that a set of selected criteria or objectives can be used to determine an idealized state of sustainability. For example, reducing energy consumption of the appliance by 20%, cutting down the CO₂ emission by 10%. Interventions that facilitate the transition towards sustainability thereby need to explicitly aim at fulfilling these pre-set objectives. On the contrary, a relative approach suggests that an idealized sustainability state does not exist because the context in which people situate keeps changing. Therefore, achieving sustainability should be regarded as a dynamic and ongoing process in which constant improvements and adjustments should be made.

The absolute approach is, to some extent, in line with the concept behind design for sustainable behavior change. More precisely, as described previously, a design for sustainable behavior change perspective tends to treat sustainability dichotomously. There seems to be a clear distinction between what is perceived as sustainable and what is perceived as unsustainable. A behavior change perspective thus implies that there is a desired or undesired sustainable state, and design is used as a means to achieve the desired state (Adams et al., 2016).

A design for sustainable behavior retention perspective aligns with the relative approach mentioned above. In contrast to design for sustainable behavior change, where a definite line can be drawn based on the selected criteria to assess sustainability, in retention, a grey area exists between what is perceived as sustainable and unsustainable. In other words, depending on the specific spatial (sociocultural) and temporal (development) contexts where a particular doing is performed, it can carry both sustainable and unsustainable features with it. Moreover, a particular doing which is regarded as undesired in a specific spatio-temporal context may turn out to be desired in another.

For example, buying excessive amount of food more than normally needed in one purchase is often regarded as unsustainable behavior as it is likely lead to household food waste. However, in the context of Study D where people underwent the special time of the Covid-19 pandemic, this particular food purchasing behavior complies with the social distancing measures. Moreover, findings from Study D showed that, participants became more aware of the potential food waste issues in their food consumption activities. In order to better cope with the excessive amount food stored at home, participants also developed innovative solutions in their meal planning, food storage and food handling activities to avoid unnecessary food waste. From a development perspective, if the awareness of food waste, together with the innovative solutions in relation to more organized meal planning and food handling, can outlast the pandemic and become habitual doings embedded in people' everyday life, it would still contribute to the transition towards sustainable lifestyle.

Consequently, a design for sustainable behavior retention perspective highlights that, as people's doings, along with the spatial and temporal context in which these doings situate are dynamically evolving, the line that distinguishes what is desired and undesired, what is sustainable doings and wrongdoings, is constantly moving as well. Designers thus need to perform contextual dependent in-depth analysis to break down and analyze people's doings while keeping a holistic view on the spatio-temporal context. The bottom-up context-focused analysis that underlies the behavior retention perspective can thus complement the top-down objective-oriented behavior change perspective.

Table 19. Comparison between design for sustainable behavior change and retention

	Design for behavior change	Design for behavior retention
Overarching goals	Reduce negative impacts	Facilitate positive effects
Focus of analysis	Identifying undesired/unsustainable wrongdoings	Identifying existing desired/sustainable doings
Approaches to achieve sustainability	Absolute approach	Relative approach
Analysis and design explorations	Top-down sustainability objectives	Bottom-up spatial and temporal contexts

7.2 Peeking into the differences between the Activity-based, Behavior-based and Practice-based theoretical approach

Three dominant theories can be identified in the field of Design for Sustainable Everyday Life: behavior model-based theoretical lens from a social-psychology perspective (hereinafter referred to as Behavior-based lens), a practice-based theoretical lens from a social-practice theory perspective (hereinafter referred to as SPT-based lens), and activity-based theoretical lens from an activity theory perspective (hereinafter referred to as AT-based lens). A comprehensive comparison of the strengths and limitations between the Behavior-based lens and SPT-based lens can be found in previously published PhD dissertations in the field (see, e.g., Daae, 2014; Pettersen, 2013; Piscicelli, 2016; Tromp, 2013). Furthermore, in her dissertation, Selvefors (2017) compared the AT-based lens with the other two lenses. Building upon their insights, as this PhD study takes AT as the guiding theoretical framework, in this dissertation, the comparison is specifically focused on the strengths and limitations that an AT-based theoretical lens may bring to Design for Sustainable Everyday Life.

