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**THE ERGONOMICS OF SHAREABLE THINGS: FROM A SYNTHESIS
OF HISTORICAL SHARING ACTIVITIES TO A SET OF CRITERIA
FOR PHYSICAL SHARING EXPERIENCES**

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Abstract: Sharing is a complex system of resource allocation at the crossroad of developing businesses (e.g., the ‘sharing economy’) and promising societal and environmental impacts. Yet, it is suffering from adoption problems (e.g., vandalism, unwarranted privatization, reluctance) that call for more ergonomics research.

In order to contribute to research on sharing within human factors and ergonomics, the evolution of sharing is synthesized to highlight its roots, developments and societal outcomes. A subset of sharing activities, sharing physical objects, is identified. In order to provide common ground to researchers and practitioners it is defined as ‘a cooperative and distributive behaviour where a user does not have exclusive interactions with a material resource which is, then, enjoyed in common’. A lack of research on shared physical objects within human factors and ergonomics is identified. Finally, seven shareability criteria (Governance, Utility, Balanced appropriation, Cooperativity, Durability, Decontamination, Onboarding/Support) are proposed in order to support practitioners when designing experiences that include sharing physical things.

Keywords: sharing; ergonomic criteria; shareability; sharing economy; shareable things; sharing physical objects

1/ Introduction

Sharing and individual possession are often opposed. Sharing is often idealized as an altruistic behaviour whereas individual possession is equated to selfishness and individualism. Nowadays, sharing has grown back in popularity and most of this growth has been ascribed to the success of services offered by companies belonging to the so-called ‘sharing economy’ even if this trend goes beyond them (e.g., citizen cooperatives) and is not new (e.g., libraries or carpooling). The reasons given for this growth in sharing activities are mostly i) economic efficiency (e.g., profiting from underused assets, reducing or avoiding the burden of ownership) and ii) environmental and societal benefits (e.g., decreasing the need for natural resources, improving social cohesion) even if the positive impact of the ‘sharing economy’ giants on this regard is heavily debated. Typical examples of physical assets used to promote the sharing economy in the general public are cars (in use for 5% of their lifetime) and power drills (in use for 10 minutes of their lifetime). In the wake of these modern sharing practices, the relationships between users and physical objects have started to shift by slowly moving away from the dominance of individual ownership. Yet there is an oversight of physical sharing activities (or ‘physical sharing’) by human factors & ergonomics (hereafter HF&E) research despite the existence of sharing services and products in their historical fields of expertise (e.g., transportation). One branch of HF&E is concerned with devising criteria (also termed heuristics, principles, dimensions, recommendations, guidelines) which could find interesting applications in sharing research.

The paper is organized in four sections. The first part is devoted to the historical evolution of sharing and its impacts on modern societies. The second section tackles definitional issues regarding sharing physical artefacts. The third section reviews past work on sharing within 9 ergonomics journals and proceedings. The fourth part will consider designing shareable things with the support of a set of criteria.

Therefore, this paper contributes to the ergonomics literature on sharing by addressing the following research questions:

- (1) Where does sharing come from and what are its impacts on modern societies?
- (2) How to define physical sharing activities?
- (3) What is the state of sharing in the HF&E literature?
- (4) What are the criteria to consider in order to design shareable things?

2/ Collecting published data on sharing activities

This synthesis covers activities involving sharing through the review of scientific articles published between 1962 and 2020. Due to the polymorphic nature of sharing and its loose meaning (e.g., depending on the authors the term can be akin to gift giving, borrowing, exchanging), it was not possible to proceed to a systematic literature review. Indeed, a request on Web of Science targeting publications whose topic is related to sharing returned 712,942 results on April 13th, 2020. Limiting this request with additional keywords drops results below a usable number (e.g., searching for articles covering the topic of ‘physical sharing’ in Web of Science returns 10 results as of April 13th, 2020).

Thus, for the historical (section 3) and definitional synthesis (section 4), we proceeded to a snowball sampling approach from a core of highly cited and broad-reaching publications (e.g., Belk 2014; Bardhi and Eckhardt 2012) ; 54 publications were identified and used.

Regarding the section focused on sharing within the ergonomics field, publications were identified through the Web of Science database by limiting the search to 9 scientific journals and proceedings which titles explicitly refer to ‘ergonomics’ or ‘human factors’ in the SCImago database within the ‘Human Factors and Ergonomics’ section (i.e. Human Factors, Applied Ergonomics, Ergonomics, International Journal of Industrial Ergonomics, Theoretical Issues in Ergonomics Science, Human Factors and Ergonomics In Manufacturing, Ergonomics in Design, International Journal of Human Factors and Ergonomics, Proceedings of the Human Factors and Ergonomics Society) and whose topic (abstract, title, keywords) is related to sharing (i.e. included at least one of the following keywords : collaborative consumption, access-based consumption, sharing, shared, carpooling). The request returned 271 results on July 3rd, 2020. From this pool, 209 relevant articles were extracted (the other were excluded since they were not related to the topic of the study, e.g., some researchers were writing about ‘sharing their results’ or ‘market share’). The articles were used as the basis for section 5.

Finally, 6 publications on criteria or recommendations for physical sharing experiences were identified from the previously described pools of publications. Indeed, a

more systematic method was not functional here since most of them were not referenced under the ‘criteria’, ‘recommendations’ or ‘heuristics’ keywords.

3/ The history and evolution of sharing

Sharing is probably ‘*as old as humankind*’ (Belk 2014), ‘*the most universal form of human economic behaviour*’ (Price 1975) and ‘*the basic form of economic distribution in hominid societies for several hundred thousand years*’ (ibid.).

When considering sharing with an historical perspective, three periods seem to appear. First, the importance of sharing structures in traditional societies. Second, sharing becoming marginalized or, more rarely, institutionalized in ownership-centred societies. Third, under the impetus of new technological possibilities, environmental crisis and a push against capitalism new sharing activities are emerging, such as those related to the ‘sharing economy’.

3.1/ Sharing in traditional societies

Discussion on sharing within prehistoric human groups is scarce because of a lack of observable evidence. Therefore, anthropologists and ethnographers have turned to sharing within modern hunter gatherer societies as a proxy inspired by the seminal works of Mauss (1923) and Malinowski (1932). Many motivations for sharing in hunter gatherer societies have been suggested: reducing risks (Erdal et al. 1994), limiting the development of inequalities via accumulation of wealth, power etc. (Woodburn 1982), avoiding wasting food and redistributing natural abundance (Bird-David 1990). In her review, Lamberton (2015, 696–99) highlighted the benefits to survival derived from sharing and underlain by four motivations (kin selection-based nepotism, costly signalling, tolerated scrounging, reciprocal altruism). These very diverse motivations are explained by the diversity of needs, e.g., the Hadza people of Tanzania lived in a place where adequate access to food was not a problem, thus the main goal of sharing is to limit inequality (Woodburn 1998) whereas the sharing system of the !Kung people of Namibia and Botswana (living in a more hostile environment where food can become scarce), focuses primarily on building relationships which can in turn foster trust that will help the group overcome trying times (Woodburn 1998). This emphasize the possibility to design different sharing systems to serve different outcomes.

