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Assessing the impact of design strategies on clothing lifetimes, usage and volumes: The case of product personalisation

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ABSTRACT

Product lifetimes and obsolescence have been central points of discussion in the fashion field. In this context, design researchers and practitioners have proposed a variety of strategies to enable slower cycles of product replacement, leading to smaller volumes of clothing production and consumption. A previous review of these strategies, however, revealed that there is no empirical evidence of their efficacy in terms of lifetime extension or environmental sustainability. Therefore, this research takes a first step in covering this knowledge gap. It proposes methods to assess the impact of such approaches and applies them to the specific case of "product personalisation", the strategy most frequently mentioned in literature.

Clothing has characteristics that are not present in other product categories common in lifetimes studies. These characteristics enable comparative analysis of products, diachronic studies over relatively short periods of time, and estimations of the environmental benefits of lifetime extension. Taking advantage of such particularities, the article evaluates the environmental gains of personalised products by comparing their performance with ready-made garments in terms of age, usage, influence on new product demand, and waste. The research is based on a series of wardrobe studies and company interviews.

The outcomes of these studies question the environmental benefits of product personalisation. When compared with ready-made garments, personalised garments were not kept for longer time, nor were they used more frequently. Moreover, no evidence of their contribution to reductions in new product demand and waste was found.

These findings confirm the need for more empirical research to understand the effect of this and other design strategies aimed at delaying clothing obsolescence and reducing production volumes and waste. Such enquiries can provide relevant feedback to practitioners developing creative solutions. In that way, empirical research and creative practice can benefit from each other's input and build iterative cycles that ensure effective actions. The methods advanced in this study aim at supporting this valuable line of research, leading to a more environmentally-sound apparel sector.

1. Introduction

The popularity of fast fashion, the globalization of apparel production, and a relative fall in retail prices have put clothing at the centre of environmental discussions across Europe. Clothing lifetimes and obsolescence have received particular attention, with popular media, public policy and academic actors acknowledging the responsibility of both producers and consumers on shorter cycles of product replacement and rising quantities of clothing production and consumption (see e.g. Allwood et al., 2006; Cooper et al., 2013; Maldini et al., 2017; Roos et al., 2015; Tojo et al., 2012). The growing number of articles presented at the Product Lifetimes and the Environment (PLATE) conference focusing on the apparel sector (Bakker and Mugge, 2017; Cooper et al., 2015) is just one

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example of increasing interest on the environmental impact of the sector due to rising volumes of clothing production and waste (see e.g. WRAP, 2017 for recent developments in the UK).

Fashion design researchers and practitioners have proposed a variety of strategies to tackle these issues. In a review of sustainable fashion strategies aimed at reducing the volume and speed of clothing production and consumption, Maldini and Balkenende (2017) found 27 relevant publications proposing six distinctive but overlapping approaches; namely production on demand, service-based fashion systems, multifunctional, transformable and modular garments, design for slowness and longevity, design for repairing, and user involvement in design and/or manufacture. However, the review revealed that there was no empirical evidence of the efficacy of these strategies in terms of lifetime extension, frequency of use, or environmental sustainability. This knowledge gap had been previously acknowledged by other authors. For example, in an article proposing "design strategies that can lead development to a more sustainable path" in clothing production and consumption, Niinimäki and Hassi (2011, op. 1881) point out that their actual effect has not been verified; "all these strategies do not necessarily decrease the environmental impact of the production if they, for example, do not lower the amount of production in total". Therefore, the goal of this study is to take a first step in covering this gap.

Previous studies of product obsolescence have acknowledged that both producers and users have direct influence on products' lifetimes (e.g. Cooper, 2004), leading to methodological challenges in measuring cycles of product replacement. Some studies have relied on users' estimations (e.g. Langley et al., 2013). However, others have criticized this approach for its inaccuracy (e.g. Laitala and Klepp, 2015; Oguchi and Daigo, 2017). The methodological difficulty of measuring actual product lifetimes may partly explain why the effect of the above-mentioned design strategies remains unknown. However, this study highlights the opportunity of conducting comparative research to uncover the influence of these strategies on clothing lifetimes, usage, and the associated environmental effects.

When compared with other product categories common in lifetimes studies (such as cars or household appliances), clothing has certain particularities that enable testing the impact of design strategies. Firstly, the environmental advantages of lifetime extension in clothing are mostly in delaying the production of new items, since production is by far the most impactful phase. Life Cycle Assessments covering a variety of garment types in the UK and Sweden point out that end-of-life is much less impactful, both for estimations assuming material reuse and recycling (WRAP, 2012) and incineration (Roos et al., 2015). Moreover, unlike the other product categories where earlier replacement could be occasionally beneficial in terms of energy efficiency (Bakker et al., 2014), the impact of clothing during the use phase (mostly in washing, drying and ironing, see Klepp et al., 2017) is fairly similar for old and new products, rendering (dis)advantages of longer lifetimes in this phase somewhat irrelevant. In short, extending the lifetime of garments results in significant environmental savings mostly if production of new items is avoided (WRAP, 2017). Therefore, the environmental advantages of delaying clothing obsolescence can be assessed by studying their relation to the number and speed of new items produced and consumed.

A second particularity of clothes is that we all own them in large numbers, enabling comparisons of the performance of various items by one particular user, and between similar users. Such comparative studies are more difficult, or even impossible, in products owned as a single unit (e.g. ovens or stoves) or by specific users (e.g. electric bicycles).

We note that, because we wear several garments every day, promoting frequency of use is as important as delaying obsolescence for reducing environmental impacts (Laitala and Klepp, 2015). A clear indicator of obsolescence is when garments leave the active section of the wardrobe to be stored with no intention of use. Previous wardrobe studies indicate that in the UK, the Netherlands, and Germany, approximately 30% of the wardrobe has not been worn in the last year (Maldini et al., 2017; WRAP, 2012). A Norwegian wardrobe study found that 20% of the garments disposed have barely been worn (Laitala and Klepp, 2015). In those cases, the environmental benefits of lifetime extension are dubious. In sum, when assessing the environmental impact of clothing, lifetimes and usage should be considered together. Moreover, promoting usage and longer lifetimes can have significant environmental advantages as long as they contribute to a reduction in the production of new clothes.