According to Wever (2012), at least two clusters can be distinguished among the wide range of research questions proposed in sustainable behavior design. The first cluster aims at developing theoretical understanding about factors that may potentially influence users' sustainable or unsustainable doings. Specifically, it involves questions including how to frame and understand users' doings, and what factors may influence users' response to the designs (see e.g., Kuijer, 2014; Lockton, 2013). The second cluster aims at providing design practitioners with approaches and tools to support their sustainable products and services design process. Questions related to this cluster revolve around determining what and where sustainable design interventions should be introduced (see, e.g., Daae, Chamberlin, & Boks, 2018; Lockton, 2017). Although being applied for different goals, theoretical lenses play a central role in the research conducted in both clusters. In the first cluster, it often serves as a framework to guide empirical analysis, while in the second cluster, it is widely used as a tool to inform sustainable design explorations. Based on the above understanding, five perspectives are extracted and applied here for the comparison (as shown in Table 20):

- With regard to empirical analysis: 1). unit of analysis, 2). analytical approach, and 3). users' roles.
- With regard to design exploration: 4). primary goals of design intervention, 5). Primary levels of design intervention

First, in terms of empirical analysis, both the AT-based lens and Behavior-based lens focus on understanding the role that artefacts can play in influencing people's doings. The Behavior-based lens explicitly focuses on analyzing the interaction between users and artefacts and the corresponding sustainable or unsustainable behavior generated as the result of the interaction (Kuijer, 2014; Tromp, 2013). The analysis is often conducted by first deconstructing a system into different elements (e.g., user behavior and attributes of designed artefact) and then making inferences about the relations between specific user behavior and specific attributes of the designed artefact (Jackson et al., 2005).

In contrast to the Behavior-based lens, AT aims to understand the interaction between users and artefacts in a broader context: people's activity systems. According to Kaptelinin & Nardi (2006), AT suggests that "the attributes of individual components are of little consequence when the components are integrated within a higher-level unit" (p 40). In other words, it implies that the socio-ecological impacts of an artefact on people's doings should not be oversimplified to a sum of users' behavior. Rather, the activity system, that is, the purposeful need-based artefact-mediated interaction of users (subjects) with the world (objects), should be taken as the fundamental unit of analysis. Consequently, although users' interaction with specific artefact inevitably influences the sustainable or unsustainable behavior of individual users, from the perspective of AT, such interaction is not the root cause of sustainability issues. Instead, the way how the subjects use different artefacts as mediating tools to fulfill certain objects/goals is what lies behind the sustainability issues. Therefore, compared with the Behavior-based lens, the AT-based lens treats sustainability as a system property embedded in the complex sociocultural context rather than an individual element added onto the designed artefact. Taking activity as the basic unit of analysis thus might enable designers to expand the analysis scope from users' behavior to meaningful motive-oriented activities.

Therefore, compared with the Behavior-based lens, the spatial (sociocultural contexts) and temporal (development) perspectives are the strengths that the AT-based lens brings. Whereas the limitation of the AT-based lens is that it does not deconstruct doings into different behavior determinants. Instead, it interprets doings from different theoretical principles. As a consequence, it may not be applicable when it comes to predicting the likelihood of a certain behavior or providing models for identifying relevant factors that affect a certain behavior.

While the AT-based lens can be distinguished from the Behavior-based lens, it is relatively hard to distinguish the concept behind the AT-based lens from the SPT-based lens. The SPT-based lens takes practices as the unity of analysis. It focuses on investigating how people perform their routinized practices and why they perform them (Reckwitz, 2002; Shove, Pantzar, & Watson, 2012; Warde, 2005). Daily doings such as shopping, cooking, commuting can be regarded as practices. At the same time, they can also be called activities. Both lenses emphasize the importance of understanding the context of people's everyday life doings, and they acknowledge that people's daily doings can undergo constant change triggered by the dynamics of social contexts (Scott, Bakker, & Quist, 2012). Therefore, they argue that a systemic analytical approach is needed to understand how contextual factors can influence people's doings. Moreover, both lenses argue that people's daily doings (either activities or practices) cannot be studied in isolation from each other as they are often interwoven in complex networks. Furthermore, the concept of artefacts is highlighted in the theoretical models of both lenses. In SPT, artefact is referred to as "Stuff", while in PT, artefact is often referred to as meditating tools.

Although distinguishing AT and SPT from a broader Design for Sustainable Everyday Life perspective might be difficult, efforts can still be made by focusing on the particular set-up of this dissertation. As the dissertation is focused on understanding how people transit their doings when people undergo context change disruptions, AT's emphasis on the hierarchical structure of the human activity system is one of the strengths compared with the SPT-based lens. It allows designers to break down and categorize activities into the ones that are unconsciously performed by the users (operation layer) and the ones that are consciously intended by the users (action layer). Furthermore, as AT acknowledges the dynamic transition between the operation layer and the action layer, it can also be used to identify design opportunities that may be neglected in a SPT-based lens.

Second, in terms of design exploration. Design interventions introduced from a Behavior-based lens aim to either promote specific desired user behavior or change undesired and unsustainable behavior (Niedderer et al., 2014). The functioning level of design intervention is targeted at the product innovation level. The SPT-based lens takes a more synthetic approach and aims to influence the practices that people perform towards a less resource intensive direction. Compared with the Behavior-based lens, the design interventions introduced from the SPT-based lens tend to be more disruptive as they often aim at redesigning and reconfiguring people's current practices. For example, reconfiguring the mobility practices (Hasselqvist &

Hesselgren, 2019) and bathing practices (Kuijer, Jong, & Eijk, 2013). The functioning level of design intervention thus can be categorized into a socio-technical system innovation level, where a 'cluster of aligned elements, including artefacts, technology, knowledge, user practices and markets, regulation, cultural meaning, infrastructure, maintenance networks and supply networks, together fulfill a specific societal function' (Geels, 2005).