In any case, sharing in hunter gatherer societies (or ‘*prototypical sharing*’, Woodburn [1998]) does not ‘*map neatly on to English sharing*’ (ibid.).

3.2/ Industrial societies and the sharing turn

In industrialized societies, sharing practices became less and less common, e.g., Europeans used to eat using common benches and plates which disappeared with the Industrial Revolution (Belk 2010). The shift from collaborative sharing systems to a capitalist market has been explained by increasingly larger human groups where traditional sharing became impractical which, in turn, led to the necessity to implement pricing systems and contracts for efficiency reasons (Lamberton 2015). A complimentary explanation states that values of

financial security became more important than values of social security (Belk 2007), hence the drop in motivation to share. We can also hypothesize that the institutionalization of some sharing practices (e.g., by public libraries, tax) might have diminished the need for informal sharing.

With the waning of sharing activities, individual ownership became the norm which allowed unprecedented levels of economic development when, at the same time, citizens became less welcoming toward strangers (Belk 2007). Yet, despite this norm of individual ownership, Furby (1978) found that the norm of sharing within US children was stronger than that of children living in kibbutz, even though kibbutz promotes values of collective production. This indicates that despite values in the US being turned toward individual ownership, sharing survives, even if ‘shadowy’ in our societies (Hann 1998). In the 2000s, the rising critic of consumerism (caused by environmental concerns and social inequalities), the shift to experiential values (Inglehart 1981; Pine and Gilmore 1998), the 2008 economic collapse and the boom of communication and technological capabilities (Lamberton 2015; Belk 2014; Benkler 2004) had an effect on those dormant values. Grassmuck (2012) termed this phenomenon the ‘sharing turn’ whose most visible side has been named the ‘sharing economy’ (one of the earliest occurrences of the term seems to be from a 2008 book by Lawrence Lessig, where it is used in contrast to the ‘commercial economy’). Two everyday things are spearheading this ‘sharing economy’: the car (which is idle 95% of the time according to Shoup [2011]) and the power drill (in use 6 to 13 minutes during its whole lifetime according to Botsman and Rogers [2010]). The ‘sharing economy’ is defined as ‘*an IT-facilitated peer-to-peer model for commercial or non-commercial sharing of underutilized goods and service capacity through an intermediary without a transfer of ownership*’ (Schlagwein, Schoder, and Spindeldreher 2019).

The most successful ‘sharing economy’ commercial offers target lodging, car-sharing and carpooling thanks to clear utilitarian benefits (e.g., in the case of the car the total cost of ownership is very high - around 6500€/year - and use is very low - 5% of total life). Community sharing practices have also bloomed (such as libraries of things: ‘The Thingery’ in Canada or ‘Trucothèques’ in France). Yet it is disheartening to check examples listed in research publications on the topic, most have since closed or remained embryonic.

3.3/ Impacts of the sharing economy

In the beginning an overtly positive view of the ‘sharing economy’ was preeminent (e.g., Harris and Gorenflo 2012; Botsman and Rogers 2010). Sharing activities are indeed ‘*presented as collaborative and prosocial, altruistic and environmentally sustainable*’ (Bardhi and Eckhardt 2012) and have been observed to ‘*regenerates people's sense of [...] togetherness among themselves and with the environment*’ (Bird-David 2005). These qualities were automatically attributed to the ‘sharing economy’. At the time, the conception was that ‘*the Internet is leading to a global community of sharing, communicating, and giving, with a free flow of information providing equality of access*’ (Belk 2007).

The environmental benefits, which are among the most promising features attached to the ‘sharing economy’, stem from a reduction in materials and energy used during production and consumption thanks to an increased access to underutilized assets as well as a change in ownership patterns. The areas where the environmental impacts have been deemed the most important are transportation, accommodation, small goods and services (Skjelvik, Erlandsen, and Haavardsholm 2017; Rademaekers et al. 2017). In a simulation by Viegas, Martinez, and Crist (2016) – where all transportation within a city was provided through fleets of shared vehicles – very positive impacts were measured: congestion disappeared, there was a one third decrease in traffic emissions, 95% less space was needed for public parking while retaining only 3% of the original fleet’s size. Skjelvik, Erlandsen, and Haavardsholm (2017) have estimated that a shared car could replace 4-13 cars thus decreasing carbon emissions of 130 to 1,000 kg per household per year. As for a real-world example, the carpooling company Blablacar claims to have increased car occupancy of its users in France to 3.45 passengers per car (from 1.9) and to have saved 894.000 tons of CO₂ in 2018 (Le BIPE, Butt d’Espous, and Wagner 2019).

At the end-user level, the ‘sharing economy’ is supposed to alleviate the burden of ownership (which is both psychological and monetary). Other benefits have been reported such as a monetary benefit (Henten and Windekilde 2015; Andersson, Hjalmarsson, and Avital 2013), the freedom to try other products and reduce the obsolescence risk (Lawson 2011), job creation in the field of support and maintenance (in the simulation by Viegas, Martinez, and Crist [2016] the shared vehicle fleet is running ten times more kilometres than current cars), diminishing the cost of congestion (Alonso-Mora et al. 2017) and a decrease in accidents (Dills and Mulholland 2018).

Bardhi and Eckhardt (2012) were among the first to challenge the romanticized view of the ‘sharing economy’, i.e. they discovered that car-sharing is motivated primarily by self-interest and utilitarianism which leads to opportunistic behaviours. Negative impacts have also been reported such as driving users to marketize some aspect of their private life and authenticity (Bussche and Morales 2019), increasing social inequalities (Bokányi and Hannák 2020), racial discriminations based on the identity of the user (Edelman, Luca, and Svirsky 2017). Worker precarity is another negative impact of the ‘sharing economy’ (Prassl 2019).

At the societal level, the ‘sharing economy’ has also been criticized for promoting the commoditization (Belk 2010) or ‘Uberisation’ of everything (Barns 2020). An example is the possibility to pay an extra fee in exchange for silence from a ride hailing driver (Uber Comfort mode).

More relevant to ergonomics, the mismatch of offerings with the real activities of users led to degradation and thefts that conducted to the termination of sharing services such as Autolib and Gobeebike in France. Contrary to positive environmental impact expectation, overproduction of cheap products aimed at sharing, such as bikes, led to them being put into mass ‘graveyards’ (e.g., Taylor 2018).