On the basis of these premises, this study proposes research methods to evaluate the impact of circular or sustainable fashion design strategies; in particular those focusing on clothing volumes, obsolescence, and replacement speed. These methods are applied to the case of "user involvement in design and/or manufacture", the strategy that is most commonly mentioned in sustainable fashion publications (Maldini and Balkenende, 2017) and that we summarize here as "product personalisation". The case study enables not only the assessment of this specific strategy, it also advances methods to understand the effect of other approaches in future studies.

2. Case study

Personalised products in the apparel sector are the result of activities such as bespoke tailoring, made-to-measure, mass customization, home or self-production and do-it-yourself. Despite the variety of practices involved, they all meet two central conditions that are not present in mass-produced ready-mades: individual user involvement in design, and production on demand. According to the literature (Armstrong et al., 2015; Ballie, 2013; Black, 2008; Black et al., 2009; Busch, 2013, 2008; Fletcher, 2008; Fletcher and Grose, 2012; Hirscher, 2013; Hirscher and Fuad-Luke, 2013; Niinimäki, 2009; Niinimäki and Hassi, 2011), the involvement of the wearer in the design process can add functional and emotional value to products, which in turn promote longer lifetimes and more intensive usage, leading to decreasing product demand. For example, Hirscher et al. (2018) point out that self-production is "perceived to provide longer-lasting emotional experiences with less material consumption", and Fletcher (2008, p. 194) discusses how user participation enriches the meaning of products, which are hopefully "worn and found pleasurable for longer" leading to a reduction in "what we buy and discard".

Additionally, the production of these garments based on individual demand is expected to ensure that only what is wanted is produced, avoiding obsolete inventory. In mass manufacture, production batches are big and it is difficult to predict how much will actually be sold. Production on demand starts by individual product orders presumably leading to no garments unsold. Black (2008, p. 223), for instance, has acknowledged that manufacturing garments in this way using emerging technologies can "reduce the amount of clothing made overall to what is actually needed".

This research takes such arguments as hypotheses and tests them in a series of wardrobe studies and company interviews. The wardrobe studies investigate clothing demand and its relation to two categories of garments: ready-mades and personalised. Garments in the wardrobe are compared in terms of frequency of use, age, and their relationship with consumption patterns. In addition, the company interviews discuss unsold volumes. Ready-made garments are those that are manufactured by the industry,

offered on the market, and then selected by the user. Personalised garments are those made on the basis of individual demand, through direct involvement of the user in the design process and regardless of the degree of involvement; these include self-made and custom-made garments. In custom-made garments, users do not participate in the manufacture phase; production is made by others including family members, friends, craftsmen or companies. Items that are adjusted or customized after purchase are considered equal to other ready-mades for the purpose of the study.

The first hypothesis (H1) is that ready-made garments are related to higher clothing demand, while personalised garments are related to lower clothing demand. H1 is tested in four different comparative studies regarding number of garments owned, number of garments acquired during six months, usage of garments, and age of garments. The tests are based on 40 wardrobes, half of which include at least 10 personalised garments (group P) and half of which only include ready-made garments (group R). The presumed comparative advantages of personalisation imply lower number of garments owned by subjects in group P (H1.1) and/or lower number of garments acquired by subjects in group P over a period of time (H1.2).

Moreover, two garment types were selected in every wardrobe within group P for further investigation (e.g. trousers and T-shirts). All garments in these categories were compared, observing if personalised items are used more often than ready-made garments (H1.3) and kept for a longer time (H1.4).

The second hypothesis (H2) is that companies offering personalised garments on-demand have fewer unsold products than companies offering ready-made garments. This hypothesis is explored by asking 20 companies offering custom-made clothing about their unsold volumes and comparing the findings with an existing study of the ready-made sector.

The studies introduced above aim at contributing to the field of design for reduced production volumes at two levels. At a concrete level, they assess the environmental impact of clothing personalisation by looking for empirical evidence of common expectations in sustainable fashion. Moreover, at a methodological level, they propose means to evaluate the impact of other present or future strategies with similar goals. The overall objective is to help close knowledge gaps in the field, in order to move forward and ensure impactful solutions.

3. Methods

Given that H1 refers to clothing demand and H2 to clothing production, the methods employed to test them are different. The sub-sections below provide more details about these studies.

3.1. Clothing demand (wardrobe studies)

3.1.1. Subjects

The wardrobe studies included 40 subjects living in different provinces of the Netherlands. The group is varied in terms of age (22–71 years old), gender (24 females and 16 males, equally distributed in groups P and R), household composition (living alone, in couples, with children, or in shared households) and income (from <20,000 € to > 80,000 € annual gross income per household). Most of respondents live in cities, but ten subjects live in villages and towns; these are equally distributed in groups P and R.

Table 1 summarizes the respondents' inclusion criteria and the recruitment process. Wardrobes including 10 or more personalised garments are uncommon in the Netherlands; therefore, recruitment for "personalised wardrobes" (respondent group P) starts from our own network and invitations are distributed via e-mail, social media and word of mouth. Every respondent in this group is asked to provide the contact details of another person with a similar profile who does not own personalised garments, to be invited for the control group (group R: ready-made wardrobes). These may be for example friends, neighbours, colleagues or family members. The demographic details considered for matching are gender, age, household composition, income per household member, house size and locality (village/town/city). If respondent P is unable to indicate a respondent for group R or the latter is not willing to participate, the researcher recruits a matching respondent based on the variables above.

The research design deliberately favours depth rather than breadth. It includes a relatively small number of respondents and employs a variety of methods (quantitative and qualitative) in order to contextualise the results.