From an AT-based lens, how the subjects (users) use different artefacts as mediating tools to fulfill certain objects/goals is what lies behind the sustainability issues. To put it plainly, if an artefact, designed with the intention to promote users' sustainable behavior, does not fit into the context of the user's activity systems, it would only lead to limited desired sustainability effects. On the contrary, if an artefact, designed without any particular considerations related to promoting sustainable behavior, is used in an activity system that is already sustainably constructed, the potential negative impacts brought by the artefact are likely to be minimal. However, taking activity as the basic unit of analysis does not mean that individual users should be de-centralized in the design process. As Don Norman noted, "a deep understanding of people is still a part of activity-centered design. But activity-centered design is more: It also requires a deep understanding of the technology, of the tools, and of the reasons for the activities" (Norman, 2005 p: 16). In other words, the AT-based lens suggests that users are more than individuals who use the designed artefacts, they are participants in activities, each with their own socially constructed activity systems which evolves over time (Williams, 2009). Therefore, the AT-based lens can be positioned at the intermediate level between sustainable product innovation and sustainable socio-technical system innovation level.

Table 20. Differences between the AT-based lens, Behavior-based lens, and the SPT-based lens.

	AT-based lens	Behavior-based lens	SPT-based lens
Unit of analysis	Purposeful need-based interaction of users (subjects) with the world (objects) mediated by artefacts	Interaction between users and artefacts	Routinized practices
Analytical Approach	Understand why and how sustainability problems take place in complex activity systems	Deconstruct a system into different elements and make inferences between the elements	How people perform routinized practices and how they perform them
Users' roles	Participants in activities	Users of artefacts	Carriers of practices
Aim of sustainable design interventions	Mediating subject-object relationships	Influence user behavior	Disruptive resource reconfiguration of a practice
Levels of interventions	Product-service system innovation level	Product-innovation level	Socio-Technical System innovation level

7.3 Reflections about the research approach and the knowledge generation process

7.3.1 Reflections about the research approach and limitations

Multiple choices of research methodology exist when it comes to developing frameworks and toolkits for supporting sustainable design practices. As described in Section 3.2, DRM is chosen as the guiding methodology in this study. If another methodological approach were chosen, the research process would have differed from what it looks like now. Discussions around which methodology is best suited for similar studies are out of the scope of the thesis. However, reflecting on the use of DRM in the context of this study, it brings three strengths to the development of the AT-based framework and AT-informed toolkit:

- First, DRM divides design research into two interrelated objectives: the formulation of frameworks/models to *understand* a phenomenon of design interests and the development of tools to *support* design practices. The *Understand* and *Support* component of the DRM matches the overarching aim of this study, which is about understanding phenomena concerning how people transit their everyday life doings when they undergo context change disruptions. Based on the generated knowledge, developing design support for retaining people's existing sustainable doings.
- Second, DRM provides systematic guidance on transforming theoretical knowledge into concrete design practices by dividing the research into descriptive studies and prescriptive studies. The descriptive study focuses on developing *understanding*, while the prescriptive study focuses on developing *support*. This feature also aligns with the *understand* and *support* goal of the study.

- Third, DRM illustrates a clear relation between the descriptive study and the prescriptive study; it also emphasizes the importance of iteration both within and between different research stages. This methodological feature was applied in this study to guide the development and validation process of the proposed framework and toolkit. Multiple descriptive and prescriptive studies were performed and iterated.

However, the strengths of DRM co-exist with its limitations. Given that DRM is heuristic rather than algorithmic in its methodological nature, DRM could have been applied with more flexibilities in this study. Relatively more focuses can be put on Stage 4 - Descriptive Study II, which evaluates the effects of AT-informed toolkit prototype in real design practices. However, due to the time and scope constraints of the PhD study, only one iteration has been conducted in Stage 4. Further iteration, evaluation and validation of the AT-informed toolkit would be carried out as future work.

Moreover, given the methodological discussion presented above, the study did not evaluate any design interventions for retaining people's existing sustainable behavior. This is mainly due to the explorative nature of this study. As the study aims to 1). develop a theoretical framework to help designers better understand how people transit behavior when they undergo context change disruptions, and 2). explore what design implications can be informed by focusing on the design for sustainable behavior retention aspect of the transition process. Based on this study set-up, the study focuses on the design analytical level rather than the practical design implementation level. As a consequence, the study leans towards conducting conceptual exploration and generating theoretical understanding of a phenomenon rather than developing and evaluating a particular design solution to address a specific problem.