The biggest challenge to positive environmental impacts is the ‘rebound effect’ (the fact that cognitive biases such as moral licensing might drive users to consume or drive more to compensate for an action that is perceived as morally ‘good’ such as sharing a car). Martin

and Shaheen (2011) have thus measured an increase of emissions in new car-sharers and Erhardt et al. (2019) showed that companies such as Uber and Lyft cause increased congestion in San Francisco. A survey by Circella et al. (2018) showed that 36% of rides via ride-hailing pooled services in California are replacing lower-emission modes (from mass transit to walking) or creating new trips.

Overall, current researches indicate a contrasted environmental and societal impact of the 'sharing economy' except in carsharing/pooling (despite not considering rebound effects). In the end, the environmental and societal impacts of the 'sharing economy' will probably depend on the regulation and which model it will favour for the future (i.e. market-governed, state-governed or community-governed 'sharing economy' according to Frenken [2017])

3.4/ Sharing is a complex set of diverging activities that needs to be simplified and defined

Sharing has an important place in modern hunter-gatherer tribes as a mode of economic distribution with societal implications and we can hypothesize that this was also the fact for prehistorical hunter-gatherers. Even if sharing activities decreased in importance following the need for more efficient economic practices, they never completely disappeared in our societies and were even brought back to light by formal and informal organizations looking to offer more environmentally or socially-sound economic services. This resurgence was broadly termed the 'sharing economy'. It is heralded by companies whose practices deviate quite a lot from classic sharing practices. The actual benefits of this movement are strongly disputed. Most researches have tackled issues, impacts and motivations within the 'sharing economy'; yet the activities studied are so diverse (e.g., from material to immaterial sharing, from commercial sharing to non-commercial sharing) that it is difficult for HF&E practitioners to find common ground between them; sharing is often a vague and ill-defined concept.

4/ Toward a definition of the activity of sharing physical objects

Researchers from many fields have described, defined and classified sharing very differently depending on which facet they examined and from which scientific paradigm they analysed it. In this section, we will give an overview of these different descriptions and definitions. Indeed, they are the basis on which a usable HF&E definition of sharing physical objects can be built.

4.1/ Current definitions of sharing

Sharing is a noun formed from the verb 'to share' which can be traced back to the Indo-European root *sker- ('cut') which gave the Old English *scearu* recorded in meanings of division or separation (Ayto 1990). This is the first meaning of sharing. The second, more modern, meaning of '*a property owned by a number in common*' has been traced back to the XVIth century in Anglo-Norman and Anglo-Latin documents (Onions 1966). A modern dictionary definition of sharing is '*to have or to use something at the same time as someone*

else' ('Meaning of Share in English' 2020). Table 1 gives an overview of published definitions of sharing.

Table 2: Descriptions and definitions of sharing in previous publications.

Fields	Definitions	References
Sharing within small groups		
Anthropology	<i>'a form of economic distribution with no calculation as to what is obtained back; within a social group; and following the structure of roles by sex, and ability'</i>	Price (1975)
Anthropology	<i>'a principle of generalized or unrestricted access, whereby means of subsistence are enjoyed in common'</i>	Ingold (1987)
Sharing beyond intimate circles		
Psychology	<i>'behavior demanding sacrifice of material possessions for the benefit of others'</i>	Staub and Sherk (1970)
Psychology	<i>'showing objects, giving objects, and playing with them while in contact with another individual'</i>	Rheingold (1973)
Anthropology	<i>'Extended sharing is more integrated by systems outside of the economy proper, such as ideological conceptions of "limited good" and social prestige, than the primary sharing of the intimate economy'</i>	Price (1975)
Psychology	<i>'physical sharing is defined as occurring in situations where two (or more) persons are simultaneously using a material object (e.g. beating a drum) or when an individual allows another to use a temporarily tangible object which the former currently possesses (e.g. rolling a ball back and forth)'</i>	Barton (1977)
Anthropology	<i>'a distributive movement whereby stuff held at the outset by a single person is divided up, so as to be available for use by an aggregate of beneficiaries'</i>	Ingold (1987)
Law	<i>sharing is 'either utterly impersonal or occurs among loosely affiliated individuals who engage in social practices that involve contributions of the capacity of their private goods in patterns that combine to form large-scale and effective systems for provisioning goods, services and resources'</i>	Benkler (2004)
Consumer research	<i>'the act and process of distributing what is ours to others for their use and/or the act and process of receiving or taking something from others for our use'</i>	Belk (2007)
Ethnography / information science	<i>'informal, non-remunerative resource distributing activities where multiple individuals have a relationship to a single device as purchaser, owner, possessor, operator and/or user'</i>	Burrell (2010)

Information science	<i>'nonownership alternative to obtaining product benefits'</i>	Bucher, Fieseler, and Lutz (2016)
Economy and sociology	<i>'consumers granting each other temporary access to their underutilized physical assets ('idle capacity'), possibly for money'</i>	Frenken (2017)
Consumer research	<i>'the act of distributing what is ours to others for their use, and receiving something from others for our use in return. It is based on interpersonal relationships as well as market or monetary exchange, often facilitated through technology'</i>	Reich and Yuan (2019)

These definitions concern human activity, uses, behaviours, products, goods, services, human relations, tools, property, cooperation, temporality: many dimensions of human activities where HF&E are involved. They present sharing as an alternative (Bucher, Fieseler, and Lutz 2016), a distributive process (Belk 2007; Burrell 2010; Reich and Yuan 2019), a contribution or sacrifice (Staub and Sherk 1970; Benkler 2004), a social practice (Benkler 2004; Reich and Yuan 2019), a relationship of multiple parties with a single device (Burrell 2010). They emphasize the facilitating effect of technology (Reich and Yuan 2019), a specific way to use objects through simultaneous use (Rheingold 1973; Barton 1977) or by allowing temporary use to others (Barton 1977; Frenken 2017), the coexistence of different parties (owner, user, technological platform, object, purchaser, operator) and a focus on underutilized assets (Frenken 2017). Two, more controversial, features stand out: the breadth of Belk's definition which can include giving (because of a lack of emphasize on temporality or transfer of ownership) and Burrell's emphasize of the informal and non-remunerative aspects of sharing.

It is now essential to clarify and operationalize 'sharing' further to provide common ground to HF&E researchers and practitioners. Indeed, according to Burrell (2010), a lack of *'explicit guidelines for what to recognize as sharing [limits] the application of insights'*.