3.1.2. Protocol

The wardrobe study includes qualitative and quantitative aspects such as the number and age of garments owned by respondents. Moreover, patterns of clothing purchase, use, care, and disposal are analysed. The questionnaire starts by the demographic details of subjects and the importance given to clothes, fashion trends, and their appearance; these are answered separately based on a five point Likert-like scale. Next, each wardrobe is analysed in detail during a personal meeting with its owner lasting approximately two hours for personalised wardrobes and 40 min for ready-made wardrobes. Starting at the date of this meeting, respondents keep track of their wardrobe turnover during six months, handing

Table 2
Response sheet template for the wardrobe count.

Garment type	Number of items	Of which personalised items
Coats/jackets		
Shoes/boots		
Bags		
Scarves/shawls		
Hats/gloves		
Suits		
Trousers		
Shorts		
Sweaters/cardigans		
T-shirts/tank tops		
Blouses/shirts		
Dresses		
Skirts		
Other:		
Total		

Table 1
Respondents for H1.

	Definition	Description and recruitment
Respondent group P	Subjects whose wardrobes include at least ten personalised garments (personalised wardrobes)	20 subjects recruited from our network. 10 respondents are consumers of custom-made clothing and 10 make clothes for their own use.
Respondent group R	Subjects whose wardrobes do not include personalised garments (ready-made wardrobes)	Control group. 20 subjects with similar demographic characteristics to respondent group A.

the information to the researcher after completion. Responses are processed anonymously with no compensation offered to the subjects.

The relationship between personalisation and reduced demand -based on ownership of fewer garments with added value- is studied by comparing the size of personalised wardrobes and ready-made wardrobes (H1.1). The number of garments owned by respondent groups P and R are compared by counting them in the presence of the researcher according to previously defined garment types (see Table 2). The concept of "wardrobe" is considered broadly, including all garments owned by respondents regardless of the place where they are stored. Socks and underwear are excluded for privacy and practical reasons, but accessories such as shoes, hats, scarves and gloves are included. The counting process starts at the hall of the home continuing at the closet (Fig. 1), the laundry area, and extra storage spaces such as the attic or spaces underneath the bed (Fig. 2). When subjects own clothes that are kept elsewhere (e.g. at work), they are requested to count and report them later. Group P is asked to specify the personalised pieces in each garment type. In order to complement this data with qualitative information, they discuss some of their personalised pieces, their experience practicing clothing personalisation (including the time they have been involved in it), and the effects in their wardrobe.

The process described above is complemented by a study of wardrobe turnover over six months in groups P and R (H1.2). After the wardrobe count, respondents are asked to keep track of the garments acquired (wardrobe inflow) and discarded (wardrobe outflow). This includes items bought, made, exchanged, given away, etc. The template comprises fields such as date, garment type, kind of acquisition or disposal and reason for acquisition or disposal.

Fig. 1. Shared wardrobe of respondents 14A (left) and 15A (right), both users of custom-made clothing.

Fig. 2. Storage space in respondent 11B's bedroom, including bags with clothes, which were integrated in the wardrobe study.

Within the P group, the self-reported usage in personalised and ready-made garments is compared (H1.3). The process includes:

a) inviting respondents to randomly select two garment types from their wardrobe which include both personalised and ready-made items (see garment types selected in Table 3);
b) organizing all the items in this garment type in 5 groups based on usage (used always, frequently, average, rarely and never) (Fig. 3);
c) documenting the number of personalised and ready-made items in each group;
d) assigning a value to each group based on usage (never = 1-always = 5);
e) dividing the total value by the number of items in the garment type (keeping personalised and ready-mades separately);
f) comparing the resulting score for personalised and ready-mades items in the same garment type.

The relationship between personalisation and longevity is studied by comparing self-reported age in personalised and ready-made garments owned by each individual in respondent group P (H1.4). The process is identical to that of usage and includes the same garment types. However, items are organized in 5 groups based on age (old, relatively old, average, relatively new and new).

In the previous section, we discussed the challenge of collecting reliable data on clothing age and usage based on users' estimations. In fact, during a pilot phase of this study respondents were asked to provide figures (for instance, age of garments in years or months and usage in number of times worn per week, month or year). Answering such questions proved to be extremely difficult for all respondents, leading to unreliable results. Therefore, the protocol was adjusted to a comparative format in the final study. We highlight the value of such an approach to collect useful data about clothing; however, this may not be applicable for other product categories.

3.2. Clothing unsold (company interviews)

3.2.1. Subjects

In order to study volumes of clothing unsold, 20 companies offering custom-made clothing (group C) were asked about the percentage of product remakes in their organisation. The recruitment process starts by contacting well-known companies in the sector and continues via snowball sampling. Only companies with their headquarters in Europe are included. The interviewees are

Table 3
Garment types used to study usage and longevity.

Respondent number	Personalisation	Garment type 1	Number of items in type 1		Garment type 2	Number of items in type 2	
			Personalised	Ready-made		Personalised	Ready-made
1A	Self-made	Trousers	3	14	Sweaters/cardigans	3	43
2A	Self-made	Jumpsuits	4	4	Dresses	4	26
3A	Custom-made	Suits	1	1	Blouses/shirts	10	9
4A	Self-made	Skirts	6	7	Scarves/shawls	5	3
5A	Self-made	Coats/jackets	2	9	Sweaters/cardigans	2	9
6A	Self-made	Skirts	3	4	Sweaters/cardigans	4	5
7A	Self-made	Vests	13	12	Sweaters/cardigans	9	8
8A	Self-made	Blouses/shirts	5	1	Sweaters/cardigans	12	7
9A	Custom-made	Dresses	8	29	Sweaters/cardigans	2	20
10A	Custom-made	Trousers	4	5	T-shirts/tank tops	5	6
11A	Self-made	Skirts	3	6	Sweaters/cardigans	12	12
12A	Custom-made	Trousers	4	13	None		
13A	Custom-made	Coats/jackets	5	10	Trousers	5	20
14A	Custom-made	Shorts	7	3	Jumpsuits	2	6
15A	Custom-made	Shorts	6	16	Suits	3	3
16A	Custom-made	Coats/jackets	2	10	Trousers	12	8
17A	Custom-made	Sweaters/cardigans	5	27	Shorts	2	10
18A	Self-made	T-shirts/tank tops	24	25	Blouses/shirts	6	1
19A	Custom-made	Coats/jackets	3	10	Bags	2	9
20A	Custom-made	No response			No response		

Fig. 3. Sweaters and cardigans owned by respondent 11A (a knitter) organized according to use frequency (from used “never” to “always”).