7.3.2 Reflections about research credibility and transferability

According to Creswell (2003), credibility refers to the internal validity, that is, to what extent is the result trustworthy based on the particular research set-up and methods applied. Transferability refers to the external validity, that is, to what extent is the finding generalizable to other research contexts. In this study, both credibility and transferability are examined along the way as the study proceeds. Table 21 summarizes the potential risks of bias concerning credibility and transferability and how they were mitigated by the measures taken in this study.

Table 17. The potential risks of bias concerning credibility and transferability and the measures undertaken to avoid the identified risks.

Criteria	Potential risks of bias	Measures taken to avoid the bias
Credibility	Data were collected and analyzed only with the intention to support the preconception that the framework is valid and useful.	<ul style="list-style-type: none">• Abductive analytical approach.• Data triangulation.
Transferability	Limited generalizability of the AT-based theoretical framework	<ul style="list-style-type: none">• Consistent research context and focus.• Use multiple methods and resources to uncover evidence and build connections between insights generated in each research stage

In terms of research credibility, although the AT-based framework developed in this study has gone through three rounds of iterations and one round of validation, these iterations and validation are all based on the research projects that I am involved in. In most of the case studies, I play two major roles. On the one hand, I am the one who conceives the project and collects and analyzes data, and on the other hand, I also test and evaluate the framework based on the collected data. This mix of roles may bring a potential risk that data collection and analysis of each case study were subjective to the evaluation and validation purpose that I set for the framework. In other words, only the data that support the preconception that the framework is valid and useful were collected and analyzed. Data that did not match this preconception could run into the risk that they were somehow ignored.

To avoid this potential risk, I applied an abductive analytical approach in all the descriptive studies included in this dissertation. The collected data were first analyzed deductively from a bottom-up direction, allowing themes to emerge and consolidate. Following that, an AT-theoretical lens was used deductively to analyze the identified themes from a top-down direction, deconstructing and reconstructing the empirical data according to AT-based theoretical framework and principles. Furthermore, data triangulation was employed to avoid bias in the data collection process. For example, in Study C-I (see Paper III), a systematic literature review, co-creation workshops, and individual interviews were carried out to collect relevant data. Similarly, in Study A-II (see Paper I), diary probes and in-practice studies were used to gain an in-depth view of participants' food consumption doings.

In terms of research transferability, as the AT-based framework is developed based on the studies presented in this dissertation, one could argue that the

generalizability of the framework is limited to the pre-defined scope of this PhD research. However, in qualitative research, findings are often context-independent. The case studies included in the dissertation, no matter if it has an explorative or descriptive nature, or directly conducted by me or facilitated by me, all share two commonalities. First, they all focus on the area of people's daily food consumption. Second, they are all explicitly targeted at understanding how people transit their doings when they undergo context change disruptions. Consequently, the overall context of the research is consistent, which allows the research findings (e.g., the proposed AT-based framework) to be applied to other similar research contexts.

Moreover, to avoid the potential bias regarding the research transferability, multiple methods and resources were used to gather insights and build connections between insights generated in each research stage. I reported the results from the multiple case studies conducted within the scope of this PhD study, and integrated the results and reflections with the findings from the narrative literature review, the systematic literature review, and the meta-synthesis of existing relevant studies. However, one weakness of the study remains unsolved, that is, the AT-based framework and the AT-informed toolkit are, to a large extent, built upon my understandings, explorations and reflections as an independent researcher. A perfect case-scenario would be to evaluate the applicability and the usefulness of the framework and toolkit in studies other than those in which I am involved. For example, let other design researchers who work with sustainable behavior design topics to apply the AT-based framework in their projects with their data, and then get their first-hand feedback about the effects of the AT-based framework. However, the limited time, scope and resources of this PhD study did not allow this to happen.

7.3.3 Reflections about the methods used in relation to an activity theoretical lens

AT does not prescribe to a particular research method. It allows methods to be chosen depending on the specific research focuses and questions (Kaptelinin & Nardi, 2006). As this study focuses on developing understandings of how people transit their doings when they undergo context change disruptions, it requires researchers to go into the field, gain direct interaction with participants, and co-construct knowledge with the participants. Therefore, a set of empirical data collection methods, including diary probes, in-practice studies and co-creations, were employed in the study. Although the use of these methods has already been widely discussed in the existing design research studies, how they can be used under the guidance of an activity theoretical perspective and what knowledge can be generated to help design researchers understand people's activity system has not

been thoroughly discussed. Therefore, in this section, I aim to provide some reflections about the strengths and limitations of the data collection methods mentioned above in relation to an activity theoretical lens (see Table 22).

Table 22. Reflections about the strengths and limitations of the data collection methods used in relation to an activity theoretical lens.