4.2 Toward a definition of sharing physical artefacts

John (2013) gives an important distinction between *communicative* (e.g., sharing digital pictures, ideas) and *distributive* sharing (sharing physical objects). In our work, we will only target distributive sharing because i) it suffers from more design-related issues (since we have to design both the physical object and the sharing system) and ii) it is very promising in terms of positive social and environmental impacts (e.g., by reducing overconsumption).

Here, we define the activity of physical sharing as *'a cooperative and distributive behaviour where a user does not have exclusive interactions with a material resource which is, then, enjoyed in common with another or others'*.

A physical sharing activity or experience is a process with a unity and an organization of events spread out in time. This process involves a number of factors, among which, physical (e.g., maintaining the state of what is shared, physical contact, availability or

scarcity, duration – short-termed, long-termed, unspecified –, a space where sharing occurs), psychological (e.g., acquaintance level, trust/reputation level, cognitive abilities, personality traits, personal values regarding fairness, motivations, consumer self-identity, attachments to possession), sociological (e.g., socio-demographic characteristics, societal norms) and economic (e.g., payment, enrichment).

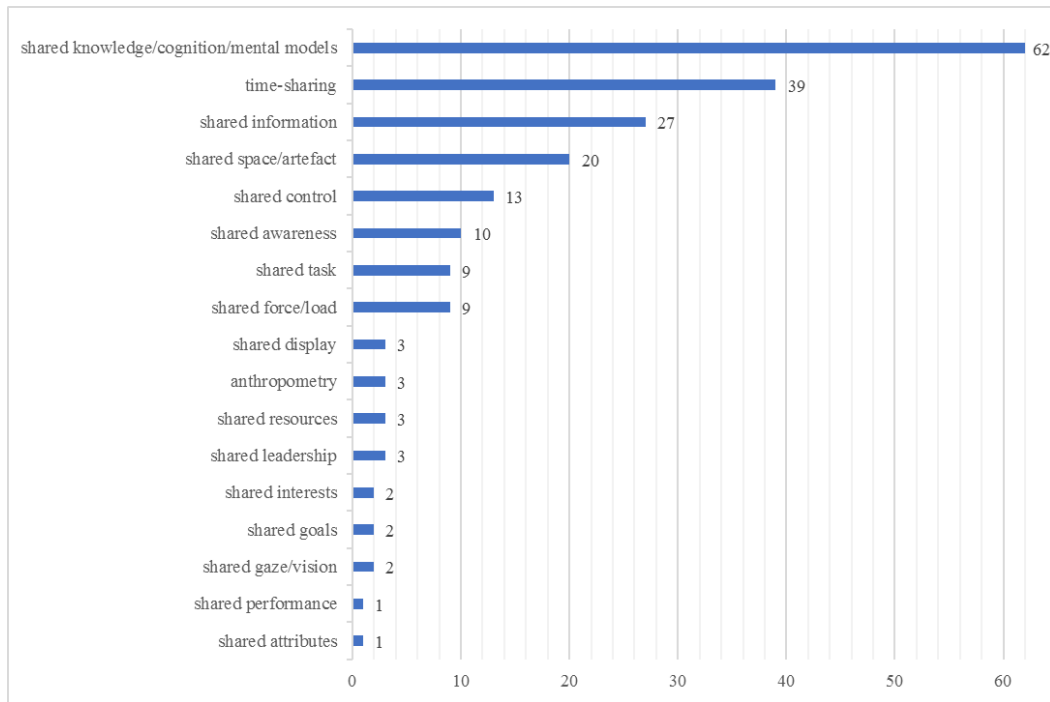
We highlight the fact that:

- (1) access can be simultaneous (e.g., carpooling) or not (e.g., sharing a book),
- (2) physical sharing entails relinquishing at least some of the exclusive rights to a material resource (e.g., rights of access, of control, of modification),
- (3) there is the possibility of financial retribution in exchange for access,
- (4) to make physical sharing viable there should not be significant alteration to the object by the parties (which prevents it to produce utility),
- (5) participating to a sharing experience leads to shared experiences or co-experiences (Battarbee and Koskinen 2005) with one or more people, interacting and building together common representations of what is shared, who is sharing, how it is shared and globally of sharing itself,
- (6) physical sharing can be initiated and accomplished if common criteria are met and satisfied (see section 6.2),
- (7) three topics are of special interest for HF&E researchers and practitioners interested in physical sharing: shared spaces, shared objects and companion interfaces.

5/ Previous HF&E research on sharing and missing pieces

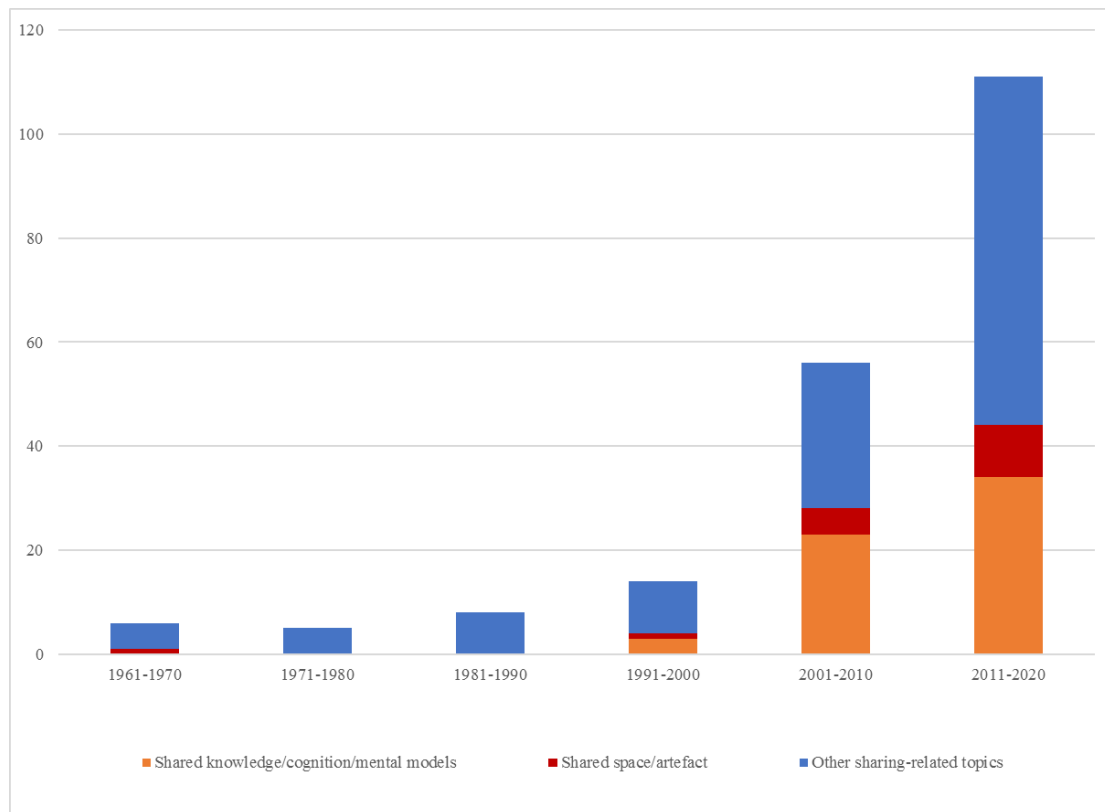
We collected 209 scientific articles published between 1962 and 2020 in order to identify prior research referring to ‘sharing’ within HF&E (see method in section 2). The publications were grouped in 17 categories (see Fig. 1).