CEOs or informed members of these companies' staff.

The organizations interviewed have their headquarters in the Netherlands, Belgium, Germany, Switzerland, Italy, Denmark and Sweden. Production facilities are located in Europe (Romania, Portugal, Poland, Italy, England, Netherlands and Lithuania) and overseas (Tunisia, Sri Lanka, Morocco, Vietnam and China). They offer suits, shirts, polo's, T-shirts, trousers, underwear, pyjamas, evening dresses and shoes that are produced on-demand on the basis of individual clients' preferences and bodies. The activity of these companies is varied, ranging from travelling tailors to mass-customization platforms. Some of the companies offer both custom-made and ready-made garments. In that case, they are asked solely about their personalised products. The number of personalised garments offered annually by these companies ranges from 150 to 900,415 and their number of employees ranges from 1 to 546.

3.2.2. Protocol

Interviews are made face-to-face for Dutch companies and virtually for companies established in other European countries. Besides the volume of product remakes, companies are questioned about the volume of their offer, the kind of products offered and the process of orders, manufacture and delivery within the organisation. Interviews take 30 min to one hour. When respondents cannot give an answer to the main inquiries during the interview, these are further discussed via e-mail in order to gather the relevant information. When answers about product remakes are given in a range, the midpoint is considered (e.g. 3.5% for an answer “between 3 and 4%”). If relevant, respondents are asked about the unsold volumes of other actors involved in their supply chain.

The outcomes of the enquiry above are compared with an existing study of unsold volumes in the ready-made apparel industry (H2). Here the “control group” has already been investigated. Wijnia (2016) has identified volumes of unsold products during production, wholesale and retail. The results of this previous study are used as control (see Table 4).

3.3. Statistics

Differences between group P and group R, and between ready-made and personalised garments in group P, were evaluated using independent t-tests after certification that the data was normally distributed. When the data was not normally distributed, the Mann-Whitney test was used. Significance was assumed when $p < 0.05$. The statistical analysis was performed using Statistica version 13.1 (Dell).

4. Results

4.1. Clothing demand

4.1.1. Wardrobe size

In Fig. 4, the sizes of personalised wardrobes (group P) and ready-made wardrobes (group R) are compared. The average number of garments owned in each group is calculated and shown in the figure (see reference AVE) and the significance is tested using a Mann-Whitney test.

If personalised garments led to ownership of fewer garments due to higher product satisfaction (H1.1, as expected from the literature), personalised wardrobes would be smaller than ready-made wardrobes. Black and white points would be placed in the lower part of the figure and grey points would be placed in the higher part of the figure. However, points are widely distributed and there is no significant difference in wardrobe size between

Table 4
Respondents for H2.

	Definition	Description and recruitment
Respondent group C	Companies offering personalised garments made on-demand	20 CEOs or informed members of staff, recruited via social networks and indication of other interviewees.
Previous study	Control group (Wijnia, 2016)	Manufacturers, wholesalers and retailers of ready-mades

groups ($p = 0.15$). Therefore, the results of this study do not support the hypothesis of lower clothing demand through personalisation.

The horizontal lines in Fig. 4 show that medium wardrobes in both groups include 150–300 items. In contrast with expectations, big wardrobes (containing >300 items) are more common in group P (8) than in group R (2). Moreover, small wardrobes (containing <150 items) are less common in group P (1) than in group R (8).

Complementary to the quantitative study, subjects in group P discussed changes in their wardrobe after they started personalising. When asked about changes in style, opinions differed about the wardrobe style becoming more specific or more varied after personalisation. When asked about changes in wardrobe size, ten respondents could not give an answer, three respondents did not notice a change in wardrobe size, seven respondents owning self-made and custom-made garments reported an increase in wardrobe volumes, no respondents reported a reduction in the number of garments owned.

Group P scored significantly higher in importance given to clothes (4.5/5 versus 3.6/5, $p = 0.01$, *t*-test), but there were not significant differences between groups in terms of importance given to fashion trends or personal appearance. The implications of these results will be further discussed.

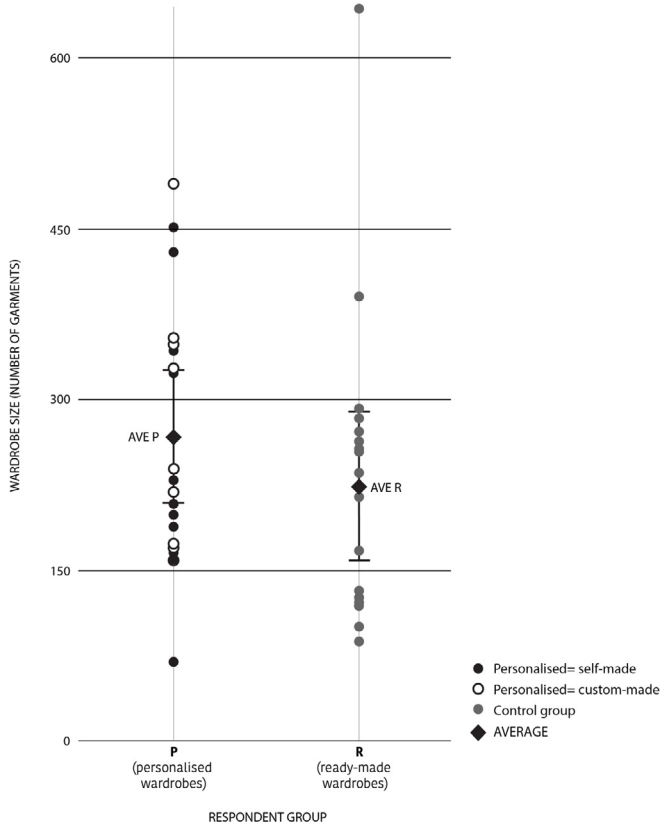

Fig. 4. Wardrobe size (in number of garments) of respondents in groups P and R. The vertical bars indicate the standard deviation.