Data collection methods	Activity layer <i>“Why people do what they do”</i>	Action layer <i>“What people actually do”</i>	Operation layer <i>“How people do what they do”</i>
Diary probes	Lack of direct communication and interaction between researchers and participants.	Data can be collected over a mid/long-term time span without researchers’ physical presence.	Lack of direct observations. Need to encourage participants to document and reflect on their doings and experiences in detail.
In-practices studies	Encounters in everyday life contextual settings.	Participants may perform their actions differently when encountering researchers.	In-filed interviews and observations can help to gain a detailed view.
Co-creations	Establish direct communication and interaction settings between researchers and participants.	Participants may report what they would do rather than what they actually have done.	Insufficient to collect data in real contextual settings.

According to the hierarchical structure of the activity system, the activity layer refers to why people do what they do, the action layer refers to what people actually do, while the operation layer refers to how people do what they do. Reflections from the study demonstrated that the diary probes method is useful for collecting data in the action layer. In other words, what the goals are and how people use specific artefacts to fulfill these goals. Another potential strength of the diary probes is that it allows a mid or even long-term research encounter with participants. For example, in Study D, diary probes were used to collect data related to participants’ food consumption doings during and after the lock-down. By comparing the data from the two sets of the diaries, differences between what people actually do in their food consumption during lock-down and post-lockdown can be identified. However, as there is no direct interaction between researchers and participants in the data collection process, the data collected from the diary probes can sometimes become over tacit. As a consequence, the rationales behind why people do what they do in

the activity layer and the detailed operations of how people do what they do may be hard to grasp only by using diary probes.

On the contrary, the in-practices studies method requires researchers to visit and directly interact with participants in their everyday contextual settings. Compared with diary studies, which is specialized in helping researchers gain an overview of what participants have done in the action layer, the in-practice studies can enable researchers to obtain an in-depth understanding of why and how participants perform a specific doing in a specific context in the activity layer and the operation layer. Therefore, when used in combination in the specific context of this study to understand people's behavior transition when they undergo context change disruptions, the limitation of the diary probes can be complemented by in-practices studies.

The co-creation method used in the study is in the form of collaborative design workshops. Reflections from the use of co-creation show that direct communication and interaction with participants in workshop settings allow researchers to gain understandings of the activity layer. However, when it comes to asking participants questions such as what you usually did or how you usually coped with a particular situation, participants often need to recall what they have done in their food consumption activities. The reason is that the co-creation sessions are not conducted at the moment when and in the real contextual settings where participants carry out their activities. Therefore, it might lead to a particular data collection concern that participants may report what they would do rather than what they actually have done.

8

Conclusion

This chapter presents answers to each research question and the potential contributions of the dissertation.

8.1 Fulfilling research aims and objectives

Based on findings from existing studies, context change disruptions (in the form of individual life-course events and socio-economical transitions) can bring a window of opportunity where people might become more likely to reconsider and unfreeze their habitual doings. Looking at this phenomenon from the theoretical stance of Design for Sustainable Everyday Life, in order to better utilize this window of opportunity to transit people's behavior in a more sustainable direction, retaining people's existing desired and sustainable doings may be as same crucial as changing the undesired and unsustainable ones. However, compared with design for behavior change, the opportunities and implications that design can bring in retaining individuals' existing sustainable doings through context change disruptions have been relatively seldom explored.

Therefore, I began this PhD study by asking whether there are any needs for design to take the responsibility to retain people's existing desired and sustainable doings when they are undergoing context change transitions? Correspondingly, the dissertation also departures from this initial research inquiry on design for sustainable behavior retention and moves on to explore an AT-based theoretical approach to generate a more systemic understanding of design's role in facilitating transitions to sustainable everyday life.

In order to better structure the research process, following a Design Research Methodology (DRM) approach, this PhD study is divided into two parts. The objective of the first part of the research focuses on the development of a theoretical

framework to systematically describe and analyze the influences that context change disruptions have on people's existing daily doings. To fulfill this objective, six small-scale explorative case studies: Study A-I (see Paper II), Study A-II (see Paper I), Study B-I (see Section 5.3.2), Study B-II (see Section 5.3.3), Study C-I (see Paper III) and Study D (see Section 5.5.1), were conducted to investigate the applicability of adopting AT as the theoretical lens for understanding the context change-induced behavior transition phenomenon. As a result, an AT-based theoretical framework was developed, iterated and validated. The objective of the second part of the research focuses on the development of an ideation toolkit prototype for design practitioners to take into account the design for sustainable behavior retention perspective in people's dynamic and complex activity systems. To fulfill this objective, the toolkit prototype is developed by incorporating the proposed AT-theoretical framework with the insights generated from a meta-synthesis study.