Figure 1: Classification of 209 HF&E publications that refer to ‘sharing’ (see section 2 for details on their selection) according to their topic. The 17 topics were identified from the keywords, abstracts or titles of the publications. Each publication was assigned to only one of the topics.



These 17 categories overlap with historical interests of HF&E research such as teamwork (e.g., the work of Berggren, Johansson, and Baroutsi [2017] on shared priorities within teams) or automation (e.g., the work of Navarro [2019] on automated driving). The 209 publications are mostly focused on the ‘division’ aspect of sharing (e.g., sharing attention between tasks) or the ‘communicative’ aspect of sharing (e.g., sharing information with others), not on ‘physical sharing’ nor on ‘shared artefacts’. The most relevant category to the current study is ‘shared space/artefacts’. It includes research on shared work environment (8 papers), shared transportation (5 papers) and shared screens (3 papers). This topic, as well as research on sharing within HF&E in general, has been developing over time (see Fig. 2).

Figure 2: Number of publications over time for the 2 topics relevant to the current study (shared knowledge/cognition/mental models and shared space/artefact). The 15 other topics were aggregated within the “other” category (dark blue). For details on publication selection see section 2.



The publications on shared space/artefacts relate to the governance of sharing, the psychology of sharing and the types of users involved. First, regarding governance, Wohlers and Hertel (2017), citing Wallach (1983), highlight 3 kinds of organizational cultures: bureaucratic (hierarchical and compartmentalized), innovative (result-oriented), supportive (people-oriented), the last two being more adapted to sharing offices since they are more collaborative. Related to governance are rules; those aimed at organizing desk-sharing are better accepted if users are involved in the planning phase of setting up a shared office (Babapour Chafi and Rolfö 2019). Moreover, in order to develop shared mental models, rules should be explicit and clearly communicated (*ibid.*). Regarding users, Wohlers and Hertel (2017) put forward the issues of territoriality (i.e., behavioural expressions of feelings of ownership towards objects through personalization) as well as belonging (through similarities) in sharing activities. However, Morrison and Macky (2017), in their summary of previous research, reported that shared offices could actually be detrimental to psychological well-being (i.e., it is harder to express personality, individuality, uniqueness and to assert a sense of control and agency over the environment). Xu et al. (2014), broaden the perspective to users by tackling shared technologies in general (beyond shared desks). They distinguish ‘passive’ (with no direct control) and ‘active’ users (with direct control). This a helpful distinction when shared use is simultaneous (e.g., carsharing). There are also differences when simultaneous users are friends or strangers, e.g., Lewis et al. (2017) highlight the importance of proxemics and problems of space invasion in shared transportation (airplane). They identify factors affecting size of personal space and the different adaptive behaviours when friends (vs. strangers) invade personal space.

Overall, these works, and the categories listed in Fig. 1 are reminiscent of the trove of research on coordination, cooperation and collaboration within HF&E (for the sake of brevity we will use ‘cooperation’ hereafter as an umbrella term). This will be an essential building block when designing for sharing. Indeed, most researchers overlooked ‘*decades of rigorous research in human cooperation, of which modern collaborative systems represent a novel, but clearly related, manifestation*’ (Lamberton 2015). Cooperation is ‘*acting in ways perceived to maximize joint rewards and minimize joint cost*’ (Johnson and Johnson 2015). In the case of sharing activities, an example of common goal would be to keep the shared object in good condition. From previous HF&E research on cooperation we highlight the importance of shared mental models and the role of communication. Shared mental models provide ‘*a common understanding of which team member is responsible for which task and what the information requirements are*’ (Stout 1995). They allow accurate expectations and explanations of others’ behaviour to form as well as to anticipate and predict each other’s needs (ibid.). Communication act as a key cooperative and team process by making mental models apparent to one another (Keyton, Beck, and Asbury 2010), it allows for both cognitive synchronization (Falzon 1994) and temporo-operative synchronization (ibid.). Benefits of shared cognition range to a better task performance and better team process to trust and cohesion (Cannon-Bowers and Salas 2001).

Another strength of previous HF&E research is anthropometry that can help identify a mismatch between variable users’ characteristics and shared objects (e.g., problems with students’ furniture such as shared desks, see Musa and Ismaila [2014]).

As for missing pieces to support a theory of physical sharing within HF&E, appropriation, time and psychological ownership come to mind. First, the ‘acceptance’ to ‘appropriation’ continuum is well-known by HF&E researchers. Yet in sharing, ‘*the limited access of the object and the market mediation inhibits appropriation practices from taking place*’ (Bardhi and Eckhardt 2012). This fragmented access could be resolved by binding these moments together using technology in order to create ‘*relationship histories*’ (McGraw, Tetlock, and Kristel 2003). The only work identified within HF&E on acceptance of shared objects is by Motamedi et al. (2019). They compared the difference in the acceptance of sharing vs. individual ownership of autonomous vehicles. Surprisingly the acceptance models of the two were found to be similar. Nevertheless, their comparison shows perceived ease of use as a more important variable in the intention of use of shared-use users.

Second, the sharing experience is often fragmented over time; physical sharing leads to a series of interactions with no permanent access to the object. Furthermore, since HF&E has mostly been focused on the spatial dimensions of activity to the detriment of the temporal dimension of activity (Hancock 2018), future research should be especially mindful regarding the issue of time within sharing activities. Third, we suggest including advances from *psychological ownership theory* (Pierce, Kostova, and Dirks 2003). Different from legal ownership, psychological ownership is important to users because of four basic motives regarding: effectance, self-identity, sense of ‘home’ and stimulation (Pierce and Peck 2018).

This feeling of ownership is developed through the exercise of control on the shared object, intimate knowing and investment of the self. Even more relevant to sharing is *collective psychological ownership* (ibid.) that adds the feeling of being part of a collective cognition.