4.1.2. Wardrobe inflow

From the 40 respondents participating in the study, 25 sent back the follow-up forms indicating wardrobe inflow (garments bought, made and received) and outflow (garments discarded or given away) during 6 months. These were 12 respondents from group P and 13 respondents from group R. There are no significant differences between subgroups in terms of age, income per household member, house size and locality (village/town/city). However, the subgroup P included 11 women and 1 man, while subgroup R included 9 women and 4 men. All respondents rated the accuracy of their responses in 8–10/10.

In Fig. 5, the inflow in personalised wardrobes and in ready-made wardrobes over a 6-month period are compared. The average number of garments is calculated and shown in the figure (see reference AVE) and the significance is tested using a T-test.

If personalised garments led to lower clothing consumption over time (H1.2, as expected from the literature), inflow in personalised wardrobes would be smaller than in ready-made wardrobes. Black and white points would be placed in the lower part of the figure and grey points would be placed in the higher part of the figure. The variation in wardrobe inflow is considerable (standard deviation is 7.3 for P and 4.6 for R) and there is no significant difference in wardrobe inflow between groups ($p = 0.55$). Therefore, the results of this study do not support the hypothesis of lower clothing demand through personalisation.

4.1.3. Clothing usage

Fig. 6 shows the outcomes of the comparative study for clothing usage within group P. Each point in the figure indicates a specific respondent and garment type (respondent number, garment type number). The usage score of ready-mades (see section 3.1.2) is

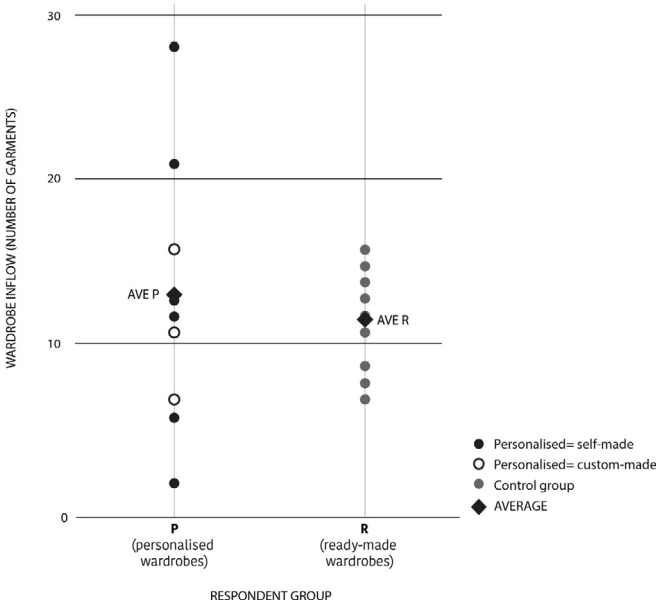

Fig. 5. Wardrobe inflow (in number of garments) of respondents in groups P and R over a six-month period.

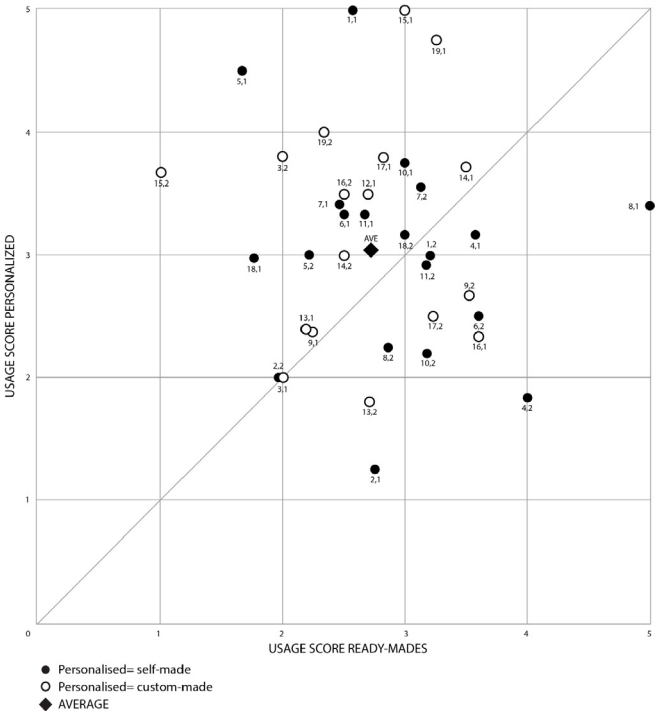

Fig. 6. Usage score of ready-made and personalised items for two garment types owned by each respondent in group P.

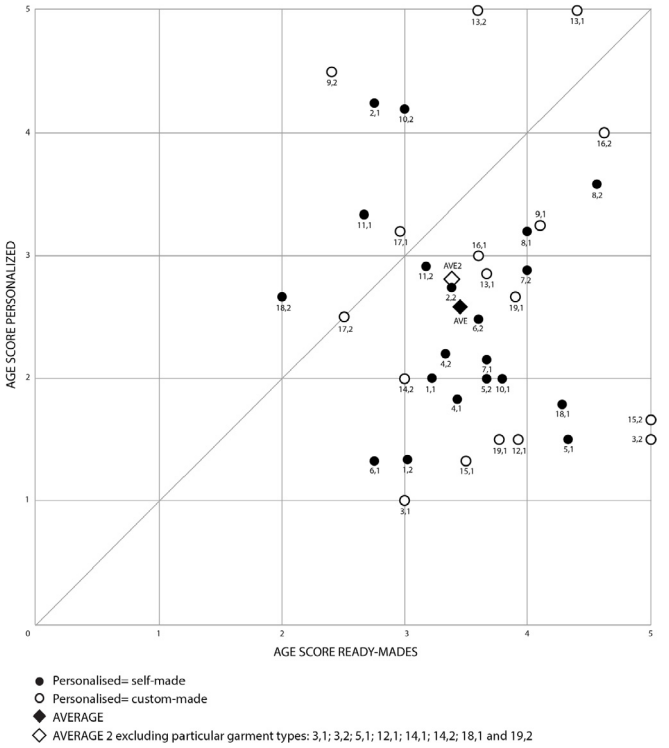

Fig. 7. Age score of ready-made and personalised items for two garment types owned by each respondent in group P.

displayed in the horizontal axis, while that of personalised items is displayed in the vertical axis. Therefore, the position of each point indicates if the use frequency of personalised garments is higher (upper-left) or lower (lower-right) than that of ready-mades for the same respondent and garment type. Moreover, the average is calculated and placed in the figure (see AVE) and the significance is tested using a *t*-test.