8.2 Answering the research questions

As presented in Section 1.6, the nature of each research question proposed in this PhD study disrupted across three levels of inquiry: RQ 1 is oriented towards the exploration at a conceptual level, RQ 2 fits into the design analytical level, while RQ 3.1 and 3.2 focus on the design synthesis level. Given the variety of the nature of the research questions, they are addressed with different approaches and with different emphases.

RQ 1: What is the status of current knowledge of sustainable behavior retention in the existing body of literature in the field of design for sustainable everyday life?

In order to develop an overview of to what extent is the topic of design for sustainable behavior retention explored in the current body of research on DfSB, a narrative literature review was conducted. The results showed that, compared with design for behavior change, the behavior retention perspective remains barely covered in the existing body of DfSB studies. Furthermore, the review results also indicated that, when used in DfSB, a behavior retention perspective is often associated with maintaining the positive effects of behavior change over the long-term. However, the specific topic of how to retain people's existing desired and sustainable doings when they undergo context change disruptions has not been explored in DfSB studies both from theoretical and practical aspects.

RQ 2: From the perspective of design for sustainable everyday life, how to systematically describe and analyze behavior transition induced by context change disruptions?

Following the spatio-temporal lens that Design for Sustainable Everyday Life provides, activity theory (AT) is chosen in this PhD study as the theoretical lens to systematically frame how people transit their everyday life activities when they undergo context change disruptions. Specifically, three theoretical dimensions of AT: 1). the hierarchical structure of an activity system, 2). long-term development and evolution perspective of an activity system, and 3). reality-based contextual scales of analysis were used to formulate an AT-based theoretical framework (see Figure 34). Furthermore, a five-step analytical guide is developed to support the use of the AT-based theoretical framework:

- Step 1: Identify the three key components which constitute the activity system: subjects (users), objects (motivations and goals) and mediating artefacts (tools).
- Step 2: Break down the activity system into three hierarchical layers: activity layer, action layer and operation layer.
- Step 3: Distribute the activity system and its related effects across different contextual levels of analysis: independent activity level, neighboring or supporting activities, and implications at the societal level.
- Step 4: Illustrate how the target activity system develops over time: the pre-existing activity, existing activity under the influence of context change disruptions, and anticipated forms of activity shaped by design interventions.
- Step 5: Identify tensions and contradictions that take place within the different hierarchical structure and contextual levels of analysis, along with how the tensions and contradictions are resolved and how they may lead the future evolution of the activity system towards a more sustainable direction.

Figure 34. The AT-based theoretical framework developed to systematically describe and analyze behavior transition induced by context change disruptions.

RQ 3.1: How might the proposed AT theoretical lens be incorporated into a toolkit to highlight the behavior retention perspective in sustainable design explorations?

Based on the results of the case studies included in this dissertation, a theoretical framework based on Activity theory (AT) is developed, iterated and validated. By incorporating the proposed framework with theoretical understanding generated from a prescriptive meta-synthesis study, an AT-informed toolkit prototype was developed and evaluated. The toolkit focuses on informing early-stage design ideas for design practitioners to take into account the design for sustainable behavior retention perspective in people's dynamic and complex activity systems.

RQ 3.2: Building upon the AT theoretical lens, what design implications can a sustainable behavior retention perspective bring to the field of design for sustainable everyday life?

To highlight the implications that a design for sustainable behavior retention can inform to the field of design for sustainable everyday life, the concept of the retention perspectives is compared with the concept of the design for sustainable behavior change. Insights generated from the comparison indicated three design implications.

- First, in terms of sustainable behavior transition, the outcome resulting from the behavior retention perspective may not always necessarily be in contradiction with the outcome of behavior change. Instead, design for sustainable behavior retention may complement design for behavior change by providing a bottom-up and context-focused relative approach to achieve sustainability.
- Secondly, within the scope of Design for Sustainable Everyday Life, creating behavior change is not the only path to achieve sustainable behavior transition. Retaining people's existing sustainable behavior can also open up windows of opportunity to embed sustainable design interventions in people's daily doings.
- Thirdly, by taking activity as the unit of analysis, the effects of change and the effects of retention should not be viewed as two sides of a paper, each covers the existence of the other. Instead, they are compatible entities that can mutually affect the transition of existing doings and the formation of new doings when people undergo context change disruptions. Therefore, from a research perspective, solely focusing on triggering behavior change may let design researchers and practitioners neglect the potential effects of retention, which is of equal importance when it comes to fostering a transition towards a sustainable lifestyle.

Consequently, the dissertation concludes with a call for design researchers in the field of Design for Sustainable Everyday Life to investigate the role that design can play in retaining people's existing sustainable doings, to explore what would happen on the other side of change.