This section revealed the current state of research on sharing within the sampled HF&E journals and proceedings. We identified a gap: no overarching theoretical publications on sharing were identified. Nevertheless, previous work on desk sharing, cooperation and anthropometry do exist and will be useful to design better sharing experiences. In addition, including work on appropriation, time and psychological ownership will be beneficial.

Beyond these theoretical perspectives, designers are also in need of practical tools to *'find new ways of delivering value in ways that set these [sharing] experiences apart from simply buying products or traditional rental services'* in order to ensure *'that they gain enough critical mass to continue to improve and scale'* (Botsman and Rogers 2010). We address this in the next section by proposing a set of 7 ergonomic criteria (or 'shareability criteria').

6/ Towards ergonomic criteria for sharing activities

Up until recently, the dominant approach within designers in general has been to enable sharing technically. The failure to provide positive experiences and to design for the whole range of user behaviours (from vandalism to unauthorized privatization) have resulted in many services shutdown (e.g., Autolib, Gobeebike, Leibahr, BlueIndy, Car2Go, Get&Go MICRA, Mercedes me Car Sharing). Since then a second approach has emerged with more consideration to tailor-made experiences for the sharing activity (e.g., the Backyard project from Samara, a product development team at Airbnb which aims at answering the question: *'what does a home that is designed and built for sharing actually look and feel like?'*).

To support designers interested in designing for physical sharing, HF&E could provide a set of criteria. One classical approach to bridge the research-practice gap in HF&E is indeed to devise such sets of criteria (also called heuristics, dimensions, recommendations, guidelines etc.). Criteria are general evaluative principles that are time-effective to use, do not require extensive planning, are applicable even early on and allow for the discovery of many problems (Quiñones and Rusu 2017). In addition to evaluation, they can be used for designing (Nemery and Brangier 2014). Even if ergonomic criteria are historically tied with usability they have since opened up to new domains (e.g., criteria for shift schedules, Kundi [2003]). In the same way, is it possible to devise criteria for shareability? Indeed, an object has several co-existing qualities that can temper or negate its shareability (Burrell 2010). These qualities are still ill-defined in the literature ; thus, a criteria approach could provide a holistic view of a set of desired qualities needed to reach 'shareability'.

In this section, we will summarize previous research aiming at designing shareable objects and discuss their limits, then we will propose a tentative set of 7 criteria that could be used to support both design and evaluation of shared things.

6.1/ Previous approach regarding shareability

Designing for sharing begs the question of what makes an object ‘shareable’, in other words what are the characteristics of an ideal physical sharing experience? This falls under HF&E’ mission to ‘*match the user’s capabilities with the system requirements*’ (Brewer and Hsiang 2002).

One of the oldest mentions of a similar concept, transferability, is made by Woodburn (1998) when writing about hunting devices within the Hadza people (*‘It is transferability which gives objects value.’*). Bodenhorn (2000) distinguishes shareable and non-shareable artefacts. Benkler (2004) later expanded on the notion, by giving a description of shareable objects as a *‘particular class of physical goods [...] that systematically have excess capacity’*. Overall, the notion appears numerous times (e.g., Rogers et al. 2009; Botsman and Rogers 2010; Burrell 2010; Demailly and Novel 2014; Fremstad 2016) but little effort has been made to make it more concrete.

We argue that criteria for shareability are especially needed i) to support HF&E practice because individual ownership is so prevalent in our cultures, that it is part of designers’ ideology (i.e. *‘designers themselves are shaped by organizational, political, and economic forces’* according to Friedman and Kahn [2003]) and taints designing for sharing attempts, it is our hope that shareability criteria will support HF&E practitioners in disengaging from such values and ii) to lead to more satisfying sharing experiences that can *‘“culturalize” people to share and behave more collaboratively’* (Botsman and Rogers 2010).

One of the earliest tentative to give recommendations to promote sharing activities in children (Barton 1981) emphasized the positive effect of practice, prompts and praise. One of the first actionable tool to support the design of collaborative systems proposed 10 guidelines (Jegou and Manzini 2008). More recently, Fedosov et al. (2018a, 2018b, 2019) proposed a set of 24 design cards in order to help designers during ideation, prototyping, evaluation and reporting of sharing economy platforms or services. The cards are based on Fedosov, Albano, and Langheinrich (2018) list of 5 sharing dimensions (Content, Audience, Motivations, Privacy & Trust, User Experience). Each card wears 4 main information: a goal (e.g., *‘Build a common space’*), a recommendation (e.g., *‘Automate sharing based on user needs and available infrastructure’*), a description and an example.

In Table 2 below is a selection of publications pertaining to these ‘designing for sharing’ approaches. The purpose of the summarized works is to propose guidelines or strategies in order to bridge the research-practice gap (Norman 2010).

These first approaches to support designing for sharing have three limitations. First, they are complex. Fedosov et al. (2019) encompass both informational and physical sharing leading to a set of 24 design cards; Kuikka and Swenne (2017) proposed 14 recommendations. Second, the publications don’t include design strategies that could support built-in differentiated use of the guidelines (e.g., guidelines on how to use the cards to design for platforms aimed at commercial vs. non-commercial system ; aimed at efficiency vs. prosocial impacts) such as Marache-Francisco and Brangier’s (2013) strategies for practical

implementation of gamification criteria. Third, important components of the sharing experience are not covered (such as hygiene).

Table 2: list of publications with a ‘designing for sharing’ approach

Reference	Results	Domains
Jegou and Manzini (2008)	The authors propose a series of guidelines pertaining to increasing services accessibility (e.g., ‘enhance local visibility’) and preserving relational qualities (e.g., ‘keep the relational scale’)	collaborative services
Kuikka and Swenne (2017)	The authors propose 14 guidelines to help with the design of shared cars (e.g., ‘the HMI should withstand high wear’; ‘the HMI should minimize the risk of damage’)	car sharing
Gruen (2017)	The author proposes 4 key elements to design better shared products and services (meaning, uniformity, co-creation and personalisation)	car sharing
Kim et al. (2018)	The authors propose 5 recommendations regarding the location of secondary controls in shared vehicles (e.g., ‘the most frequently used secondary controls on the steering wheel may be optimally located on the right side in a sharing-friendly car’)	car sharing
Fedosov et al. (2019, 2018b)	The authors devise a set of 24 design cards (e.g., ‘approach state of and relationship with physical objects over time’, ‘develop the audience management tools to reach different circles’)	sharing facilitated by digital technology
Ma and Hanrahan (2020)	The authors outline 5 recommendations (e.g., ‘recognize the common rhythms of exchange within a community’)	ridesharing

6.2/ The seven shareability criteria

Using papers from Table 2, our historical and definitional synthesis (section 3 and 4) and the review of research within HF&E (section 5) as a basis, our review converged around a list of 7 criteria (see Table 3 for a summary). We emphasize the fact that it is possible to implement the criteria through both the properties of a shared physical object and of a companion digital interface.