If -as suggested in the literature- personalised clothes were used more frequently than ready-made garments (H1.3), points would be concentrated in the upper-left corner of the figure. However, points are widely distributed with no significant difference between the usage score of personalised and ready-made garments ($p = 0.19$). Therefore, the results of this study do not support the hypothesis of lower clothing demand through personalisation.

4.1.4. Clothing age

Fig. 7 shows the results of a similar study for clothing age. Each point in the figure indicates a specific respondent and garment type (respondent number, garment type number). The age score of ready-mades (see section 3.1.2) is displayed in the horizontal axis, while that of personalised items is displayed in the vertical axis. Therefore, the position of each point indicates if the age of personalised garments is higher (upper-left) or lower (lower-right) than that of ready-mades for the same respondent and garment type. Moreover, the average is calculated and placed in the figure (see AVE) and the significance is tested using a *t*-test. A second average (AVE2) is calculated excluding special cases; this is further explained in the discussion section.

According to the literature, personalised garments are kept in the wardrobe for longer time (H1.4). In that case, the points would be concentrated in the upper-left corner of the figure. On the contrary, the majority are placed in the lower-right corner indicating that ready-made garments are kept for longer time. The results of the *t*-test indicate that personalised garments are significantly newer than ready-made garments ($p = 0.00$). Therefore, the results of this study do not support the hypothesis of lower clothing demand through personalisation.

4.2. Clothing unsold

The outcomes of the 20 company interviews are summarized in Table 5. The interviews indicated that retail, production management and production are the main activities in the supply chain, differing from those active in the ready-made sector (see e.g. Wijnia, 2016). Retailers are those interacting with the final consumer, both personally or through online environments, and starting an order in the chain. Production managers are in charge of modular design systems, systems to manage orders and delivery, collections, material supply, etc. Producers are the product manufacturers. Several companies operate along the whole chain or take two of these roles. Some respondents pointed out that they had to expand their activities throughout the chain in order to have control over individual orders; while others were planning to do that in the future.

In Table 5, companies are organized in three categories. The first category includes seven retailers of suits and other formal wear. They have direct contact with consumers, but the management of their orders and the production is done by external suppliers. The second category includes nine companies offering shirts, t-shirts, dresses, pyjamas, underwear, suits, shoes, etc. They sell online in their own webshop or via internal/external brick and mortar retailers. They own the manufacture facilities or have strong partnerships with their production suppliers and can also provide information about their activity. Finally, the third category includes companies operating in specific stages of the supply chain; special cases that are difficult to analyse in context.

The “unsold” garments reported are items that have to be remade because of client dissatisfaction or delivery problems (retail and management-related issues) or quality control (production and

Table 5
Outcomes of the company interviews.

Category	Respondent number	Annual volumes (number of items)	Activity			Percentage of unsold garments
			Production	Production management	Retail	
1	2C	4,200				0%
	5C	200				1%
	7C	1,600				0%
	8C	6,000				1%
	9C	150				0.5%
	11C	570				2%
	20C	416				0%
2	1C	50,000				3.6 %
	3C	250,000				5.5%
	12C	400	10%	0.5%		10.5%
	13C	1,720				2%
	14C	85,000	7.5%	3.5%		11%
	15C	11,000	3.5%	5.5%		9%
	16C	2,080				2.5%
	18C	900,415	0.2%	3.8%		4%
	19C	20,800	5%	2%		7%
3	4C	?				0.5%
	6C	143,000				?
	10C	336,000				2%
	17C	180,000				1%

management-related issues). The final destination of these items is unknown. In the case of client dissatisfaction, they may be kept, given away, or sent back to the company by users. In the case of quality control selection, they may be transformed into other garments, recycled, or incinerated. They may also be lost during delivery.

The percentages of unsold products reported by interviewees are compared with percentages of unsold products in the ready-made apparel sector reported by Wijnia (2016), see Table 6. These percentages include items given away or thrown away along the chain and exclude volumes sold with discount. Although the nature of unsold products is evidently different in both sectors, the term is used in both cases for differences between production volumes and demand.

Given that this study involves a small number of respondents, weighted averages are not calculated. When evaluating the outcomes of both studies solely for retailers (category 1 in respondent group C), the volume of unsold products is indeed smaller for on-demand production than for the ready-made sector (where average, according to Wijnia, is 4.2%). However, when the whole supply chain is considered (category 2 in respondent group C), the relative volumes of unsold products are comparable (total unsold volume in Wijnia's study is 6.5%). Therefore, the results of this study do not support the hypothesis of reduced unsold volumes in on-demand production of personalised products compared to production of ready-mades.

5. Discussion

The results of the studies regarding clothing demand (H1.1-H1.4) and unsold volumes (H2) are discussed separately in the subsections below.

5.1. Clothing demand

The outcomes of the inquiries above indicate that personalisation does not lead to lower clothing demand. Personalised garments are neither used more often, nor kept for longer than ready-made garments. Individuals owning ten or more personalised garments do not own fewer items, nor do they acquire fewer

Table 6
Unsold inventory in the ready-made apparel sector according to Wijnia (2016).

Activity	Number of respondents	Method	Unsold inventory (%)
Production	66 (international)	Face-to-face interview at international textile fair	1.4% of total inventory
Wholesale	16 (Netherlands)	Phone interviews	1.1% of remaining inventory
Retail	363 (Netherlands)	Phone interviews	4.2% of remaining inventory
		Total	**6.5% of total inventory**

items during a six-month period than individuals owning only ready-mades.