8.3 Contributions

8.3.1 Theoretical contributions

1). The AT-based theoretical framework and AT-informed toolkit

Looking at the study from a theoretical perspective, AT has been widely applied as a theoretical lens to investigate complex environmental and social sustainability problems in various studies both within and outside the design discipline. However, the rich theoretical concepts of AT are still waiting to be translated into the language that design researchers and practitioners can easily understand. The AT theoretical lens adopted in this study contributes to filling this knowledge gap by providing a framework to enable design practitioners and researchers to identify which target activity should be the focus of change and which should be retained and developed further.

Furthermore, when it comes to supporting the DfSB practices, different design guidelines have been proposed to help design researchers better identify and cope with sustainable behavior design challenges. For example, (see, e.g., Bhamra, Lilley, & Tang, 2011; J. Daae, Chamberlin, & Boks, 2018; Tromp, Hekkert, & Verbeek, 2011) and Design with Intent Method developed by Lockton, Harrison, & Stanton (2010), Behavior Change Design Sprints developed by Colusso, Do, & Hsieh (2018) Dimensions of behavior change developed by Daae & Boks (2014), Change Points developed by Hoolohan & Browne (2020). However, these toolkits are, to a large extent, developed to provide designers with strategies and techniques to trigger behavior changes, more precisely, to change people's undesired and unsustainable behavior through design. There lacks the exploration on the opportunities and implications that design can play in retaining people's existing desired and sustainable doings. As the AT-informed design toolkit is developed with an explicit aim to highlight the importance of a sustainable behavior retention aspect in the design ideation process, it can provide a basis for and raise awareness of a more systemic picture that takes both sustainable behavior change and retention perspectives into early-stage design ideation.

8.3.2 Potential societal values

Looking at Design for Sustainable Everyday Life from a broader socioeconomic perspective, we may find that the nature of sustainability challenges that design deals with in developed and developing regions seems to be different. In developed countries, given the fact that most people live an unsustainable

lifestyle. Therefore, the challenge lies in how to change the existing unsustainable lifestyle towards a sustainable direction and how to foster a long-lasting effect brought by the change.

Whereas people in developing countries and emerging economics may have been performing socio-ecologically desired doings over the years. As a result, most people there have already developed habitual doings, along with necessary knowledge and past experience that meet the standard and concept of sustainable lifestyles. However, as people there have been undergoing a significant socio-economic transition towards growing prosperities, it may also bring a potential risk for unsustainable doings to take place, resulting in undesired behavior changes in every aspect of individuals' life, such as from public transportation to overreliance on private automobiles, from food conservation to waste (Jackson et al., 2005). Facing these context change disruptions caused by socio-economic and individual life-course event transitions, the challenges faced by Design for Sustainable Everyday Life is how to better retain people's existing desired and sustainable lifestyle. Consequently, exploring the design for sustainable behavior retention perspective may potentially support people in pursuing higher standard of living comforts without the need to walk into the Western-liked consumerism lifestyles.

8.4 Opportunities outlook

This dissertation is written in the course of the Covid-19 pandemic. Facing the unprecedented impacts of the pandemic on people's everyday lives, I kept asking myself: could the knowledge generated from this research concerning how people transform their doings when undergoing context change disruptions be used to cope with the future sustainability-oriented societal changes.

Comparing the global sustainability issues with the ongoing Covid-19 pandemic, at first glance, they might seem to be two completely different crises with different causes and impacts. For example, the real impacts of sustainability issues such as climate change are often manifested through the collateral damages brought by a chain of events. By contrast, the Covid-19 pandemic brought sudden changes to society, causing disruptions to individual life-course. However, they share some similarities in terms of the effects on people's everyday life. Both crises can, to some extent, disrupt people's existing everyday life rhythms. Consequently, people have to dynamically adapt and continuously adjust their everyday doings to keep up with the changes brought by the crisis.

The crisis thus constitutes a moment of change where people become more likely to rethink their pre-existing doings. From a Design for Sustainable Everyday Life perspective, it naturally opens up a unique window of opportunity for design to transform some of people's existing unsustainable behavioral patterns. Therefore, in the future, the AT-based framework may be potentially applied to provide an analytical tool for design researchers and practitioners to understand how societal changes may influence the way people carry out their everyday activities, and to identify potential opportunities for design to intervene and transform the targeted activity towards a more sustainable direction.

9

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Appendix 1

The AT-informed ideation prototype

**Motivations,
goals, and
outcomes: 1)**

Can you enable users to attain a series of different goals in a row within the target activity?

Example: When users are looking for accommodations on Airbnb, the website not only helps users to find places to stay, but also provides sightseeing and restaurants in the surrounding place.

Explore Airbnb

Homes

Experiences

Restaurants

**Motivations,
goals, and
outcomes: 2)**

What would happen if your design requires users to put more efforts to attain their original goals, but these efforts can bring users more benefits as a return?

Example: The Stockholm congestion tax is implemented to reduce peak hour traffic congestion. Although drivers need to pay certain amount of money, people can get benefits of less traffic and better transportation environment.