6.2.1/ Governance

This criterion refers to the ability of the sharing system’s governance mechanisms to ensure proper regulation. In the literature they are referred to as coordinating centres (Hamari, Sjöklint, and Ukkonen 2015), monitoring systems (Lamberton 2015), control over other sharing partners’ usage (Lamberton and Rose 2012), accountability (Fedosov et al. 2018b), making owners feel in control (Kuikka and Swenne 2017), rules (Benkler 2004; Rochat 2014;

Babapour Chafi and Rolfö 2019) and moral constraints (Rochat 2014). In her work Ostrom (1990) outlines the practical implementation of such a criterion, e.g., clear boundaries and memberships, congruent rules, collective-choice arena, monitoring, conflict resolution mechanisms, gradual sanctions. Governance can be decentralized since sharing users might be willing to take on extra roles (Hazée et al. 2020). If the criterion is not met, the shared object can be deteriorated or privatized, users' safety can be compromised, the service provider can lose its investment. If the criterion is met, the system can manage the minimum conditions for its viability and ensure common benefits.

6.2.2/ Utility

This criterion refers to the ability of the sharing system to highlight, maximize and ensure the concrete value of sharing for the users, society or environment. The importance of utility has been highlighted by Lamberton (2015). Utility can be degraded by free-riding behaviours leading to a Tragedy of the Commons (Hardin 1968) type situation. Utility falls under two categories. First, is pragmatic utility such as economic utility (Hamari, Sjöklint, and Ukkonen 2015), availability/scarcity, efficiency, convenience (e.g., flexibility from Lamberton and Rose 2012), usefulness (Motamedi et al. 2019), transaction and storage utility (Lamberton and Rose 2012). Second, is a more emotional or idealistic utility such as having company (Benkler 2004), societal benefits, environmental benefits (Benkler 2004; Hamari, Sjöklint, and Ukkonen 2015), anti-industry utility (Lamberton and Rose 2012) and object history value (Li and Lutz 2019). If the criterion is not met, individual possession can remain more attractive. If the criterion is met the user can identify the utility he can get from sharing, the system can become attractive and desirable.

6.2.3/ Balanced appropriation

When designing a sharing system, users will ideally care for the object but not so much that they will be tempted to privatize it. Psychological ownership (PO) is '*the state in which individuals feel as though the target of ownership or a piece of that target is "theirs"*' (Pierce, Kostova, and Dirks 2003), a distinct construct from legal ownership. PO is helpful in that regard since it encourages customers to care for the accessed object (Gruen 2017) but should be limited in order to ensure balanced appropriation. In case of failure to regulate PO, the user could feel the need to privatize the object or will not care for it. Regulation of PO can be attempted by supervising the three variables of PO: exercise of control, intimate knowing and investment of the self into the shared objects (Pierce and Peck 2018). Currently, the short duration of sharing experiences usually deter any appropriation from taking place (e.g., for the case of carsharing see Bardhi and Eckhardt [2012]) primarily because of the short-term duration of rentals, anonymity and market mediation.

6.2.4/ Cooperativity

This criterion refers to the ability of the sharing system to develop, facilitate and maintain

coordinative, cooperative and collaborative interactions between parties. Sharing has been defined by researchers as a social phenomenon (Rochat 2014) encompassing bodily copresence, relatedness and interaction (Widlök 2013) which can be operationalized by enabling communication channels (Kuikka and Swenne 2017; Fedosov et al. 2018b), creating empathy between users and owners, building trust-based relationships, promoting reciprocity/altruism, promoting relatedness to others, giving clear feedback on combined efforts pay off (Lamberton 2015), adding features that enhance common ground (Farnham, Zaner, and Cheng 2001) and understanding and using shared mental models. If the criterion is not met, the parties could have a competitive behaviour and try to maximize personal utility at the detriment of the sharing system.

6.2.5/ Durability

This criterion refers to the physical and emotional features of the object that enables it to withstand intensive and prolonged use. On the physical side high wear of shared products has been highlighted (Viegas, Martinez, and Crist 2016) and durability can be achieved through maintainability (as opposed to ‘disposability’ according to Schulze [2011]), by minimizing the risk of damage (Kuikka and Swenne 2017), by increasing lifetime capacity (*‘total amount of functionality it can deliver over its usable life’*, Benkler [2004]), by reducing the rate of decay (making the rate at which the object decays smaller than the rate at which a user can consume its utility, Benkler [2004]). On the emotional side, durability relates to enhancing user-object interactions and considering attachment over time (Baxter 2017). For example, the neo-retro and simplistic design styles were considered timeless by users in the case of refurbished products (which face the same durability issues than shared goods) by Wallner, Magnier, and Mugge (2020). If the criterion is not met, the object will be quickly deteriorated endangering the financial stability and the safety of the sharing system.

6.2.6/ Decontamination

This criterion refers to the features that can limit the influence of past interactions on future interactions. Negative contagion can lead to avoidance, devaluation and misuse (Baxter 2017). Negative contagion is defined by Bardhi and Eckhardt (2012) as *‘disgust that consumers feel when they are aware that an object has been physically touched by someone else’*. Baxter (2017) reframed the concept as ‘contaminated interactions’ defined as *‘the presence of some real or imagined property that alters how a user perceives and engages with a material’* (ibid.) as such they can be positive, negative or neutral. Proper design should select material with properties limiting contamination or facilitate cleansing of any sign of previous use by the user or by the service provider.

An example of negative contagion is the Covid-19 pandemic which led to the universal adaptation of decontamination practices (e.g., regular disinfection of shared mass transportation, implementation of buffer periods between users of shared cars). If the criterion is not met, the shared object can be discarded, used reluctantly or with little care. Not meeting

the criterion is also a threat to the users' health and safety.

6.2.7/ Onboarding/Support

First, the importance of an easy understanding of shared objects has been emphasized by Kim et al. (2018) regarding secondary controls of shared cars. They equated users of the 'sharing economy' as '*individuals in unfamiliar environment*', a kind of '*temporary disability*' (Kim and Joines 2018). As strategies they advise following market conventions, using anthropometric rules (e.g., right-handed people are the most numerous), simplifying layouts and matching user expectations (Kim et al. 2018). Strongly related, the challenge of onboarding has been studied by many researchers since gaining a critical mass of users is necessary for the sustainability of the sharing system (Dillahunt et al. 2017). Second, guidance through priming or learning is especially important in societies where sharing has been superseded by individual ownership (see section 3.2). The importance of guidance has been highlighted by practice-oriented research by Fedosov et al. (2018b) and Kuikka and Swenne (2017) but also by basic research such as Barton (1981). In the latter, behavioural techniques were tested in order to find the most suitable way to develop sharing in children; the study shows a better effect of behavioural techniques when peers are the inducer (vs. non-peers, i.e., adults) and the most efficient techniques were practicing, prompting and praising. The end goal of the criterion is to prime, foster, encourage develop and nurture sharing-friendly behaviours in users. If the criterion is not met, behaviours in line with individual ownership can prevail since it is currently the default mode of relation to objects in societies.