Regarding wardrobe sizes, they presented an enormous variation in both groups and there were no statistical differences between them. However, big wardrobes were predominant in group P and small wardrobes were more common in group R. This may be explained by the higher importance that respondents in group P give to clothes. It is impossible to determine if importance given to clothes is cause and/or consequence of personalisation. On the other hand, the fact that seven respondents in group P reported an increase in wardrobe size after they started personalising suggests that this practice may play a role in encouraging materialism in this specific product category and therefore in growing clothing demand.

The wardrobe follow-up showed that there were no significant differences in wardrobe inflow between a subgroup of subjects in group P and R during a six-month period. More importantly, it demonstrated that clothing is acquired for other purposes than substitution of discarded items. Respondents indicated reasons such as “I loved the colour”, “it was on sale”, “for a special occasion”, “to match my new dress”, and “just in case”. Regarding wardrobe outflow, some motives mentioned by respondents were “not so nice”, “not my style anymore”, “I don't wear it anymore” or “moving”. The study made clear that wardrobe inflow and outflow are fairly independent; therefore, one cannot assume dropping demand due to added value or durability of the items in stock.

In the literature, it is assumed that longer clothing lifetimes contribute to a reduction in new product demand. The wardrobe is seen as a “pull” system that incorporates new garments based on replacement of unsatisfactory pieces. In that way, postponing disposal means postponing purchases and longevity leads to decreasing demand. However, wardrobes in practice incorporate new garments for various reasons; clothes get pushed in and pulled out following unpredictable paths. New items are often bought without consideration of those already owned, and garments move to the back of the wardrobe because more attractive ones are coming in (a “push” system). Therefore, longer lifetimes and delayed obsolescence do not always have positive environmental effects.

In sum, the comparative analysis of wardrobe size (H1.1.) and wardrobe inflow (H1.2) pointed out that factors not considered in the literature play a strong role in the environmental impact of personalisation practices. Clothing consumption is not necessarily based on replacement; therefore, strategies aimed at reducing demand on the basis of product longevity are not always effective. Moreover, personalisation may encourage materialism and consequently growing clothing demand. These factors explain, at least partially, the contrast between previous scholarship and the results of this study.

The more detailed comparative analyses of garment usage (H1.3) and longevity (H1.4) within group P led to similar conclusions. No significant differences were found in use frequency between ready-made and personalised garments for the same user and garment type. Moreover, contrary to expectations, personalised garments were significantly newer than ready-made garments.

We note that this difference could be associated with other reasons than their functional or emotional value. Some of the garment types at the lower-right corner of Fig. 7 correspond to subjects that have made a shift in recent years from ready-made to personalised items in a specific garment type. For example, respondent 3A has grown a belly and has fitting problems with ready-made suits and shirts. During the last 2.5 years, he switched to custom-made garments in order to get a better fit. He now owns ready-made and custom-made suits and shirts, the latter being significantly newer. This can be seen in Fig. 7, points 3,1 and 3,2. Respondent 18A used to buy ready-made T-shirts until recently, after retirement she started making her own. She now owns ready-made and self-made T-shirts, the latter being significantly newer. This can be seen in Fig. 7, point 18,1.

Such cases may question de adequacy of the method used to study clothing longevity, since we are interested in life-spans rather than newness. However, newness of personalised items was also higher for those garment types that have included personalised items for more than five years. A second average is calculated and placed in Fig. 7 (AVE 2) excluding the cases above and other similar ones (3,1; 3,2; 5,1; 12,1; 14,1; 14,2; 18,1 and 19,2). When those cases are excluded from the analysis, the results of the *t*-test still show a significant difference in age between personalised and ready-made garments ($p = 0.01$), ready-made garments being significantly older.

One example of a respondent who has participated in personalisation for more than five years is subject 4A; she has made her own clothes since childhood. Similarly, respondent 7A has been very prolific in knitting and sewing for more than 10 years. When asked about possible reasons behind these findings, they mention that they have perfected the craft and therefore sometimes they are not proud enough of earlier pieces to keep them. Other personalised pieces are “special” and therefore less prone to be forgotten in a hidden corner of the wardrobe. If not used, they are more often given away or transformed into new pieces. Lastly, basic ready-made items can always accommodate changes in style using new combinations, so they can be kept for longer. Personalised items tend to be more specific in style and therefore it is clearer when they are not going to be worn again.

In sum, the characteristics of respondents and garment types involved in the longevity study of group P may have over-emphasized newness in personalised items. However, analysing the responses of subjects who have participated in custom-made and self-made practices for a long time, we can conclude that because of being “special” personalised garments may also lead to shorter life spans than ready-made garments. This finding is remarkable, since the literature links product emotional value with longevity. Respondents' arguments above point out that these can sometimes have an inverse relationship. Moreover, some practitioners of personalisation become attached to the process of self-making or purchasing custom-made clothes, leading to rising demand and therefore growing environmental impacts. These observations do not apply for all respondents and garment types. For example, respondents 9A and 13A, both ladies above 60 years old owning big wardrobes, keep custom-made garments of the past as special memories, and they even use them from time to time. However, as Fig. 7 shows, these are exceptions rather than the norm.

Another striking result of this study is that no consistent differences were found between self-made and custom-made garments in terms of use frequency and longevity (within group P). The literature points out that a higher degree of user involvement may result in higher product value, usage, and longevity. From this perspective, self-made garments would be kept for longer and used more frequently than custom-made garments; self-made garments providing total freedom in terms of design choices. However, in Figs. 6 and 7 these are distributed rather uniformly, showing that a higher degree of user involvement in design does not necessarily result in higher usage or longevity.