**Motivations,
goals, and
outcomes: 3)**

What if your design restricts users to attain their original goals?

Example: Some online games restrict players from spending too much time in playing without taking a pause.

**Motivations,
goals, and
outcome: 4)**

Can you design some features to turn the activity outcome into a win-win situation?

Example: When people need to send gifts to friends, they can choose to purchase charitable gifts on UNICEF website, and then send the gifts to poor children in the name of your friends. Your friends will receive the gift card.

**Motivations,
goals, and
outcome: 5)**

Are there any unexcepted user goals or needs that may become attainable through your design?

Example: Users use aluminum food as containers for growing plants.

**Socio-cultural
context settings:**
1)

Can you predict the potential technology advancement that would take place in the current society, and then can you incorporate the technology in your design?

Example: More stores started to use automatic self-check-out system. This system brings the customers conveniences and solved check-out time, space, and labor issues.

**Socio-cultural
context settings:**
2)

Can you identify any social and environmental concerns within the user activity system that you want to facilitate or avoid through your design?

Example: This soymilk packaging presents the benefits of plant power, thus telling consumers how the product can benefit both their own health and the environment.

**Socio-cultural
context settings:**
3)

Are there any cultural differences within the user activity? And can you learn from how people carry out the target activity in another culture?

Example: In Eastern culture, chopsticks are commonly used as the tools for eating, while in Western culture, people prefer to use forks and knives.

**Socio-cultural
context settings:**
4)

Can you improve the existing product so that it can fit into a specific environment?

Example: These helmet umbrellas allow users to walk in windy and crowded city area.

**Socio-cultural
context settings:
5)**

What if your design aims at making the target activity easy to collaborate?

Example: When checking-out, POS system used in supermarkets or restaurants enables customers to collaborate with salesclerks in a more efficient way.

**Mediating
tools: 1)**

What if you design a completely new way to help users attain their original goals?

Example: Automatic parking system helps drivers to park their car into a parking spot with enhanced safety and less mental effort.

Mediating tools: 2) | What would happen if your design is flexible and easy to be adapted to different scenarios of the target activity?

Example: Android phone operation system has a “one-handed” mode, which suits the usage scenario in which users’ hands are occupied with something.

Mediating tools: 3) | Can you design some features which support multiple actions which users usually perform within the target activity?

Example: Most of the flight ticket booking systems provide seat selection and food preferences function, so that customers can pre-order relevant services when purchasing the tickets.

**Contradictions
and tensions: 1)**

Are there any user goals that are hard for users to attain as they couldn't adjust the tools to meet their particular needs? What if your design can solve such specific problem?

Example: when using this dish washer, there is no way to designate a specific area in the dish washer to be cleaned.

**Contradictions
and tensions: 2)**

Are there any user needs or goals that can not supported by the tools at hand, so that users have to find some other supportive tools to carry out the target activity?

Example: Unfortunately, if users want to connect a USB or HDMI cable to a New MacBook computer, they have to use an adapter.

Contradictions and tensions: 3) | Can you design some features to mediate users' different ways of carrying out the target activity?

Example: Google Map usually presents several available choices to users, with information of duration, distance, and current traffic condition.

Internalization and externalization: 1) | Can you use metaphors to guide users' target activity in your design?

Example: The car fuel gauge uses a gas station sign to indicate when to refuel.
Similarly, online stores often use a cart sign to indicate where to check-out.

Internalization and externalization: 2) | Can you design some features which can help users to transit their planning to actual performance?

Example: Shopping list is commonly used as a planning tool for shopping activities.

Internalization and externalization: 3) | Can you design some features so that user is willing to learn how to use your design even it requires lots of efforts and time?

Example: It takes a lot of efforts to learn how to ride a bike in the beginning, but once you have gained the skills, biking can make your transportation much more convenient and fun.

History and development: 1)

Can you design some features so that users can immediately recognize how to use the design based on their past experience?

Example: The design of stair climbers and its working mechanisms are inspired by daily life practices.

History and development: 2)

Can you predict the potential changes in the target activity based on how it has been developed in the history?

Example: The design of music devices has gone through significant changes, however some of the features, like ear phone plug-in still remains in nowadays' products.

History and development: 3) | What if your design can support the transformation of users' current activity into a future one?

Example: VR toolkits support the transformation of paper sketching into 3D sketching.

History and development: 4) | Can you adopt some design features from the old tools which were previously used in the user target activities to your current design?

Example: In order to not interrupt users' typing flow, the modern computer keyboard follows the same layout of the old typewriter.

History and development: 5) | What are the potential changes that you aim to achieve/avoid in users' target activity systems? Can your design induce/prevent such changes?

Papers

The papers associated with this thesis have been removed for copyright reasons. For more details about these see:

<http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-172011>

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