Table 3: proposed set of criteria for the design and the evaluation of physical sharing experiences

Criteria	Definition	Selection of source criteria and references
Governance	The criterion refers to the ability of the sharing system to organize and ensure a fair regulation protecting the user, object and provider.	'Establish procedures for accountability' (Fedosov et al. 2018b); 'The UX should make owners feel in control' (Kuikka and Swenne 2017); 'Fluidify management' (Jegou and Manzini 2008)
Utility	The criterion refers to the ability of the sharing system to highlight, maximize and ensure the concrete value of sharing for the users, society or environment.	'Emphasize and clearly describe the value, practicality and convenience of the service' (Fedosov et al. 2018b); 'Timeliness' (Light and Miskelly 2014); 'Support regular/habitual patterns' (Ma and Hanrahan 2020)
Balanced appropriation	The criterion refers to the ability of the sharing system to achieve a balance between unwarranted privatization and disinterest towards the shared object.	'Allow users to enhance physical objects with digital content' (Fedosov et al. 2018b); 'Personalization' (Gruen 2017)

Cooperativity	The criterion refers to the ability of the sharing system to develop and maintain coordinative, cooperative or collaborative behaviours.	‘The UX should enable communication channels’ (Kuikka and Swenne 2017); ‘The UX should create empathy between parties’ (Kuikka and Swenne 2017); ‘Create and maintain social relationships’ (Fedosov et al. 2018b); ‘Keep the relational scale’ (Jegou and Manzini 2008)
Durability	The criterion refers to the features of the object that enables it to withstand intensive and prolonged use.	‘The HMI should withstand high wear’ (Kuikka and Swenne 2017); ‘the HMI should minimize the risk of damage’ (ibid.)
Decontamination	The criterion refers to the features that can limit the negative physical or psychological impact of previous interactions on future interactions.	The criterion doesn’t appear in previous design guides but has been highlighted as important in sharing in several studies (Bardhi and Eckhardt 2012; Baxter 2017; Hazée et al. 2019)
Onboarding/ Support	This criterion refers to the features of the sharing system that i) enable a quick and easy understanding of its functions by a diverse user base early on and ii) nurture sharing-friendly behaviours in users on the medium and long term.	‘Accessibility and inclusivity’ (Light and Miskelly 2014); ‘The UX should appeal to a wide range of people’ (Kuikka and Swenne 2017); ‘The UX should facilitate first time users’ (ibid.); ‘The UX should encourage owners to share’ (ibid.); ‘Emphasize reciprocity to drive sharing’ (Fedosov et al. 2018b); ‘Redirect feelings of indebtedness towards positive and participatory outcomes’ (ibid.)

7/ Discussion and limitations

The COVID-19 crisis begs the question of the future of sharing. On one hand we see that crises generally increase cooperative and sharing practices (McMaster and Baber 2012; Dannenberg and Barrett 2018) or mitigate disaster harm (Ozanne 2019). On the other hand, the 2020 pandemic impacted very strongly sharing services by fear of contamination (e.g., car sharing operators implemented hours-long ‘cooldown’ periods between rides, health organizations such as the CDC suggested to limit sharing activities) and, generally, less demand. Increased HFE support in designing ‘shareable things’ could offset the effect of the pandemic by making sharing experiences more in line with users’ needs and expectations (e.g., in terms of decontamination or governance).

As for limitations of this work, the historical review could have included more research on the ‘commons’, that entails a special blend of sharing activities, and given more details about traditional sharing practices (e.g., list what is shared/not shared) in order to contrast them with modern sharing practices. As for the review of the HF&E literature it

could have included more journals as well as keywords relating to ‘collaboration’, ‘cooperation’ or ‘multi-user systems’ to broaden the scope of the review. The implementation of sharing ideals (such as altruistic values) in commercial sharing systems might not be successful (e.g., Bardhi and Eckhardt’s [2012] study on carsharing). As such, our criteria are still lacking nuance and could give designers the impression that implementing ‘cooperative’ or ‘governance’ features will make sharing ‘work’. This is not entirely the case and differentiated use of the criteria will need to be detailed, e.g., for commercial systems the “Cooperativity” criterion will probably see implementation that are closer to ‘coordination’ whereas for community-driven systems ‘collaboration’ is possible to achieve. Finally, additional research is needed to validate and improve the set of shareability criteria (e.g., the validation technique by Nemery, Brangier, and Kopp [2011]).

8/ Conclusion

The purpose of this review was to give an overview of the history of sharing and its impacts, map previous HF&E research on sharing, define the activity of sharing physical objects, and propose a set of shareability criteria.

While sharing was apparently prevalent in hunter-gatherer societies, it became less prevalent when other forms of more efficient economic organization (such as individual possession) developed. Under the driving forces of social inequalities, economic and environmental crisis and the Internet, sharing made a comeback with the so-called ‘sharing economy’ in the early 2010’s. Its impact has been disputed between small non-profit cooperatives with little impact beyond their communities and Internet giants that can disrupt entire industries (e.g., Airbnb and hotels) with more focus on economic growth than societal and environmental impacts. Nevertheless, the positive impacts of shared transportation are well established.

Previous HF&E research on sharing has tackled sharing within the limits of historical HF&E preoccupations (e.g., work, automation) with topics ranging from shared mental models and anthropometry to control and time. Little work has targeted sharing physical things, or sharing physical things was just a backdrop and not a significant focus. To the best of our knowledge, sharing was rarely addressed directly and not theorized upon within HF&E. This is a common issue even beyond HF&E, since most of the literature is indeed focused on why people share (Kovacheva and Lamberton 2018) or on critic/assessment of the impacts of sharing, less research is dedicated to how sharing experiences can be improved. To reduce the scope of sharing and provide common ground, we propose to define the activity of sharing physical things (also called distributive sharing or physical sharing) as ‘*a cooperative and distributive behaviour where a user does not have exclusive interactions with a material resource which is, then, enjoyed in common with another or others*’. Finally, we propose a set of 7 shareability criteria (Governance, Utility, Balanced appropriation, Cooperativity, Durability, Decontamination, Onboarding/Support).

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