We note that this study included a small number of respondents and should therefore be regarded as a first exploratory study on the topic. Forty subjects were considered a suitable number in order to contextualise the findings with rich qualitative data while ensuring the feasibility of the study; however, the findings are not

representative of all clothing users. Individuals regularly involved in personalisation are rare in the Netherlands and Western Europe, therefore recruiting 20 subjects meeting the requirements for group P took more than one year. All possible respondents were included with no further selection. However, repeating the study with larger groups or in different contexts may lead to different results. The analysis of wardrobe inflow involved an even smaller number of subjects; therefore, we recommend further studies of wardrobe turnover through time.

Additional limitations of the comparative study of clothing demand are the demographic details selected for matching groups P and R. It is impossible to control all demographic characteristics between groups and no two people are the same. We selected measurable attributes that were expected to have a strong effect in the wardrobe; namely gender, age, locality, income, and space available. In fact, when all participants are considered, women, subjects with higher income per household member, and subjects with more space available at home (square meters per household member) owned more clothes. But these were equally distributed in both groups. Importance given to appearance and clothes had a positive relation with wardrobe size too, but groups differed only in importance given to clothes, as already discussed. There was no correlation found between importance given to fashion trends and wardrobe size.

In order to promote matching in other non-measurable characteristics of the groups (e.g. cultural aspects), we asked individuals in group P to indicate someone in group R from their own network. However, other attributes that were not considered may have a strong effect on clothing demand. The research was not based on an experimental setting where conditions are fully controlled; a systematic observation of daily practices was found more suitable for a first exploration of the hypotheses. This methodological choice may have led to overlook other differences between groups affecting clothing demand, but it also enabled unexpected findings with important implications for design for lower clothing volumes (e.g. on wardrobe dynamics) discussed above.

In any case, the results for H1.1 and H1.2 are consistent with that of H1.3 and H1.4. If personalised garments are not kept for longer or used more frequently than ready-mades by the same subject, no significant differences between subjects in terms of clothing demand are to be expected. Lastly, regarding the comparative study of clothing age and usage, a potential limitation of the method employed is that respondents may have a different level of awareness of their personalised and ready-made pieces. Such difference may have affected responses when they organized their garments according to age or use frequency.

5.2. Clothing unsold

The results of the company interviews presented in section 4.2 suggest that retail of personalised garments can help to reduce the unsold volume of clothes when we analyse this phase specifically. However, when the entire production chain is taken into account the percentages reported vary greatly from company to company, and they are comparable to the total weighted average calculated by Wijnia (2016) for the ready-made sector. This variety suggests that smaller unsold volumes are not inherent to production on-demand. Other variables such as offering a 100% product satisfaction warranty, selling online and/or offline, the production management systems and platforms, the profile of customers or the products offered, etc. may affect unsold volumes more significantly.

Although production-on-demand starts from individual orders and it may seem to eliminate unsold garments, the experience of the companies interviewed shows otherwise. In order to cope with the challenge of selling products that have not yet been made and experienced by users, they have developed other mechanisms to ensure client satisfaction such as strong quality control systems and satisfaction warranties, leading to small percentages of clothing unsold.

Given the small number of respondents, the figures in Table 5 may be more useful for building hypotheses to be tested with larger samples than to draw final conclusions. However, European companies offering personalised garments on demand are not common either. During the snowball sampling process, respondents considered the aim of 20 interviews rather ambitious and struggled to indicate organizations that had not been already included. The fact that this study used a different questionnaire to that of Wijnia for the company interviews, presents further potential limitations. Both studies used face-to-face and telephone interviews with companies, but while Wijnia asked respondents about “unsold” volumes, we asked the volume of items “remade”. This is due to the different nature of obsolete inventory in the ready-made and custom-made sectors. Our comparisons are based on what these two terms have in common; namely, that they identify a difference between production volumes and demand.

6. Conclusions and recommendations for further research

The introduction of this study stressed the importance of evaluating the impact of sustainable design strategies for reduced clothing volumes. Since the strategies proposed in literature have not been previously tested, we advanced possible methods for doing so, by taking “product personalisation” as a case study. Contrary to expectations, the outcomes pointed out that personalised garments were not kept for longer time, nor were they worn more frequently, than standard ready-made garments. Moreover, personalised garments did not result in decreasing clothing demand or pre-consumer waste; hence questioning their environmental advantages. Such results confirm the need for more empirical research to understand the effect of this and other design strategies aimed at delaying clothing obsolescence and reducing production volumes and waste, leading to more impactful solutions.

Clothing is particular in the way it is made or purchased, stored, used, maintained, and discarded. These characteristics enable comparative studies and diachronic studies of consumption during relatively short periods of time, bypassing to some extent the issue of inaccuracy in users' estimations and opening up opportunities for valuable research. Similar methods to the ones proposed here could be applied to existing strategies aimed at reducing clothing volumes or to others emerging in the future. For example, the impact of fashion libraries could be assessed by comparing demand for new clothes by the libraries themselves plus that of their members, with consumption by a control group with similar characteristics. Moreover, the performance of clothing designed with longevity in mind could be compared with other items owned by the same user. The results of such studies can provide relevant feedback to practitioners developing creative solutions for the challenge of growing clothing volumes. In that way, empirical research and creative practice can benefit from each other's input and build iterative cycles that ensure effective solutions.

The fact that garments are owned and used in large numbers calls not only for specific research methods, but also for specific strategies to reduce volumes of production and waste. The study of wardrobe turnover pointed out that clothing consumption does not always respond to the patterns assumed in existing sustainable fashion strategies. For example, product replacement was not a central drive for purchases, questioning the environmental benefits of clothing longevity. More empirical research on the complex relationships between garments and the activity of the wardrobe as a

system are needed in order to confront growing production and consumption volumes. A better understanding of patterns of clothing purchase, usage, maintenance, and disposal, the motivations behind them, the specific role of different garments in the wardrobe and the relationships between them -among other issues- could lead to novel lines of action. Although the wardrobe has received growing attention in fashion research during recent years (see e.g. Fletcher and Klepp, 2017), more studies focusing on clothing quantities and following its activity through time are needed. In mapping the activity of the wardrobe and uncovering the nuances of clothing consumption we may find opportunities for design strategies applicable specifically to this product category, leading to a more responsible apparel sector in terms of its environmental impact.

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